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Progeny Evaluation of *Azadirachta indica* (Neem) for Morphometric and Quality Traits under Nursery Conditions

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***Abstract*:** The present study aimed to assess genetic variations for morphometric traits in *Azadirachta indica* progenies under subtropical climatic conditions of Punjab conditions. The seed sources collected across the Punjab were evaluated for seed traits, germination behaviour, growth and biomass traits. Seeds collected from the IGMRI and Parker House mother trees planted at PAU Ludhiana had the maximum seed weight (14.40g/100 seeds) and seed kernel oil content (44.84%), respectively. However, azadirachtin content was maximum in the seeds collected from mother trees planted in south-western districts of Punjab lies in semi-arid region i.e. Bathinda (1.26%), Fazilka (1.25%) and Mansa (1.21%).Seed germination ranged from 6 to 32 days with 17.98 mean germination days and ~72.00% germination success. The maximum germination percent was of IGMRI, PAU Ludhiana (96.66%) followed by Mansa (90.00%) sources. The maximum seedling height (69.11 cm) and collar diameter (1.28 mm) was observed S10 (Barnala progeny) and S7 (BISA, PAU Ludhiana progeny). The maximum root length, number of roots, fresh and dry weight was noticed in seedlings of Raikot progeny; (49.83 cm).The average sturdiness quotient was 36.99 for neem seedlings. Hence the integration of these progenies in the neem improvement programme would result in better field performance for high growth and azadirachtin content.

Keywords: Neem, *Azadirachta indica*, Punjab, Seed source, Seed traits growth and biomass

Neem, botanically called as *Azadirachta indica* A. Juss, belongs to mahagony family Meliaceaeand has two varieties, *A. indica*, believed to be -indigenous of Myanmar and possibly to Shivalik's, Deccan plateau and other parts of South India (Brandis 1906) and *A. excelsa*, reportedly indigenous to South-East Asia. Morphologically anatomically, genus *Azadirachta* and *Melia* appear closely related (Mohanram and Nair 1996). There are acknowledged to be two different varieties of neem; *Azadirachta indica* (Indian neem) and *Azadirachta indica* var. *siamensis* (Thai neem). Indian neem is widely distributed over the Indian sub-continent, while Thai neem is a naturally distributed widely in Thailand and neighbouring nations in South East -Asia (Willan *et al* 1990). In Indian sub-continent, Indian neem is a highly revered by the local people of the region. There are 50 genera and nearly 640 species of woody plants in the Meliaceae family. According to morphology, members of the genus *Melia* are sometimes confused with species of the genus *Azadirachta indica*. However, an easy and precise distinction can be made between the two genera based on the morphology of leaf and ovary.

Creating large scale plantation and as a consequence related to pharmaceutical industry based raw material can be established thus tree can contribute to rural development and economic welfare (Kumar and Mishra 2009). Neem is therefore a priority species for reforestation and for producing a variety of products. In nurseries, seeds are the typically used to propagate trees. However, the seeds are said to have a short viability which is the main issue with employing neem in agroforestry and reforestation programme. Neem trees are found over a wide variety of agro-ecological habitats in India and its neighbouring nations exhibit significant differences in morphological (such as seed weight, leaf form, and phenology) and biochemical (such as there have been reports on azadirachtin and kernel oil content. The real differences in these characteristics that can relate to the variation in the progenies or to adaptation of same genotypes to the various ecosystems where it grows. It is well established that many tree species with a range of geographical diversity exhibit morphological, biochemical and genetic variations as an adaptation to varying environmental conditions (Knothe 2005)

Seed dimensions and weight are variable character with genotype and it is influenced by hereditary, developmental stage and environmental factors (Schmidit 2000). These seed characters influence the dispersal, seed water relations, germination, establishment, survival and growth of seedlings (Wunderle 1997). The life time of seeds is determined by genetic and physiological variables, as well as the storage of environment (Coronado et al 2007). For quality

germplasm, the pattern of inter and intra specific variation, genetic variability among the local germplasm needs to be investigated and analysed. In fact, trees like neem have got less attention to any genetic improvement efforts and, therefore, are considered to possess greater variability compared to other plants. It is important to emphasise the species variety and intraspecific variability that are common in the natural world. Neem's morphological and phenological variants have been the subject of numerous researches (Remedio 2014), but little is known about the genetic foundation of these variations under subtropical climatic conditions of Punjab conditions. Keeping in view, the above-mentioned facts and discrepancies, the present study had been planned to assess the genetic diversity in neem for morphometric characteristics at nursery stage under Punjab climatic conditions.

MATERIAL AND METHODS

The experiment was conducted at, Punjab Agricultural University, Ludhiana, Punjab since 2022-2023. The experimental area falls under the broad region having tropical to sub-tropical climate. The experimental site is located at 30°-54°N latitude and 75°-48° E longitude, 247 m above mean sea level with prolong dry season, high humid spell followed by coldest winters. May and June are considered as the hottest months with intense evapo-transpiration during which hot desiccating winds blow throughout the day. The rainy season occurs from July-to September when the region receives majority share of annual rainfall. December and January are the coldest months when occasional ground frost occurs in the plains. A few light showers during the winters may be received from the North-western depressions arising in the Mediterranean Sea. The site receives on an average 760 mm of rainfall throughout the year which is unevenly distributed and near about 75-80 % of which is showered between the months of July to September. The texture of the soil is sandy loam to clayey with normal reaction. Generally, the soil of the central plain region of Punjab state is identified as alluvial which has a slight problem of alkalinity and salinity. The=soil of the experimental zone has evolved under semi-arid conditions.

Extensive survey was carried out across the Punjab state to select the superior trees at PAU regional stations, KVKs and roadside plantations of state forest department on the basis of high seed-bearing potential and canopy cover for two consecutive years, i.e. 2020-21 and 2021-22. Completely ripen fruits were collected from these marked trees in June-July, 2022 (Table 1). Fruits were de-pulped immediately after collection and placed on cemented floor for sun drying process. Completely dried seeds were further used for data recording of seed characteristics. Seed dimension, seed weight, seed kernel oil and azadirachtin content were measured in the depulped seeds.

The progeny evaluation experiment of these seed sources was established in three replications with plot size of 50 seeds per plus tree following Completely Randomised Design.Fully mature and depulped seeds were sown about 1 inch deep in 7×5 inches white poly bags containing the mixture of sand, soil and FYM @ 1:1:1 in second fortnight of July. The germination characteristics were recorded on daily basis till the germination of last seed achieved. Normal irrigation and weeding practices were done as per the requirements. Growth traits were recorded at 30, 60, 90, 120 days after sowing while, root, biomass and seedling quality traits were recorded at the end of experiment i.e. 120 DAS.The experimental data were analyzedusing SPSS statistics *version* 21.

Table 1. Details of seed sources of *Azadirachta indica* selected from Punjab state

Code	Location	Latitude	Longitude
S1	Hatchery, PAU Ludhiana	30°54'10.16"	75°48'43.83"
S2	IGMRI, PAU Ludhiana	30°54'24.81"	75°49'00.48"
S3	Fazilka	31°64'18.66"	75°96'21.15"
S4	KVK Abohar	30°09'06.25"	74°13'38.61"
S5	Printing Press, PAU Ludhiana	30°54'13.68"	75°48'34.89"
S6	Rampura, Bathinda	30°15'28.82"	75°11'24.88"
S7	BISA, PAU Ludhiana	30°54'13.26"	75°48'44.62"
S8	Ralla, Mansa	30°06'10.06"	75°26'10.62"
S9	Mahal Kalan, Raikot	30°31'08.04"	75°34'04.81"
S10	Dera Gagiana, Barnala	30°19'14.72"	75°30'07.52"
S11	Bhikhi, Mansa	30°00'15.54"	75°33'44.54"
S12	KVK, Mansa	30°00'05.80"	75°20'40.12"
S13	Rurke Kalan, Barnala	30°14'47.69"	75°26'31.13"
S14	KVK, Mohali	30°51'02.99"	76°43'0.614"
S15	CIPHET, Ludhiana	30°54'14.88"	75°49'00.48"
S16	Type 10/111	30°54'24.81"	75°49'00.81"
S17	Jodhpur farm RRS, Bathinda	30°09'52.23"	74°55'23.25"
S18	KVK, Nurmahal	31°05'50.39"	75°34'58.98"
S19	Jagraon	30°48'40.42"	75°35'58.48"
S20	Dagru, Moga	30°48'59.25"	75°10'18.14"
S21	Parker House, PAU Ludhiana	30°54'08.87"	75°48'59.50"
S22	KVK, Muktsar	30°26'43.59"	74°30'30.01"
S23	Gurudwara Bodh Singh Wala	30°45'19.61"	75°10'21.68"
S24	RRS, Ballowal	31°05'59.02"	76°23'14.43"
S25	RRS, Fardikot	30°40'32.24"	74°44'57.39"
S26	KVK, Firozpur	30°54'35.85"	74°39'46.66"

RESULTS AND DISCUSSION

Seed characteristics: The significant differences were observed in physical parameter like seed length (cm), seed diameter (mm) and seed weight (g/100 seeds) among progenies of neem seed sources (Table 2). The average seed length was 1.23 mm in *Azadirachta indica* seed sources. Seed source S19 (1.62 mm) had the maximum seed length followed by S2 (1.49 mm) source. Source S20 (0.93 mm) had the minimum seed length. The average seed diameter was 6.73 mm recorded for the *A. indica* seed sources. Maximum seed diameter was observed in seed source of S26 (7.56 mm) followed by seeds source of S21 while minimum (5.91 mm) was in seeds of S24 source. The average seed weight was recorded for the *A. indica* seed sources. The average weight of 100 seeds was 9.78 g. The maximum seed weight was in the S2 while, minimum was noticed in S13 source.

Significant differences were also observed for seed kernel oil (%) and azadirachtin content (%) in the kernel of neem seed collected from the selected plus trees marked at various agro-climatic regions of Punjab (Table 2). The average seed oil content was 35.30% recorded for the *A. indica* seed sources. Source S21 (44.84%) had the highest seed oil percent and source S22 (6.06%) had the minimum seed oil percent. The average azadirachtin content in seed kernel was 0.81% recorded for the *A. indica* seed sources. Source S17 (1.26%) had the highest azadirachtin content followed by S3 source and S14 (0.55%) had the minimum azadirachtin content. It was observed that the higher azadirachtin content was observed in the semi-arid districts of Punjab like Bathinda, Mansa and Fazilka. The azadirachtin content was gradually decreased towards the central plain and north eastern districts of Punjab state. However, progeny source S2 planted at PAU Ludhiana had also high

Table 2. Variations in seed morphological and chemical traits in *Azadirachta indica* seed sources

Seed source	Seed length (cm)	Seed diameter (mm)	100 Seed weight (g)	Oil content (%) in kernels	Azadirachtin content (%)
S1	1.29	7.39	9.27	43.87	0.92
S2	1.49	6.91	14.40	35.03	1.12
S3	1.27	6.21	8.48	36.03	1.25
S4	1.19	6.23	9.69	34.49	0.81
S5	1.22	6.71	9.71	28.47	0.81
S6	1.19	6.83	7.99	38.07	0.66
S7	1.19	6.38	11.11	35.40	0.84
S8	1.17	7.18	11.25	28.70	1.21
S9	1.11	7.12	9.18	31.10	0.88
S10	1.18	6.88	7.88	39.96	0.81
S11	1.19	6.28	9.92	32.70	0.82
S12	1.23	6.60	11.21	34.50	0.86
S13	1.09	6.75	7.33	38.46	0.68
S14	1.25	6.29	12.69	37.45	0.55
S15	1.31	6.64	7.86	36.23	0.75
S16	1.18	6.00	11.60	39.47	0.86
S17	1.19	6.67	9.80	37.12	1.26
S18	1.34	7.43	11.46	36.23	0.56
S19	1.62	5.98	11.10	38.45	0.87
S20	0.93	6.58	7.88	37.46	0.86
S21	1.20	7.48	9.89	44.84	0.77
S22	1.30	7.27	8.41	36.06	0.82
S23	1.35	6.42	9.26	38.99	0.82
S24	1.04	5.91	7.71	37.51	0.61
S25	1.20	7.27	10.48	31.83	0.80
S26	1.25	7.56	8.53	39.97	0.79
LSD (0.05)	0.16	0.65	0.39	1.49	0.03

azadirachtin content. This clearly showed the effect of climatic regions on azadirachtin content in neem seed kernels.

Germination characteristics: The results pertaining to the seed germination parameters are presented in Table 3. Data on days taken to first germination showed that seed source did not differ significantly. The minimum day taken for first germination was in S2 source (6.00days), while maximum days were taken by S19 seed source (9.50days) for first germination followed by seed source of S15 (Table 3). The minimum day taken for last seed germination was 17 days in S20 seed source and maximum period was 32days in S2 seed source followed by S3 seed source. Significantly higher mean germination time (17.98%) was in S13 seed followed by S10. The minimum mean germination time was for S18 seed source (12.06%).The mean daily germination varied significantly among *A. indica* seed sources. The significantly higher mean daily germination (2.28%) was in of S2 source followed by S9 source, while, the minimum mean daily germination was for S20 (0.59%). The mean germination rate (0.06%) varied significantly among *A. indica* seed sources. The significantly higher mean germination rate (0.07%) was noticed in S1 seed followed by S3. The minimum mean germination rate (0.06%) was observed for different seed source like S6, S7,S8, S9, S12 and S13.

Significant differences were recorded for germination percentage of progenies of neem seed source (Table 3). The average value of germination percentage was 72%for*A.indica* seed sources. *Azadirachta indica* seeds attained maximum germination percentage by S2 seed

Table 3. Variabilities in seed germination characteristics of *Azadirachta indica* seed sources

Seed source	Days taken for first germination	Days taken for last germination	Mean germination time (Day)	Mean daily germination percent (%)	Mean germination rate (Day^{-1})	Germination percent (%)	Germination energy (%)	Germination value	Germination index (day)	Peak value for germination (Day^{-1})
S1	8.00	31.99	13.82	1.65	0.72	81.00	2.80	9.37	6.81	3.24
S2	6.00	32.00	14.53	2.28	0.69	96.66	3.95	9.72	7.63	3.03
S3	8.00	32.00	14.02	1.69	0.72	81.00	2.83	8.17	6.53	2.82
S4	8.00	30.99	15.03	1.32	0.66	85.00	2.27	8.44	6.45	2.78
S5	6.99	29.00	14.57	1.72	0.07	80.00	3.09	7.46	5.97	2.60
S6	8.00	30.00	16.96	1.48	0.06	78.00	2.67	7.31	6.07	2.62
S7	7.63	29.00	16.82	1.38	0.06	78.00	2.51	7.23	5.96	2.59
S8	6.83	30.00	16.24	1.39	0.06	80.66	2.56	7.31	5.94	2.53
S9	6.27	28.99	16.90	2.06	0.06	80.00	3.72	7.36	6.04	2.55
S10	7.36	29.00	17.47	1.75	0.06	77.00	3.04	6.37	5.31	2.31
S11	7.60	30.00	16.41	1.31	0.06	90.00	2.40	14.81	6.91	3.97
S12	7.37	28.00	16.64	1.64	0.06	65.33	3.34	5.30	5.07	2.23
S13	7.61	28.00	17.98	1.48	0.06	63.66	2.77	4.73	4.63	2.03
S14	7.86	26.20	16.88	1.34	0.06	69.33	2.58	5.52	5.07	2.16
S15	9.29	29.00	16.60	1.07	0.06	74.33	2.03	6.65	5.60	2.44
S16	6.94	27.00	16.98	1.26	0.06	71.33	2.47	6.01	5.18	2.31
S17	8.94	26.99	14.56	1.27	0.07	75.33	2.25	6.50	5.53	2.41
S18	7.80	18.00	12.06	0.66	0.08	65.33	1.70	5.05	4.73	2.12
S19	9.50	19.00	12.41	0.70	0.08	59.33	1.81	3.92	4.27	1.83
S20	8.06	17.00	11.68	0.59	0.08	71.00	1.56	5.52	5.20	2.15
S21	7.00	18.99	12.31	0.62	0.08	75.00	1.60	6.25	5.21	2.30
S22	7.98	20.00	12.99	0.75	0.08	72.00	1.84	5.53	4.70	2.15
S23	8.00	18.00	11.69	0.72	0.09	67.66	1.93	5.27	4.97	2.17
S24	7.00	19.00	12.62	0.72	0.07	73.00	1.83	5.77	4.90	2.21
S25	7.00	18.99	11.50	0.66	0.08	69.33	1.83	5.47	4.82	2.14
S26	9.00	20.00	13.33	0.66	0.07	78.33	1.59	7.19	5.68	2.52
LSD (0.05)	NS	1.12	0.56	0.27	0.01	16.07	0.50	4.46	1.39	0.87

source (96.66%) which is followed by S11 seed source (90.00%). The minimum germination percentage was obtained in seeds of S19 source (59.33%). The average value for germination energy was 2.43%. The significantly higher germination value (3.95) was in S2 seed source followed by S9 source while, the minimum germination energy was (1.56) in S20 source. The mean germination value was (6.85) for *A. indica* seed sources. The maximum germination was 14.81 for S11 seed source followed by S2. The minimum germination was in S19 (3.92). The mean germination index was (7.53) day for*A. indica* seed sources. The maximum germination index was for S2 (7.63) followed by S11. The minimum mean germination index was in S19 (4.27). The average peak for germination was 2.28 day^{-1} for *A. indica* seed sources. It was also apparent from the data that significantly higher peak value for germination (3.97) was in S11 seeds source followed by S1 seed source while, the minimum was in S19 seed source (1.83%). Light, as an environmental signal, often plays an important role in promoting seed germination (Mayer and Poljakoff-Mayber 1989). Higher germination percentage, germination energy and germination value conditions may be due to effect of full light, optimum temperature and micro-climate factors, which promote germination. Irengbam and Thapliyal (2016) reported significant variability among ten seed sources of *Bauhinia purpurea* with respect to germination per cent, seedling growth and vigour.

Growth, biomass and quality characteristics: The significant differences were observed for the seedling height and collar diameter among*Azadirachta indica* progenies under nursery conditions and increased progressively with increase in the age of seedlings (Table 4). Significantly

Table 4. Seedling height and diameter growth among *Azadirachta indica* seed sourceswith respect to time

Seed sources	Seedling height (cm)			Seedling collar diameter (mm)		
	30 DAS	60 DAS	120 DAS	30 DAS	60 DAS	120 DAS
S1	18.77	21.33	29.45	0.94	1.04	1.37
S2	47.15	50.12	60.12	0.73	0.89	0.98
S3	13.04	19.12	32.14	0.82	0.91	1.03
S4	41.47	51.22	68.44	0.63	0.85	1.08
S5	45.25	49.22	67.74	0.79	0.80	0.86
S6	15.10	23.44	36.11	0.81	0.83	0.97
S7	13.81	22.77	37.44	1.16	1.17	1.28
S8	18.77	26.74	39.12	0.96	1.05	1.12
S9	39.31	45.12	56.12	0.87	0.88	1.17
S10	45.17	52.31	69.11	0.36	0.52	0.85
S11	37.64	49.31	62.14	0.25	0.30	0.49
S12	32.84	37.15	48.57	0.47	0.50	0.76
S13	31.56	38.14	52.11	0.33	0.37	0.65
S14	16.51	23.41	35.14	0.18	0.20	0.31
S15	38.05	48.12	62.14	0.74	0.87	0.94
S16	25.54	32.14	49.57	0.84	0.89	0.98
S17	35.34	42.32	56.41	1.02	1.05	1.21
S18	42.64	47.15	56.14	0.70	0.77	0.91
S19	29.08	35.12	49.26	0.23	0.35	0.44
S20	15.80	22.33	43.21	0.70	0.75	0.78
S21	39.31	49.12	63.14	0.53	0.54	0.67
S22	13.04	23.14	46.14	0.70	0.77	0.97
S23	24.33	31.14	50.14	0.60	0.66	0.76
S24	15.35	23.45	46.14	0.66	0.69	0.81
S25	12.24	19.14	36.47	0.97	1.04	1.11
S26	26.04	34.21	55.45	0.61	0.71	0.82
LSD (0.05)	9.68	10.31	11.01	0.279	0.316	0.496

maximum seedling height was in seed source S2(47.15 cm), S10 (52.31 cm) and S10 (69.11 cm), while minimum wasin S25 (12.24 cm), S3 (19.12 cm) and S1 (29.45 cm) at 30 , 60and 120 DAS, respectively. The mean collar diameter wasin S7 .Plant height and collar diameter are widely used to assess the quality of nursery seedlings (Jacob *et al* 2005*).* Similarly, Gera *et al* (2003) while working with *Acacia catechu, Albizia lebbeck*, *A. indica* and *Pinus roxburghii* observed maximum plant height, collar diameter and other seedling growth parameters with improved bottom hole poly bag production system for nursery production. Prabakaran et al (2019) also recorded significant variations for growth and biomass traits in *A. indica* progenies grown under tropical environment.

Approximately, 120 days after seed sowing, the seedlings were uprooted for the biomass studies. Scrutiny of the data presented in depicts that the significant differences were observed for root length. Maximum value for root length was for S9 (49.83 mm) and minimum was in S26 (19.20 mm) (Table 5). Maximum value for numbers of root was in S5 (1.83) while, the minimum value was in S26 (0.80). The maximum total fresh weigh (4.58 g/plant) was in S3 at 120 days of sowing. The minimum value for total fresh weight was in S26 (1.08 g/plant).The maximum total dry weight of neem seedling was 1.83 g/plant in S3 seed source at120 days of sowing. The minimum total dry weight of neem seedling was 0.11 g/plant in S26.The average sturdiness quotient was 36.99 for *A. indica* seed sources (Table 5). The significantly maximum value of sturdiness quotient was 77.57 for S23 followed by S24 source. The minimum was 17.260 for S14 seed source.

Table 5. Variability among root growth, seedling biomass and seedling quality characteristics of *Azadirachta indica* seed sources

Seed source	Root length (cm)	Number of roots	Seedling fresh weight (g/plant)	Seedling dry weight (g/plant)	Sturdiness quotient
S1	45.33	1.50	2.75	1.50	45.70
S2	42.67	1.66	2.75	1.08	60.80
S3	19.63	1.16	4.58	1.83	54.07
S4	31.33	1.33	4.43	1.00	49.03
S5	43.50	1.83	3.25	1.66	63.90
S6	29.67	1.16	2.33	1.08	41.87
S7	45.17	1.00	2.41	1.25	38.47
S8	44.17	1.50	3.25	1.50	56.20
S9	49.83	1.66	3.08	0.83	45.13
S10	38.83	1.50	2.75	1.25	21.36
S11	36.67	1.00	3.16	0.75	50.50
S12	42.17	1.66	2.83	1.25	46.40
S13	28.67	1.50	3.33	1.16	57.10
S14	40.50	1.66	3.91	1.50	17.26
S15	40.50	1.00	3.83	1.08	54.87
S16	37.67	1.33	2.75	1.25	51.97
S17	31.67	1.33	3.16	1.33	42.17
S18	33.00	1.16	2.08	1.00	36.03
S19	40.00	1.33	1.83	0.75	40.13
S20	33.67	1.33	2.08	1.25	63.17
S21	30.00	1.50	1.66	0.75	35.53
S22	37.33	1.50	2.16	0.66	48.47
S23	34.67	1.33	1.83	0.91	77.57
S24	32.00	1.16	1.58	1.08	66.73
S25	31.00	1.00	1.83	0.91	45.97
S26	19.20	1.00	1.08	0.11	28.03
LSD (0.05)	12.988	NS	1.588	0.637	42.89

The significant differences were obtained among the seed sources and seedling height and collar diameters is continuously increases with the increasing age of seedling. Wide variations were recorded for growth and biomass traits among seed sources in these studies., Ginwal et al (2004) reported significant differences among the seed sources of *Eucalyptus camaldulensis* at the nursery stage for number of leaves as well as collar diameter. Hooda et al (2009) observed significant variations among the progenies for shoot length, root length, collar diameter and seedling biomass of *Pongamia pinnata*. Therefore, these variations were suggested for exploitation for indirect selection as a mechanism for the genetic enrichment of the tree's species.

Genetic estimates: In general, the phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all characters reflecting the sufficient genetic variations for the characters studied among progenies of neem seed sources (Table 6). Genotypic coefficient of variance was observed in seedling height exhibit maximum GCV (23.86%) followed by fresh biomass, dry biomass and root length. In phenotypic coefficient of variance, seedling fresh biomass (40.04%) exhibit maximum value for PCV followed by number of roots and dry biomass. The seedling height (99.01%) exhibited the very high heritability which is followed by collar diameter. Fresh biomass (32.34%), root length (30.38%) and dry biomass (26.68%) had moderate heritability, while, number of roots (3.85%) exhibited lowest heritability. Highest value for genetic advance was exhibited by seedling height (23.35) and least in numbers of roots (0.05). In genetic advance as percentage of mean, maximum value was observed for seedling height (48.92) followed by fresh biomass (26.68), and least value was observed by numbers of roots (3.05). The high heritability indicated that much of the variation for a given characteristic observed in the population was genetic in origin. High heritability (>60%) coupled with high genetic gain observed for seedling height which revealed that the traits was under the strong influence of additive gene action and selection would be quite effective.

Correlation studies: The phenotypic (Table 7) and genotypic (Table 8) correlations were estimated to assess the relationship among the traits in progenies of neem seed sources. In genotypic correlation, high positive correlation was observed for dry weight and number of roots (0.993) followed by fresh weight and dry weight (0.774), while moderate was in between of collar diameter and number of

Table 6. Estimates of genetic parameters among *Azadirachta indica*seed sources

Parameters	Seedling height	Collar diameter	Fresh biomass	Dry biomass	Root length	Number of roots
Mean	43.82	16.18	24.51	20.79	17.24	10.58
Range	29.45-69.11	0.31-1.37	1.08-4.58	0.11-1.83	19.63-49.83	1.00-1.83
GCV (%)	23.86	4.73	22.77	19.27	14.13	7.55
PCV (%)	23.98	5.98	40.04	37.30	25.64	38.43
Heritability (%)	99.01	62.44	32.34	26.68	30.38	3.85
Genetic advance	23.35	0.09	0.73	0.23	5.85	0.05
Genetic advance as % of mean	48.92	7.70	26.68	20.51	16.05	3.05

Table 7. Genotypic and phenotypic correlations among growth and biomass characteristics in *Azadirachta indica* seed sources

Characters		SH	CD	FW	DW	RL
CD	G	0.169^{NS}				
	P	0.147^{NS}				
FW	G	0.142^{NS}	-0.432^{**}			
	P	0.070^{NS}	-0.179^{NS}			
DW	G	-0.505^{**}	-0.583^{**}	0.774^{**}		
	P	-0.278^{*}	-0.264^{*}	0.381^{**}		
RL	G	0.089^{NS}	-0.079^{NS}	-0.062^{NS}	0.217^{NS}	
	P	0.044^{NS}	-0.125^{NS}	0.019^{NS}	-0.138^{NS}	
NoR	G	-0.330^{**}	0.561^{**}	0.247^{*}	0.993^{**}	-0.237^{*}
	P	-0.059^{NS}	0.074^{NS}	-0.019^{NS}	0.061^{NS}	-0.106^{NS}

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).: SH- seedling height; CD- collar diameter; FW- fresh weight; DW- dry weight; RL- root length and NoR- number of roots

roots (0.561). Negative significant correlations were among seedling height with dry weight and number of roots, collar diameter with fresh weight and dry weight, root length with number of roots. In view of phenotypic correlation, low positive correlation was observed for fresh weight and dry weight, while moderate negative significant correlation was shown by dry weight with seedling height and collar diameter. Remaining characters has no significant correlation.

CONCLUSIONS

There were significant differences among the progenies of neem seed sources which had ample scope for the genetic improvement in neem under subtropical climatic conditions of Punjab. Among the 26 progenies evaluated, seeds collected from south-western districts of Punjab had high azadirachtin content, while seed kernel oil content was higher in PAU Ludhiana source, and could be exploited by the pharmaceutical industries or fertilizer industries for preparation of neem based pesticides and neem coated urea. Germination percent was also higher for the Ludhiana and Mansa seed source. The quality seedlings based on sturdiness quotient were produced by the Moga and Ludhiana seed sources. Hence, huge genetic variabilities were obtained in neem progenies evaluated under nursery conditions and appreciable improvement in seeds traits, germination, growth and biomass parameters can be achieved by collecting seeds from selected plus trees belongs to either Ludhiana or south-western districts on a short-term basis. These seed sources show promise in their further exploitation for plantation, improvement, and multiplication under field conditions.

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