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Provenance Variation in Seed Biometry, Germination and Seedling Traits in *Azadirachta indica* A. Juss (Neem)

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ABSTRACT

The present investigationon evaluation of provenance variations in seed morphometric, germination and seedling growth attributes of Neem was conducted at Division of Genetics and Tree Improvement at Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu, India with an aim to study the variation in different provenances of *Azadirachta indica*for seed morphometry, germination and seedling traits,to identify superior provenances of *Azadirachta indica* to produce quality planting stocks, during monsoon of 2021 and 2022. Extensive surveys were conducted in 6 different agro-climatic zones in Tamil Nadu and selected 30 Candidate Plus Trees (CPT's) based on growth superiority and higher fruit yield. The significant differences were recorded on seed length (cm), seed width (cm), seed perimeter (cm), seed area, and 100 seed kernel weight (g), germination percentage, mean daily germination, germination value, germination time, peak value, time spread of germination and germination index and seedling characters such as shoot length, root length, color diameter, leaf numbers, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, shoot and root vigorous index among the provenances and seed lots. Southern Zone and Rainfall Zone provenances recorded higher values on seed length and breadth, seed weight and seedling parameters and lower values of seed parameters were observed in the Western Zone and seedling parameters in North Eastern Zone. Seed length, seed area, seed perimeter and germination percentage had a significant strong positive correlation with the shoot vigour index. Southern Zone and Rainfall Zone provenances can be recommended for establishing large-scale plantation in the Tree Outside Forest (ToF).

KEYWORDS: Provenances, germination percentage, seedling characteristics

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1. INTRODUCTION

Azadirachta indica A. Juss commonly known as Neem is a medium-sized, fast-growing, hardy, evergreen tree belonging to the family of Meliaceae, (Tiwari, 1992). It is an indigenous tree and commonly distributed in South Asia and parts of Africa. Neem trees are found in tropical dry deciduous and thorny forests of all over India.The tree has wide adaptability to tolerate high temperatures, low rainfall, long spells of drought and salinity. The elite populations of Neem are rapidly declining due to population pressure, degradation of the original habitat, lack of pollinating agents, poor seed germination and reproductive constraints. The success of the tree breeding program mainly depends on the extent of variability present in the base breeding population. Genetic, physiological, and environmental factors play an important role in determining the variability and quality of the seeds. The strong genetic control was registered in seed and seedlings' characters (Roy et al., 2004).

This species grows on almost every soil types, *viz*., clay, saline, alkaline, dry, stony, shallow soils, and even soils with high calcium composition (Pattnaiket al., 2006). More than 25 million neem trees are reported to be planted across various parts of India. In India, Uttar Pradesh has most of the neem trees, followed by Tamil Nadu, Madhya Pradesh, Andhra Pradesh, and Karnataka.The total annual production of neem seeds is 4.4 lakh tonnes and it yields 88,400 tonnes of neem oil and 3.5 lakh tonnes of neem cake (Girish et al., 2008).Neem seed extract produces large quantities ofTetratriterpenoids, among which azadirachtin (of the limonoid group) is one of the main active compounds (Tan and Luo, 2011,Suttiarporn and Choommongkol, 2020). This bitter, complex chemical has been shown to have pesticide properties (Bernardes et al., 2017, Chaudhary et al., 2017,Kovaríkova and Pavela, 2019,Isman, 2020). In spite of the presence of Azadirachtin throughout the plant parts, it is present most abundantly in the seeds of neem (Fernandes et al., 2019). Climate and habitat are two strong determinants of the azadirachtin content (Kaushik et al., 2007,Tomar et al., 2011).Meliantriol, nimbin, nimbidin, nimbinin, nimbolides, fatty acids (oleic, stearic, and palmitic), and salannin are other components present in the neem seed extract (Gunasekaran and Anita, 2010, Senthil-Nathan, 2013).Neem seed kernel extract (NSKE) is widely applied in agricultural sector (Zanuncio et al., 2016, Jenne et al., 2018, Marrone, 2019, Ferdenache et al., 2019, Shah et al., 2019).

Variations in seed morphometric characteristics within the species were reported for many forest tree species (Ibrahim, 1996; Ngulube, et al., 1997; Vanangamudi et al., 1998; Khalil and Siam, 2003). The large-scale afforestation programs are mainly relying on the seed sources and quality of planting materials. Screening of good seed sources provides a great opportunity for the tree breeder to capture natural variation. It also provides information about the magnitude of variability present in the planting material for breeding and developing genetically improved planting stock within a seed source.The germination process is regarded as the most essential and critical aspect in the plant life cycle, since it has a significant impact on the effectiveness of afforestation and reforestation programmes. (Vibekke et al., 2004; Bu et al., 2008). A successful forest nursery's planning and profitability are dependent on the correct practises that speed up the germination process and achieve a more reliable germination seed sowed.(Koirala et al., 2000).However,Knowledge of provenance variation in seed morphology, germination and seedling characters is lacking in Neem provenances available at Tamil Nadu. Hence, the main objective of the present investigation is to understand the nature, extent, and pattern of variation existing in different provenances of Neem for seed biometry, germination and seedling growth.

2. MATERIALS AND METHODS

2.1. Selection of trees and collection of fruit

An extensive survey was carried out (Lat - 08°7'52.56" to 12°52'15.20"and Long - 77°15'24.67" to 80°08' 28.93") from June 15, 2021 to August 30, 2021 to select the Candidate Plus Trees (CPTs) of Neem in six different agro-climatic zones of Tamil Nadu (Figure 1 and Table 1). The CPTs were selected based on growth superiority in fruit yield and tolerance to pests and diseases. The point grading method (Zabala, 1993) was adopted to select CPTs and a minimum distance of 200 m was maintained between the trees. Based on the method, we have selected 30 CPTs from six different agro climatic zones of Tamil Nadu. The physiologically mature fruits were collected and depulped for extraction of seeds. The seeds were properly rinsed with tap water to

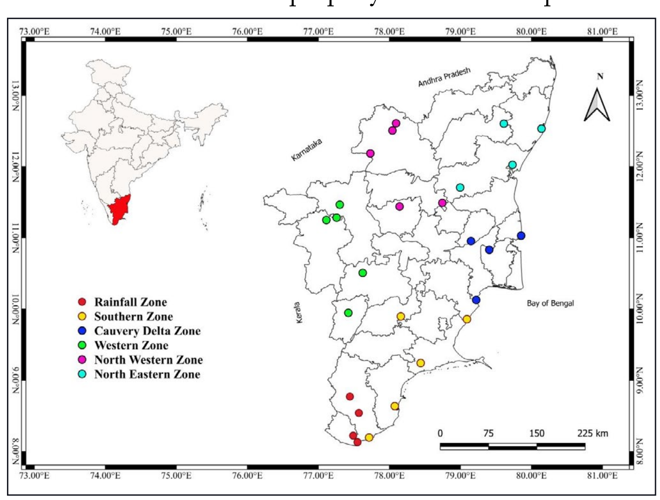

Figure 1: Map of the study area

remove pulp, dirt, and contaminants. Seeds were dried in the shade for a week before storing at room temperature (25± 2 °C). The details and geographical position of selected CPTs are given in Table 1.

2.2. Study location

The laboratory and nursery experiments were carried out in the microscopic laboratoryand clone bank complex of Genetic and Tree Improvement Division at Institute of Forest Genetics and Tree Breeding in Coimbatore, Tamil Nadu, India during the year 2020–2021. The study site is located at 11°09'N latitude and 76°84'E longitude and an altitude of 350 m above MSL. The average annual rainfall is 945 mm, most of which is received between June to September and the temperature varies from 15 to 34.9 ^{0}C.

2.3. Morphometric characters of seeds

The seed biometric traits were investigated in a random sample of 100 seeds from each seed sources. The seed morphological variations were measured by placing seeds with identities on the glass platform of a macro viewer and capturing photographs with an image analyzer (Leica

Table 1: Geographical Locations of Selected CPT's of Neem in Tamil Nadu, India

Agro Climatic Zone (Acz)	District	Provenances	Latitude (N)	Longitude (E)	Altitude (M)
North Eastern Zone (NEZ)	Kanchipuram	Kanchipuram	12°52'15.20"	79°42' 49.40"	111
	Chengalpattu	Poonthandalam	12°32'01.88"	80°08' 28.93"	12
	Villupuram	Vanur	12°01'34.00"	79°43' 58.80"	19
	Kallakurichi	Needamangalam	11°42'26.30"	78°59' 43.95"	114
	Tiruvannamalai	Cheyyar	12°36'13.20"	79°36' 39.70"	105
North Western Zone (NWZ)	Namakkal	Pugalur	11°02'51.84"	78°03' 19.93"	195
	Salem	Veppanthattai	11°29'29.24"	78°44'42.70"	174
	Dharmapuri	Dharmapuri	12°11'09.49"	77°43'53.86"	650
	Krishnagiri	Denkanikottai	12°30'26.79"	78°02' 32.33"	756
		Palakuri	12°36'33.80"	78°05' 37.70"	718
Western Zone (WZ)	Coimbatore	Annur	11°15'03.44"	77°06'44.02	385
	Erode	Gobichettipalayam	11°27'56.97"	77°18'03.24	190
	Tiruppur	Pothampalayam	11°17'0.016"	77°15'24.67"	343
	Preambular	Kunnam	11°18'43.94"	79°04'07.00"	87
	Theni	Upparapatti	09°56'47.10"	77°25' 17.80"	300
Cauvery Delta Zone (CDZ)	Thanjavur	Kumbakonam	10°58'19.75"	79°22'59.36"	34
	Mayiladuthurai	Tharangambadi	11°01'50.14"	79°51'16.86"	8
	Ariyalur	Sullangudi	10°57'16.87"	79°08'54.34"	34
	Tiruvarur	Nannilam	10°49'56.67"	79°24'20.90"	27
	Pudhukottai	Manalmelkudi	10°07'38.98"	79°13'17.95"	10
Southern Zone (SZ)	Ramanathapuram	Tiruvadanai	09°51'26.38"	79°05'29.27"	8
	Sivagangai	Sivagangai	9°58'33.12"	77°46' 47.66"	92
	Madurai	Viraganur	09°53'48.33"	78°09' 38.35"	101
	Thoothukudi	Mukkani	08°38'13.46"	78°04' 31.18"	23
	Tirunelveli	Koodangulam	08°11'43.01"	77°42' 50.07"	102
Rainfall Zone (RZ)	Kanyakumari	Agatheeswaran	08°7'52.56"	77°33' 3.11"	55
		Thuvali	08°13'18.84"	77°29' 22.29"	8.87
	Tirunelveli	Nanguneri	08°32'23.67"	77°34' 11.02"	152
		Vadamalaisamuthiram	08°32'23.67"	77°34' 11.02"	152
	Tenkasi	Alankulam	08°46'12.72"	77°26' 36.54"	127

Q wins the 500 MC.) The experiment was laid out in a Completely Randomized Design with four replications and 25 seeds used replications^{-1}. The seed morphometric characters such as seed length (cm), seed width (cm), seed perimeter (cm), seed area, and 100 seed and kernel weight (g) were recorded from each seed source. The weight of the seeds and kernels was calculated using an electronic top pan balance by ISTA 1993 guidelines (Sartorius-MA 4).

2.4. Seed germination

The elevated mother bed (2×10 m^2) was made of river sand mixed with red soil (1:1). Seeds were soaked in normal water for 3 hours and sown at a depth of 2 cm. Watering was done twice a day until germination was complete. The seed was considered germinated when the sprouting of plumule appeared around 1 cm above the soil, the germination data was recorded up to 30 from the date of sowing and the percentage of germination was calculated as per methods of ISTA (1995).The germinated seedlings were transplanted into the polythene bags (20×10 cm^2) containing red soil + red soil + sand (2:1:1) as a potting medium. The germination percentage, germination value (GV), and mean germination time (MGT) were calculated and analyzed according to (Czabator, 1962) method. (Bonner, 1983) the mean daily germination (MDG), germination rate index and time spread of germination were all calculated.

2.5. Seedling parameters and biomass characterization.

Shoot length, root length, collar diameter, and number of leaves, root and shoot weights were measured 180 days after sowing. Seedling height was measured using a ruler to measure at 1 cm above the soil surface, and collar diameter was measured using a vernier caliper from the soil level. The number of leaves in the seedlings was counted directly to calculate the number of leaves. The fresh and dry weight of roots and shoots was determined in electronic top pan balance (Sartorius-MA 4).

2.6. Statistical analysis

SPSS version 6.1 was used to perform an analysis of variance (ANOVA) on seed morphometrics, germination, and seedling characteristics. To assess variation in different provenances of *A.indica*, a completely randomized design was adopted. A simple (Pearson) correlation was created to connect the varied variables of seed and seedling morphometric traits, germination characters, germination percentage and biomass attributes.

3. RESULTS AND DISCUSSION

Seed morphology, germination, and seedling characteristics are inherited from the parents and are heavily influenced by the parent tree's age, growth, and environmental conditions (Isik, 1986). Germination value index values are used to determine the pace at which a seed germinates and completes its germination, and they are dependent on seed size and weight (Baldwin, 1942), (Czabator, 1962). In general, bigger seeds initiate and complete germination sooner than smaller seeds, which is owing to the presence of more nourishment in the endosperm (Kandya, 1978).

3.1. Morphometric characters of seeds

Significant differences were found across the 30 seed lots of *Azadirachtaindica* (Table 2). The significant difference in various seed structural and seedling characteristics between *A. indica* provenances reveals the option of selecting larger and heavier seeds for future development work. Significant zonal influence demonstrated that environmental factors contribute to modifying the outward look of the species as it grows in a wide range of ecological conditions, and therefore the population may be predicted to undergo markedly selective pressure on seed characters. Genetic diversity may contribute to zonal and provenance variability, which has to be studied further. SZ-AI 3 had the largest seed area (1.11 cm^2), whereas NWZ-AI 2 and WZ-AI 4 had smaller seed area (0.61 cm^2). Seed lengths varied from 1.16 cm (WZ-AI 4) to 1.89 cm (SZ-AI 3), the highest seed

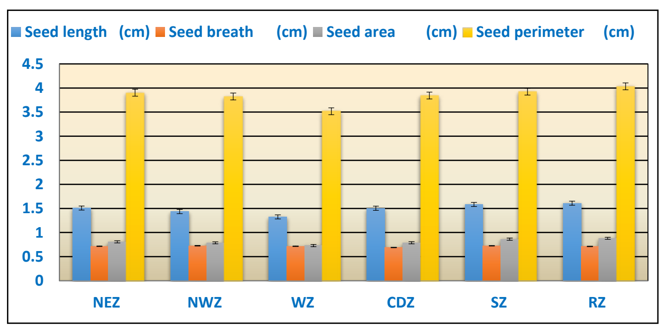

Figure 2: Zonal variations of seed length, seed breadth, seed area and seed perimeter of A.indicaseed sources in Tamil Nadu

breadth of 0.85 cm reported in SZ-AI 4, and the lowest values in RZ-AI 3. (0.61 cm). The seed perimeter varied from 3.09 cm (WZ-AI 4) to 4.61 cm (SZ-AI 3) (Figure 2). The weight of a hundred seed fluctuated from 10.35 gm to 37.85 g, with the highest seed weight in SZ-AI 1 and the lowest weight in CDZ-AI 5. The 100-kernel weight varies from 6.25 g (WZ-AI 4) to 15.44 g (SZ-AI 5), respectively. Seed size determines seed performance soon after germination (Cicek, 2007). Seed size and weight are two key characteristics for enhancing seedling productivity and selecting superior seeds (Figure 3). (Armstrong and

Table 2: Provenances variation in seed morphometric characters of*A. indica* collected from different zones

Agro climatic Zone	Accession code	Seed Length (Cm)	Seed breath (Cm)	Seed area (Cm)	Seed perimeter (Cm)	100 seed weight (G)	100 Kernel weight (G)
NEZ	NEZ AI-1	1.56	0.69	0.81	4.06	16.10	8.29
	NEZ AI-2	1.65	0.69	0.85	4.26	12.07	8.26
	NEZ AI-3	1.47	0.70	0.77	3.70	19.18	8.59
	NEZ AI-4	1.33	0.72	0.72	3.51	17.42	9.47
	NEZ AI-5	1.54	0.77	0.88	3.98	17.41	10.51
NWZ	NWZ AI-1-	1.47	0.76	0.79	4.42	28.41	12.07
	NWZ AI-2	1.24	0.64	0.61	3.25	14.33	7.17
	NWZ AI-3	1.47	0.71	0.79	3.64	23.17	11.61
	NWZ AI-4	1.50	0.75	0.84	3.90	26.38	13.34
	NWZ AI-5	1.50	0.77	0.90	3.91	26.45	13.04
WZ	WZ AI-1	1.33	0.64	0.65	3.45	19.17	9.18
	WZ AI-2	1.19	0.71	0.62	3.30	20.68	10.62
	WZ AI-3	1.50	0.77	0.85	3.93	16.50	9.65
	WZ AI-4	1.16	0.68	0.61	3.09	12.46	6.25
	WZ AI-5	1.44	0.78	0.92	3.82	20.62	9.98
CDZ	CDZ AI-1	1.56	0.73	0.89	3.97	15.23	6.56
	CDZ AI-2	1.45	0.70	0.75	4.03	12.97	10.13
	CDZ AI-3	1.34	0.69	0.72	3.42	15.26	6.95
	CDZ AI-4	1.72	0.66	0.85	4.13	18.11	9.57
	CDZ AI-5	1.45	0.67	0.73	3.67	10.35	10.06
SZ	SZ AI-1	1.35	0.70	0.71	3.46	37.85	9.32
	SZ AI-2	1.52	0.68	0.80	3.77	15.02	10.17
	SZ AI-3	1.89	0.66	1.11	4.61	24.62	12.34
	SZ AI-4	1.56	0.85	0.79	3.79	28.31	9.67
	SZ AI-5	1.60	0.73	0.90	4.00	13.99	15.44
RZ	RZ AI-1	1.80	0.71	1.00	4.43	25.61	10.83
	RZ AI-2	1.80	0.71	1.00	4.43	25.61	10.83
	RZ AI-3	1.47	0.61	0.69	3.65	28.10	14.01
	RZ AI-4	1.58	0.79	0.92	4.09	24.06	11.36
	RZ AI-5	1.39	0.74	0.79	3.57	21.06	10.29
	Mean	1.49	0.71	0.81	3.84	19.78	10.62
	SEm±	0.03	0.01	0.02	0.07	1.16	0.66
	CD (p=0.05)	0.07	0.02	0.05	0.16	2.78	1.59

Westoby, 1993, Isik,1986, Uniyal et al., 2002).This difference in seed morphology among provenances is most likely due to the impact of geographical isolation, cross pollination the nature of the species, and the prevalent climatic conditions of the seed sources. Likewise, variation in seed and seedling characteristics has previously been reported in many tree species, such as *Acacia auriculiformis* and *A. mangium,*(Ramakrishna Hegde et al., 2000), *A. nilotica Albizia lebbeck,* (Radhakrishnan, 2001), *A. indica,* (Kumaran, 1997), *Madhuca latifolia* (Divakara, 2002).

3.2. Germination parameters - calculation

Germination data demonstrated statistically significant differences in Germination percentage, Mean daily

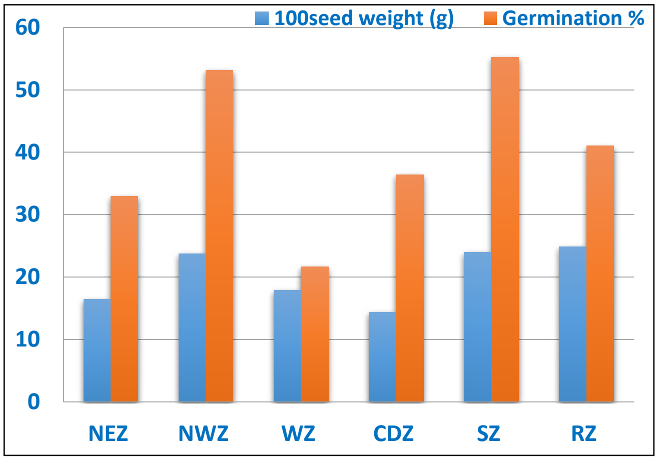

Figure 3: Bargraph represents the comparison of Seed weight and germination percentage

germination, peak value, mean germination time, germination value, and germination rate index at the 5% level of significance (Table 3). All germination indicators and seedling traits in the nursery showed significant variation between seed sources. The SZ-AI 1 provenance had the greatest germination percentage of 94%, whereas WZ-AI 4 and CDZ-AI 2 had the lowest germination percentage of 8%. (Ponnamal et al., 1993). also observed similar findings. For example, in the Southern zone seeds from SZ-AI 1 had the maximum seed weight and germination percentage. The germination of a seed population is proportional to its final germination percentage value (Scott et al., 1984). The WZ-AI 4 seed lot had the highest mean daily germination (4.20), while the NWZ-AI 1 and NWZ-AI 5 seed lots had the minimum (0.30).The peak value varies from 1.60 (SZ-AI 1) to 18 (WZ-AI 4). The mean germination time

Table 3: Provenances variation in germination parameters of *A. indica* collected from different zones

Agro climatic zone	Accession code	Germination percentage	Mean daily germination	Germination value	Mean germination time	Peak value	Time spread of germination	Germination rate index
NEZ	NEZ AI-1	47	0.82	3.45	136.06	4.28	23.00	10.86
	NEZ AI-2	54	0.73	1.46	117.38	2.50	27.00	15.28
	NEZ AI-3	40	1.06	6.89	196.11	6.55	9.25	8.22
	NEZ AI-4	55	0.79	2.37	277.14	3.10	30.50	13.42
	NEZ AI-5	54	0.45	2.15	140.5	4.81	9.25	15.60
NWZ	NWZ AI-1-	65	0.30	0.60	64.24	2.50	9.00	15.28
	NWZ AI-2	40	1.06	5.31	289.7	5.33	28.25	15.73
	NWZ AI-3	48	0.90	2.02	176.33	2.21	31.00	15.32
	NWZ AI-4	51	0.49	1.26	115.31	2.60	11.00	13.58
	NWZ AI-5	62	0.30	0.60	82.33	1.74	8.25	19.33
WZ	WZ AI-1	15	1.14	10.66	52.39	8.46	8.25	4.47
	WZ AI-2	10	1.84	21.24	58.99	11.50	8.00	2.30
	WZ AI-3	50	0.79	2.90	247.31	3.32	25.75	15.54
	WZ AI-4	8	4.20	72.31	108.33	18.00	33.25	1.44
	WZ AI-5	25	1.58	11.76	216.57	6.65	28.00	9.18
CDZ	CDZ AI-1	89	0.47	0.93	410.18	1.85	27.25	33.60
	CDZ AI-2	8	3.06	52.48	156.05	17.00	10.00	2.27
	CDZ AI-3	13	3.13	56.21	180.86	17.75	26.25	2.68
	CDZ AI-4	16	2.62	22.35	145.97	8.49	31.00	3.98
	CDZ AI-5	56	0.71	1.87	152.25	2.61	29.50	19.10
SZ	SZ AI-1	94	0.45	0.71	184.98	1.60	30.00	34.23
	SZ AI-2	35	1.09	7.07	304.91	5.27	34.25	10.48
	SZ AI-3	35	0.70	2.20	119.45	3.04	11.75	8.60
	SZ AI-4	71	0.55	0.91	174.99	1.61	30.25	23.60
	SZ AI-5	41	0.51	1.92	72.47	3.74	9.00	8.71

Table 3: Continue...

Agro climatic zone	Accession code	Germination percentage	Mean daily germination	Germination value	Mean germination time	Peak value	Time spread of germination	Germination rate index
RZ	RZ AI-1	53	0.42	1.23	110.25	2.81	12.00	20.09
	RZ AI-2	66	0.34	0.82	99.98	2.24	12.25	18.10
	RZ AI-3	31	0.63	4.49	74.94	6.26	8.50	8.13
	RZ AI-4	30	1.45	6.20	201.59	4.27	27.00	7.12
	RZ AI-5	25	1.60	9.49	239.69	5.60	25.00	8.64
	Mean	42.9	1.14	10.46	163.57	5.59	20.44	12.81
	SEm±	4.11	0.17	3.28	15.26	0.85	1.80	1.50
	CD (p=0.05)	9.89	0.42	7.89	36.68	2.05	4.32	3.61

varied from 52.39 (WZ-AI 1) to 410.18 (CDZ-AI 1). When mean germination time is lower than population on seeds germinates faster (Orchard, 1977). The highest germination rate index (34.23) was reported in the SZ-AI 1 seed lot, while the lowest was (1.44) in the WZ-AI 4 seed lot. The percentage of germination on each day of the germination period is reflected in germination rate index (GRI). Higher GRI values imply faster germination (Esechi, 1994). The germination value ranges from 0.60 (NWZ-AI 1 and NWZ-AI 5) to 72.31 (WZ-AI 4). The higher the time spread of germination TSG value leads to the greater the differential in germination speed between faster, slow germinating individuals of a seed lot. The highest TSG (34.25) was reported in the (SZ-AI 2) while the lowest was (8.00) in the WZ-AI 2. The present study found significant variation in germination values among seed sources, which is consistent with the findings of Singh and Singh (1981) in Fir and Spruce, Hegdae et al. (2000) in *A. auriculiformis* and *A. mangium.*

3.3. Seedling parameters and biomass characterization

Seed lots of *A. indica* showed significant variations (p 0.05) in shoot length (SL), root length (RL), collar diameter (CD), number of leaves (NL), shoot and root fresh weight (FW) and dry weight (DW), root vigour index (RVI), and shoot vigour index (SVI) (Table 4). Shoot and root lengths varied from 19.27 cm (NWZ-AI 2) to 35.27 cm (SZ-AI 4) and 15.85 cm (NEZ-AI 2) to 33.87 cm (SZ-AI 2). SZ-AI 2 had a greater collar diameter (5.75 mm), whereas NEZ-AI 4 had a lower collar diameter (2.87 mm). The number of leaves ranged from 5.25 to 11.75, with the most reported in SZ-AI 3 (11.75) and the fewest in NWZ-AI 2. (5.25). These variances may be attributable to the fact that seedling development is heavily influenced by seed characteristics, genetic constitution, and nutritional content of various seeds sources. This is supported by multiple authors' results that larger seeds generate healthier seedlings than smaller seeds, however this tendency was not observed in all species. (Carleton and Cooper, 1972), (Marshall, 1986, Wulff, 1986, Bonfil, 1998). Seed size has a clear influence on seedling growth in *Acacia nilotica*, according to (Shaukat et al., 1999). SZ-AI 4 had a higher Shoot vigour index value (3043.8), whereas CDZ-AI 2 had a lower value (219). The greatest value of the root vigour index was recorded in NWZ-AI 5 (8706.35), while the minimum value was recorded in CDZ-AI 2. (160.6). Southern zone fared the best for all seedling characteristics across all seed sources, shoot dry weights from SZ-AI 5 (0.30 g) to NWZ-AI 1 (1.77 g), and root dry weights from SZ-AI 5 (0.44 g) to NWZ-AI 3 (1.93 g). This difference is mostly due to genetic and environmental variables that influence seedling development. This is supported by studies on *Jatropha curcas* and *Madhuca latifolia* by (George et al., 2003).

3.4. Correlation analysis

Table 5 highlights the correlation between seed morphometric seedling and biomass characters of *Azadirachta indica*. Seed length was found to be strongly and positively correlated with area (r= 0.895), seed perimeter (r=0.910), and seed breath was found to be strongly and positively correlated with seed area (r=0.605), positive correlation with seed perimeter (r=0.393) and 100 kernel weight (r=0.365). Seed area has a strong positive correlation with the seed perimeter (r=0.861) and seed perimeter exhibits a positive correlation with the hundred seed weight (r=0.417) and seed dry weight (r=0.361). The germination percentage was found strong positive correlation with the shoot vigour index (r=0.915). Shoot length exhibits strong positive correlation with the collar diameter (r=0.507), number of leaves (r=570), seed dry weight (r=0.720) and shoot vigour index (r=0.517). The collar dia was found to be strongly and positively correlated with seed dry weight (r=0.655) and exhibits a positive correlation with the number of leaves (r=0.442). The seed dry weight was found to be strongly and positively correlated with shoot vigour index (r=0.516). The germination percentage was negatively

Table 4: Provenances variation in seedling characters of *A. indica* collected from different zones

ACZ	Accession Code	Shoot length (Cm)	Root length (Cm)	Collar dia (Mm)	Leaves no.	Shoot fresh weight (G)	Root fresh weight (G)	Shoot dry weight (G)	Root dry weight (G)	Shoot vigour index	Root vigour index
NEZ	NEZ AI-1	26.80	23.80	5.27	7.25	4.17	4.43	1.36	1.28	1259.60	1118.60
	NEZ AI-2	21.50	15.85	4.95	8.50	2.26	2.80	0.76	0.91	1161	855.90
	NEZ AI-3	21.22	17.97	4.07	6.00	1.70	1.49	0.51	0.60	849	719
	NEZ AI-4	19.35	29.15	2.87	6.75	1.25	1.85	0.47	0.59	1064.25	7112.87
	NEZ AI-5	20.70	27.22	3.25	6.50	1.47	1.74	0.54	0.53	1117.80	7491.15
NWZ	NWZ AI-1-	28.00	20.77	4.17	7.50	5.03	3.62	1.77	1.07	1820	1350.37
	NWZ AI-2	19.27	25.97	3.37	5.25	1.23	1.48	0.40	0.39	771	1039
	NWZ AI-3	27.57	28.92	5.32	7.75	3.29	6.41	1.15	1.93	1323.60	1388.40
	NWZ AI-4	20.50	32.22	4.50	9.75	1.74	3.08	0.54	0.99	1045.50	1643.47
	NWZ AI-5	19.37	23.25	4.52	7.25	2.70	3.66	1.02	1.26	1201.25	8706.35
WZ	WZ AI-1	21.80	21.62	4.37	9.75	2.36	2.98	0.78	0.96	327	3564.75
	WZ AI-2	19.37	23.25	4.52	7.25	2.03	3.29	0.63	1.19	193.75	1404.25
	WZ AI-3	32.92	22.37	4.87	10.5	2.76	4.19	0.91	1.41	1646.25	1118.75
	WZ AI-4	27.50	30.67	4.25	10.5	2.49	3.61	0.78	0.86	220	245.40
	WZ AI-5	30.27	28.82	4.77	9.00	3.32	5.82	1.05	1.86	756.87	720.62
CDZ	CDZ AI-1	34.20	25.97	4.67	8.75	3.60	3.95	1.33	1.36	2504.52	2311.77
	CDZ AI-2	27.37	20.07	5.60	10.75	3.55	2.78	1.23	0.89	219	160.60
	CDZ AI-3	20.67	22.30	4.55	8.75	2.05	2.98	0.68	1.05	268.77	2407.92
	CDZ AI-4	32.85	23.75	4.62	6.75	3.08	3.16	0.98	1.09	525.60	380
	CDZ AI-5	24.22	29.85	4.50	6.00	2.03	3.58	0.79	1.19	1356.60	1671.60
SZ	SZ AI-1	21.15	28.45	5.20	6.25	2.76	3.79	0.88	1.16	1988.10	2674.30
	SZ AI-2	27.95	33.87	5.75	9.50	3.58	3.76	0.95	1.25	978.25	938.87
	SZ AI-3	21.67	20.45	3.95	11.75	1.55	2.24	0.56	0.92	758.62	715.75
	SZ AI-4	35.27	21.89	4.92	9.75	3.92	3.91	1.29	1.32	3043.80	1554.54
	SZ AI-5	20.80	26.87	2.57	6.25	0.96	1.24	0.30	0.44	852.80	1101.87
RZ	RZ AI-1	26.37	24.60	4.57	7.50	2.48	2.38	1.06	0.82	1397.87	1303.80
	RZ AI-2	32.60	26.82	5.10	7.25	3.49	5.03	1.18	1.69	2151.6	2235.75
	RZ AI-3	28.22	30.80	4.17	8.25	2.77	3.40	1.14	1.14	874.97	954.80
	RZ AI-4	21.63	30.22	4.02	6.50	1.85	3.76	0.64	1.25	612.75	906.75
	RZ AI-5	21.20	32.72	3.55	8.00	1.48	2.78	0.51	0.86	530	818.12
	Mean	25.10	25.68	4.43	8.05	2.56	3.31	0.87	1.07	1094.00	1953.84
	SEm±	0.951	0.84	0.14	0.31	0.18	0.21	0.06	0.068	125.91	386.42
	CD (p=0.05)	2.28	2.03	0.34	0.75	0.43	0.52	0.14	0.16	302.55	928.48

correlated with no of leaves (r=-0.364). Significant positive correlations of seed characters were also found in *D. sissoo.* Singh and Pokhriyal, 2001, Gera et al., 2000, *Santalum album,*(Bagchiand Sharma, 1989) and *Leucaena leucocephala* (Hooda and Bahadur, 1993). In teak (Parthiban, 2001), a comparable substantial and positive correlation was reported between volume index and plant height, followed by collar diameter (Radhakrishnan, 2001).

Table 5: Correlation matrix for seed biometry and seedling biomass traits of *A. indica* in different zones of Tamil Nadu

	SeL	SB	SA	SP	SW	KW	GP	SL	RL	CD	LN	SDW	SVI
SEL	1	0.224	.895**	.910**	0.331	0.161	0.294	0.324	-0.138	0.137	-0.005	0.210	0.353
SB		1	.605**	.393*	0.215	.365*	0.126	-0.074	0.084	-0.133	-0.127	-0.044	0.070
SA			1	.861**	0.348	0.262	0.296	0.213	-0.021	0.029	-0.082	0.111	0.321
SP				1	.417*	0.218	0.298	0.288	-0.246	0.149	-0.010	.361*	0.343
SW					1	0.162	0.141	0.159	-0.030	-0.223	-0.195	0.348	0.205
KW						1	0.056	-0.104	0.329	0.040	0.102	-0.015	-0.029
GP							1	0.175	0.078	0.089	-.364*	0.304	.915**
SL								1	0.040	.507**	.570**	.720**	.517**
RL									1	-0.188	-0.128	-0.140	0.059
CD										1	.442*	.655**	0.241
LN											1	0.336	-0.121
SDW												1	.516**
SVI													1

** Correlation is Significant at the 0.01 Level (2-Tailed); * Correlation is Significant at the 0.05 Level (2-Tailed); SEL: Seed length, SB: Seed Breadth; SA: Seed Perimeter; SW: Seed Weight; KW: Kernel weight; GP: Germination percentage; SL: Shoot length; RL: Root length; CD: Collar diameter; LN: Leaves number; SDW: Shoot dry weight; SVI: Shoot vigour index

4. CONCLUSION

Wide range of variability was observed in different provenances for seeds, germination and biomass characterization and it demonstrates the possibility of selecting an appropriate seed source suited for agro climatic zone.Southern Zone has been recognized as having the potential to yield high-quality seedlings. The study's practical significance is that heavier seedlings produced from good provenances may give more success in seedling survival and growth during out planting, since quality seedlings will only be able to endure adverse climatic conditions. The selected provenances will utilize as base breeding material for further tree improvement and also for establishing large scale Neem plantations.

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