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Seed Size Correlates with Germination Traits in *Terminalia arjuna* Genotypes

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A B S T R A C T

Seed size emerged as a governing characteristic for germination parameters and seedling establishment owing to best evolutionary traits of plant which impart major contribution in genetic diversity. Large size increased germination rate and seedling survival, accelerated germination timing, and enhanced seedling growth. Present experiment is carried out to assess the seed size correlates with germination characteristics in *Terminalia arjuna.* The findings suggest that the seedling vigour is a fixed positive function of seed size needs to be reconsidered. Germination of large seeds recorded slightly higher than small size and ranges from 68.33 to 43.33%. Mean daily germination value ranged between 1.81 to 2.85, Peak value of germination ranged between 3.15 to 4.59, Germination value ranged between 5.79to 13.67 and germination speed ranged between3.71 to 5.88. The existence of conflicting selection might explain the occurrence of an optimal seed size in some plant species without invoking a seed number-size trade-off. Hence, it is recommended to use only medium and large size seeds for growing, because they do result in higher germination behavior and seedling establishment.

Introduction

The most successful tree improvement programme is that where proper seed sources were used. The loss from using the wrong sources can be great and even disastrous. Size of seed is best evolutionary traits of plant which impart major contribution in genetic diversity (Aniszewski *et al.,* 2001). The good quality seeds are those which have genetic purity, physical purity, health standards, germiniability and moisture percentage in accordance with the minimum seed certification standards. Provenance-dependent variations in seed size are also recorded (Ellison, 2001; Dlamini, 2011). Successful establishment of seedlings depends on seed size and contributes competition among the plants (Zhang, 1998), however fruit pulp adhering to the seeds has been found to have an inhibitory effect on germination in this species. Comparatively fewer large and many small seeds produced by most of the plant species (Stevenson *et al.,* 2005). Smaller seeds with sufficient number are useful for dispersal over wide areas. On the other hand, the energy potential of large seeds is considered to emerge better in most of the

habitats (Stevenson *et al.,* 2005). Large seeds show better germination parameter and establishment potential of seedlings as compared with medium and small seeds (Murali, 1997; Negi and Todaria, 1997; Khan and Shankar, 2001; Mwase and Mvula, 2011). Consideration of seed traits may be a useful aspect for propagation and conservation of valuable plants (Khurana and Singh, 2001). *Terminalia arjuna*is commonly propagated through seeds hence the seed size trait in seedling emergence has been highly acknowledged for the development of quality planting stock.

Terminalia arjuna L. (*Arjun, Koha, Kahu* and *Arjan* in Hindi; *Arjuna, Dhanvi, Indradruma, Kakubha, Karvirak* and *Nadisarjja in* Sanskrit; *Arjhan* in Bengali; *Sahjo*in Oriya; *Sadada* and *Sadado* in Gujarati; *Sadura*in Marathi; *Vellamatta* in Tamil and *Yerra Maddi*in Telugu.), Family: Combretaceae) is used as fodder, fuel wood and in the variety of herbal medicines. *Terminalia arjuna* is a fast growing tree that has a high potential of biomass production and ability to grow on marginal and degraded lands. It has immense economic importance in various industries viz., pharmaceutical, timber, paper, soap, match, food, fodder and fuel. The dried stem bark of *Terminalia arjuna* has been used widely as a drug in Ayurvedic medicine as a cardiotonic, for injury or wound, blood disorders, obesity, urinary disorders and ulcer or wound. The tree species is usually used in agro and social forestry for reclamation of degraded lands. For instance saline and alkaline soils, deep ravines and mine spoil. The growing interest in the bark of *Terminalia arjuna* and the realization of the need for raising high biomass and bark yielding plantations has led to the search for technologies for its growth and profitable production. Owing to the multipurpose value of *T. arjuna*, the need for its adequate regeneration is important (Rathore *et al.,* 2008). Collection of seeds at the appropriate time, consideration of seed size and pre-sowing treatments have been found to be useful for improving germination in some species of Terminalia (Agboola *et al.,* 1993; Amri, 2010). Selection of superior genotypes and seeds size may be useful for efficient germination and establishment of seedlings. Effect of seed size on seedling emergence and growth parameter in *T. arjuna* under nursery conditions is reported in this research paper.

Materials and Methods

The investigation was carried out in Research Farm of College of Forestry SHUAT, Allahabad, Uttar Pradesh during 2014-15 to find the association between seed size and germination parameter The experimental site at elevation of 98 m above sea level at 28.87° N latitude and 81.15° E longitude. The characteristics of the soil are sandy loam in order to Inceptisol soil. The research area has a sub-tropical climate with extremes of summer and winter. During the summer season, the temperature reaches upto 46-48°C, while during winter season, especially in the month of Nov. and Jan. temperature drops down to as low as 1-2^{0}C. During winter, frost and during summer, hot scorching wind are common features. The average rainfall in this area is around 882 mm, during the monsoon i.e. June to Sept, with a few occasional light showers and drizzles are seen in the winter also.

More than 3000 mature fruits were collected from different parts of the crown of an individual plus tree selected from 30 different locations of state Uttar Pradesh (Table 1 and Figure 1). The fruits were cleaned and stored in muslin bags at ambient conditions before sowing. All lots were dried under similar temperature and humidity to reach constant weight. Observations on fruit characters were taken of plus tree and replication wise. Dark brown, matured (ripened) seeds of *T. arjuna*, were collected from different parts of Uttar

Pradesh in the month of March 2014. For taking observations on fruit characters, 30 fruits / tree was collected randomly from different parts of the tree and average of 30 fruits measurement was recorded for fruit length, width and fruit weight for sorting and seedling establishment in the nursery. The seed sample comprised large and small seeds, which were separated out for experimental purpose. All the seeds were weighed (digital electronic balance, Mx 7000 series) and the length and diameter (Digital Vernier calipers) of the seeds were also measured. Air-dried seeds of each category were given pre-germination treatments of 2 days of water soaking and sown in triplicate (each replicate containing 20 seeds) under nursery conditions (in black 100 × 152 mm polybags (containing soil, farmyard manure [FYM], and sand in a ratio of 1:1:1) at a depth of 20 mm in the first week of July.

The seeds were regularly monitored in terms of the onset of germination and number of seedlings established, over a period of 12 months. Values obtained for weights, lengths and diameters of all seeds in each replicate were averaged. The number of days required for onset of germination, seedling emergence, mean time for the onset of germination (MGT) and percent seedling emergence in each replicate per seed-size category were averaged. Single factor-analysis of variance (ANOVA) for germination traits in relation to seed size was calculated.

The data were subjected to statistical analysis appropriate to the design and significance of different sources of variations was tested by Fisher's and Snedecor's F-test at probability level of 0.05 (Chandel, 1984) to obtain information on the mean performance and to assess the correlation of seed characteristics and total emergence of seedlings (%). Standard errors (SE) for the values obtained were calculated. Mean germination time was calculated by slightly modifying the formula suggested by Butola and Badola (2004).

Results and Discussion

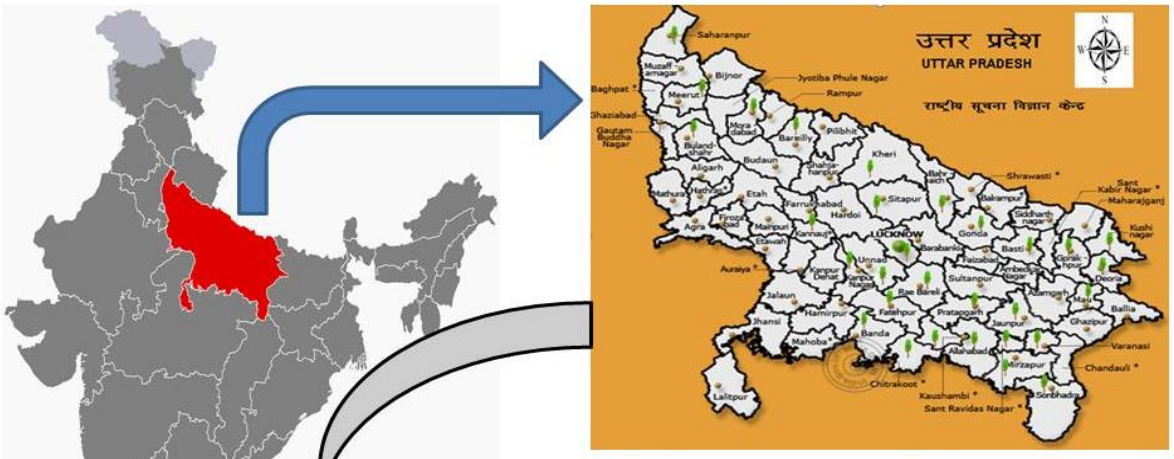
Large size increased germination rate and seedling survival, accelerated germination timing, and enhanced seedling growth. Germination of large seeds recorded slightly higher than small size and ranges from 68.33 to 43.33%. Mean daily germination value ranged between 1.81 to 2.85, Peak value of germination ranged between 3.15 to 4.59, Germination value ranged between 5.79to 13.67and germination speed ranged between 3.71 to 5.88. Most of the germination parameters of large, medium and small seeds have slight differences and varied non-significantly. Mean Germination Time (MGT) for the seedlings from large, medium and small seeds was comparable. Seed characteristics such as weight, length and diameter were positively correlated with the germination parameter of seeds (Table 2 and Fig. 2). Perusal of data represented in table 2, a greater number of seedlings germination from the large seeds followed by medium while relatively lower seedlings germination were established from small seeds. Significant variations were observed among the numbers of seedlings established from different sized. Seed size emerged as a governing characteristic for germination and seedling establishment in *T. arjuna*. Higher germination have been reported for the large seeds compared with medium and small seeds laboratory conditions (Negi and Todaria, 1997), similar to the trend currently observed under nursery conditions. However, different species of *Terminalia* may exhibit similar, or diverse, germination responses in relation to seed size and pre-treatments (Agboola *et al.*, 1993; Murali, 1997; Schiotz *et al.*, 2006; Shivanna *et al.*, 2007; Likoswe *et al.*, 2008; Amri, 2010).

Table.1 Details of morphological observations of thirty plus trees of *Terminalia arjuna* collected from different locations (S_1- S_{30})

Seed source	Location	Latitude	Longitude	Age of tree (years)	Tree height (m)	Tree girth (cm)	Fruit length (mm)	Fruit width (mm)
S_1	Chamanbagh, Fatehpur	$25^0$94'N	$80^0$80'E	10-12	14.00	72.10	31.07	22.94
S_2	Allen forest, Kanpur	$26^0$50N	$80^0$30'E	12-18	16.00	85.90	27.04	20.27
S_3	Cant, Varanasi	$25^0$33'N	$82^0$98'E	12-15	14.00	73.40	42.04	31.14
S_4	KendriyaVidyalaya, Basti	$26^0$80'N	$82^0$70'E	10-15	12.00	78.60	41.90	31.24
S_5	Baghauchghat, Deoria	26.57'N	84.00'E	10-15	16.00	84.10	39.57	29.14
S_6	Fazilnagar, Kushinagar,	$26^0$68'N	$84^0$05'E	15-17	12.00	78.10	39.77	29.10
S_7	Kartaniaghat Range Office, Bahraich	$28^0$33'N	$81^0$13'E	12-16	14.00	114.20	38.77	29.04
S_8	Irrigation Department, Gonda	$27^0$13'N	$81^0$95'E	15-17	12.00	74.30	29.17	21.70
S_9	KawwaBagh Colony, Gorakhpur	$26^0$75'N	$83^0$38'E	11-14	10.00	73.10	31.77	23.77
S_{10}	Gandhi Udhyan, Bareilly	$28^0$34'N	$79^0$43'E	10-13	15.00	77.20	25.67	19.24
S_{11}	Railway station road, Sirathu, Kaushambhi	$25^0$65'N	$81^0$32'E	12-14	14.00	87.30	38.10	28.34
S_{12}	Sitasamahitsthalsitamarhi, Bhadohi	$25^0$27'N	$82^0$26'E	11-12	14.00	112.10	32.87	24.53
S_{13}	Kukrail, Lucknow	$26^0$91'N	$80^0$98'E	11-16	14.00	114.70	32.57	24.34
S_{14}	U P Forest Corporation Lakhimpur,	$27^0$94'N	$80^0$79'E	14-15	11.00	82.20	31.27	23.27
S_{15}	Company Garden Beribagh, Saharanpur,	$29^0$97'N	$77^0$56'E	12-16	11.00	102.30	23.84	18.24
S_{16}	SHUATS, Allahabad	$25^0$41'N	$81^0$85'E	15-18	17.00	71.80	23.94	17.97
S_{17}	Shahjahanpur road, Sitapur	$27^0$58'N	$80^0$65'E	11-15	12.00	85.30	22.90	17.17
S_{18}	V.B.S.Purvanchal University, Jaunpur	$25^0$83'N	$82^0$68'E	12-15	11.00	54.80	20.34	15.44
S_{19}	Railway ground, Mau	$25^0$94'N	$83^0$56'E	12-17	10.00	75.70	21.10	15.94
S_{20}	Obra forest, Sonbhadra	$24^0$46'N	$82^0$99'E	12-16	11.00	68.30	25.37	18.97
S_{21}	Malka Park, Bulandshahar	$28^0$41'N	$77^0$85'E	15-18	11.00	98.10	25.20	18.77
S_{22}	Deer park, Moradabad	$28^0$82'N	$78^0$81'E	10-14	10.00	62.80	29.04	21.60
S_{23}	Company Garden, Pratapgarh	$25^0$92'N	$82^0$07'E	12-14	11.00	68.80	25.77	19.40
S_{24}	Gandhi Park, Meerut Cantt	$29^0$01'N	77^0 70'E	11-15	14.00	111.10	25.37	18.93
S_{25}	Indira Gandhi Vanaspati Udyan, Raibareily	$26^0$20'N	$81^0$25'E	12-15	11.00	102.20	33.57	24.97
S_{26}	Barkachha, Mirzapur	$25^0$05'N	$82^0$60'E	12-15	10.00	96.30	14.80	12.48
S_{27}	Lohiya park, Kanauj	$27^0$01'N	$79^0$92'E	11-16	11.00	66.20	22.33	16.60
S_{28}	Katai Mill, Banda	$25^0$51'N	$80^0$34'E	11-16	10.00	61.70	23.44	17.60
S_{29}	Dr. BhimraoAmbedkar Park, Unnao	$26^0$55'N	$80^0$48'E	12-16	10.00	62.60	23.03	17.24
S_{30}	AarogyaDhaamChitrakoot	$25^0$16'N	$80^0$86'E	11-16	14.00	90.20	24.94	18.60

Table.2 Seed size correlates with seedling emergence in *Terminalia arjuna* genotypes

Seed source (Genotypes)	Length (mm)	Width (mm)	100-Fruit weight (g)	Germ (%)	MDG	Peak Value	Germ Value	Germ Speed
S_1	30.40	22.07	234.13	46.67	1.94	3.28	6.39	4.11
S_2	26.47	19.53	259.00	55.00	2.29	3.76	8.79	4.81
S_3	41.20	30.00	310.40	65.00	2.71	4.25	11.58	5.38
S_4	41.00	30.00	321.87	60.00	2.50	3.93	9.82	4.89
S_5	33.13	24.13	412.00	58.33	2.43	3.83	9.33	5.01
S_6	44.53	32.47	490.67	56.67	2.36	3.78	9.12	4.83
S_7	38.00	27.80	238.07	66.67	2.78	4.33	12.10	5.88
S_8	28.60	20.87	262.13	45.00	1.88	3.15	5.90	4.06
S_9	31.13	22.80	304.27	48.33	2.02	3.21	6.46	3.71
S_{10}	25.13	18.47	277.20	50.00	2.09	3.60	7.82	4.27
S_{11}	37.40	27.27	313.00	48.33	2.02	3.46	7.08	4.43
S_{12}	32.13	23.53	313.80	61.67	2.57	4.02	10.53	5.36
S_{13}	31.80	23.27	216.40	50.00	2.08	3.59	7.79	4.32
S_{14}	30.60	22.27	202.27	50.00	2.08	3.67	7.87	4.39
S_{15}	23.40	17.20	203.67	55.00	2.29	3.45	8.02	4.92
S_{16}	23.40	17.27	213.00	50.00	2.08	3.26	6.80	4.45
S_{17}	22.60	16.53	208.73	65.00	2.71	4.04	11.19	5.58
S_{18}	20.00	15.00	231.67	60.00	2.50	3.93	10.18	5.15
S_{19}	20.80	15.27	154.00	58.33	2.43	3.87	9.59	5.04
S_{20}	24.87	18.20	163.07	58.33	2.43	3.73	9.17	5.20
S_{21}	24.67	18.00	161.87	68.33	2.85	4.59	13.67	5.82
S_{22}	28.40	20.73	169.47	43.33	1.81	3.21	5.79	3.71
S_{23}	25.27	18.53	177.27	61.67	2.57	4.12	11.01	5.52
S_{24}	24.87	18.33	184.27	50.00	2.08	3.29	6.87	4.15
S_{25}	32.87	23.93	113.27	56.67	2.36	3.60	8.56	4.99
S_{26}	14.87	10.88	114.07	48.33	2.02	3.29	6.65	3.96
S_{27}	21.93	16.13	122.93	56.67	2.36	3.57	8.46	4.62
S_{28}	23.07	17.07	125.40	53.33	2.22	3.47	7.77	4.62
S_{29}	22.53	16.47	138.27	51.67	2.15	3.38	7.40	4.28
S_{30}	24.40	17.80	175.27	51.67	2.15	3.37	7.27	4.40
S. Ed. (±)	**0.64**	**0.667**	**2.818**	**6.74**	**0.32**	**0.44**	**2.26**	**0.7**
C.D. (5%)	**1.28**	**1.337**	**5.652**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**



Seed source	Location	Seed source	Location
S_1	Chaman bagh, Fatehpur	S_{16}	SHUATS, Allahabad
S_2	Allen forest , Kanpur	S_{17}	Shahjahanpur road , Sitapur
S_3	Cant, Varanasi	S_{18}	Veer Bahadur Singh Purvanchal University, Jaunpur
S_4	Kendriya Vidyalaya, Basti	S_{19}	Railway ground, Mau
S_5	Baghauch ghat, Deoria	S_{20}	Obra forest , Sonbhadra
S_6	Fazil nagar, Kushinagar,	S_{21}	Malka Park, Bulandshahar
S_7	Kartaniaghat Range Office, Bahraich	S_{22}	Deer park, Moradabad
S_8	Irrigation Department, Gonda	S_{23}	Company Garden, Pratapgarh
S_9	Kawwa Bagh Colony, Goralchpur	S_{24}	Gandhi Park, Meerut Cantt
S_{10}	Gandhi Udhyan, Bareilly	S_{25}	Indira Gandhi Vanaspati Udyan, Raibareily
S_{11}	Railway station road, Sirathu, Kaushambhi	S_{26}	Barkachha, Mirzapur
S_{12}	Sita samahit sthal sitamarhi, Bhadohi	S_{27}	Lohiya park, Kanauj
S_{13}	Kukrail , Lucknow	S_{28}	Katai Mill, Banda
S_{14}	U P Forest Corporation Awas Vikas Colony Lakhimpur,	S_{29}	Dr. Bhimrao Ambedkar Park – Unnao
S_{15}	Company Garden Beribagh, Saharanpur,	S_{30}	Aarogya Dhaam Chitrakoot

Fig.1 Seed source T*erminalia arjuna* genotypes collected from 30 sites of Uttar Pradesh

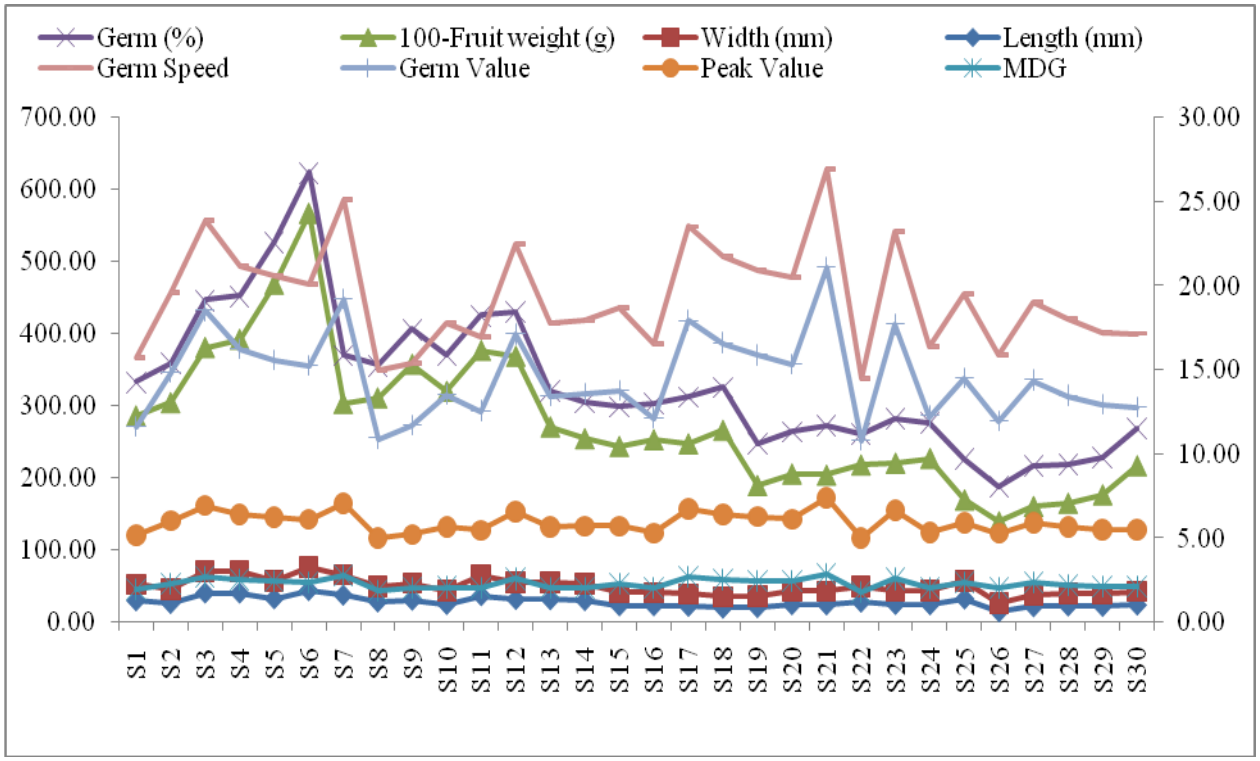


Fig.2 Seed size correlates with seedling emergence in T*erminalia arjuna* genotypes

The observed effect of fruit size on seedling vigour and growth might be a direct result, because large seeds had more reserves in their cotyledons, but also an indirect result because large acorns germinated earlier, prolonging the growing season and thereby enhancing both below- and aboveground biomass gain, as well as the vertical growth of the resulting seedling (Tripathi and Khan, 1990; Ke and Werger Seiwa, 1999; 1998, 2000).

On the basis of earlier and the present studies, it is concluded that, higher germination percentages from large seeds is a stable character in *T. arjuna*. These findings suggest that the general assumption that seedling vigour has a fixed positive function of seed/fruit size needs to be reconsidered. There may be conflict in selection of an optimal seed size in some plant species.

Therefore, it is also suggested that, prior to sowing, the seeds should be screened. This practice will help in overcoming the inhibitory effect of adherent pulp on seed germination – and consequently on seedling establishment and ultimately on the production of quality stock.

The present study concludes that there is a slight difference between the large and medium size seeds where significance differences among medium to small seed. The large seeds were repeatedly performed to a higher germinability than the medium and small sizes. The increased germination rate could be related to the larger amount of reserves available in the large seed than in the medium or small seeds. The findings of experiment also suggest that seed vigor also differ in seed size in genotypes.

Hence, it is recommended to use only medium and large size seeds for growing, because they do result in higher germination behavior and seedling establishment.

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