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Mohd. Javaid
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

LM Gupta
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

Meenakshi Gupta
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

KK Sood
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

Punit Choudhary
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

SK Gupta
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

Corresponding Author:
Mohd. Javaid
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Chatha, Jammu and Kashmir, India

Variability in fruit and seed characteristics of candidate plus trees of *Toona ciliata* in Jammu subtropics

Mohd. Javaid, LM Gupta, Meenakshi Gupta, KK Sood, Punit Choudhary and SK Gupta

Abstract
The current study on variations in fruit and seed characteristics of candidate plus trees (CPTs) of *Toona ciliata* in Jammu subtropics was conducted in the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu, Jammu & Kashmir during 2021. In this study, survey was conducted along the distribution range of species and 22 CPTs were selected in subtropical and intermediate zone of Jammu region based on their phenotypic superiority. Fruits were collected from selected CPTs during the first and second weeks of June with collection starting from lower altitudes and subsequently progressing to higher altitudes. The parameters studied were fruit length and breadth, seed length and width, number of seeds per fruit, and 100 fruit and seed weight. The study found significant differences in the morphological traits in fruit and seed characters of *T. ciliata* with fruit length ranged from 16.88 to 25.60 mm, fruit breadth ranged from 8.23 to 11.78 mm, seeds per capsule ranged between 19.67 and 28.33, fruit weight ranged from 151.70 gm to 365.00 gm and 100 seeds weight varied greatly between seed sources ranging from 0.12 to 0.36 g. The value for maximum seed length with wings was 10.44 mm, whereas, the value for minimum seed length with wings was 12.61 mm. The seed length without seed wings varied between 4.83 mm and 6.82 mm and the values for seed width without seed wings ranged between 2.2 mm and 3.08 mm. From the present study, it may be concluded that the CPTs *viz*. CPTs *viz*. CPT-1, CPT-11, CPT-12, CPT-22, and CPT-6 with large sized fruits with more number of seeds can be used for commercial raising of quality planting material and the variability recorded may be exploited for further genetic improvement in the species.

Keywords: Candidate plus trees (CPTs), *Toona ciliata*, seed, variability, morphological traits

Introduction
Morphological variations in fruit/pod and seed characteristics among the natural population are useful in selection programme for genetic improvement of forest species (Bahadur and Hooda, 1995; Kaushik *et al*., 2007) [1, 5]. For screening the naturally available genetic variations to select the best planting material for attaining higher productivity, source variation tests are very much necessary (Bhat and Chauhan, 2002) [2]. Such tests can yield valuable information that may be useful for commercial planters, nursery growers, foresters and tree breeders. Fruit and seed variability can be linked to the genetic potential of a genotype (Pavithra *et al*., 2013) [8]. Therefore, it is very important to select superior trees, which are morphological superior in terms of its commercial characters and free from pest and diseases. Efforts have already been made in some commercial important species; however, such information is scanty in many forest species and *Toona ciliata* is one among them, which is an important multipurpose tree.
Toona ciliata belonging to family Meliaceae is cosmopolitan species found in subtropical and intermediate agroecological regions of Jammu and Kashmir UT. It is widely preferred by the farmers to be grown on their farms for its high class timber value. Besides its timber use, it is also usedinmaking ships and for high-value goods such as furniture, musical instruments and carvings. Toona is one of the woods found suitable for making racquets (Luna, 1996) [7]. It has been recommended as multipurpose tree in agroforestry systems in India (Uppal and Singh, 2010) [15]. To undertake its plantation, it is imperative to identify its candidate plus trees which would act as seed source (s). With this in mind, an attempt has been made to study the variability in fruit and seed traits among the selected candidate plus trees of *T. ciliata*, an important forest resource of tropical and sub-tropical regions in India.

Materials and Methods

The present study was carried out in the Division of Agroforestry, Sher-e Kashmir University of Agricultural Science and Technology, Jammu during 2021. Twenty two CPTs of *T. ciliata* were selected in different locations from Jammu region of India, which includes six districts *viz*., Udhampur, Kathua, Samba, Jammu, Reasi and Rajouri (Table 1). Matured fruits were collected from these selected 22 trees and were measured for various fruit and seed traits. From each source, three samples were drawn randomly and from each sample, twenty seeds were selected for measurements of fruit length, fruit width, fruit weight, seeds per fruit, seed length with and without wings, seed width with and without wings, and seed weight. Data was subjected to statistical analysis and ANOVA table was constructed. Values of standard error of mean and critical difference at 5% level of significance were given in tabular form and detailed inference is described below.

Table 1: Geographical locations of selected candidate plus trees of *T. ciliata* in Jammu region

District	Sites	CPT number	Altitude (m above msl)
Udhampur	Manthal	CPT-1	726
	Maand	CPT-2	757
	Girnai	CPT-3	606
	Modia	CPT-4	654
Kathua	Sahar	CPT-5	452
	Bann	CPT-6	371
	Girnari	CPT-7	397
	Kannoh	CPT-8	346
Samba	Sohanda	CPT-9	406
	Cha-Billor	CPT-10	358
	Sandholi	CPT-11	368
	Thandikui	CPT-12	338
Jammu	Kaink	CPT-13	513
	Surinsar	CPT-14	603
	Behera	CPT-15	482
	Chatha	CPT-16	253
Reasi	Mehari	CPT-17	719
	Bhangal	CPT-18	690
	Sulla	CPT-19	469
	Bharakh	CPT-20	628
Rajouri	Seiya	CPT-21	724
	Kathanu	CPT-22	570

Results and Discussion

Seeds are unique in natural regeneration and propagation because seeds constitute unique genetic composition resulting from mixing parental genetic materials, which result in genetic variation of the offspring that enhances the ecological adaptability of species (Schmidt, 2000) [11]. Therefore, understanding intra and inter population variation for reproductive traits would be essential for popularization of species. This also helps in further selection and improvement of species for commercial traits to obtain higher yield. Genetic quality seeds are essential for production of quality seedlings in large quantities. In the present study, variation in different fruit and seed traits has been recorded among 22 genotypes of *T. ciliata* (Table 2 and 3). CPTs of *Toona ciliata* exhibited considerable amount of variation in seed and fruit characters studied.

Twenty two CPTs of *T. ciliata* showed a wide range of variation in fruit length (16.91 to 25.59 mm) with maximum fruit length (25.59 mm) observed in the fruits collected from CPT-1 (Manthal, Udhampur) and was found to be significantly superior from the rest of the entries. Whereas, CPT-3 (Girnai, Udhampur) registered minimum fruit length of 16.91 mm. Fruit width ranged between 8.32 -11.64 mm, whereas CPT-11 (Sandholi, Samba) registered the maximum fruit breadth and minimum fruit breadth in CPT-7 (Girnari, Kathua). Fruits collected from CPT-1 (Manthal, Udhampur) was foundsuperior in terms of100 fruit weight with 364.93 g over the other candidate plus trees. On the other hand, the fruits collected from CPT-3 (Girnai, Udhampur) exhibited the lowest fruit weight of 158.03 g. Among the genotypes, the fruits collected from CPT-6 (Bann, Kathua) recorded highest (28.22) seeds per fruit and CPT-7 (Girnari, Kathua) recorded minimum seeds per fruit (Table-2).

Table 2: Variation in fruit traits among the CPTs of *T. ciliata*

CPTs	Fruit length (mm)	Fruit breadth (mm)	100 fruit weight (g)	Seeds per fruit
CPT-1	25.59^{a}	10.22 ^{bc}	364.93^{a}	23.08 ^{f}
CPT-2	20.86 ^{efg}	10.10 ^{cd}	269.77 ^{def}	23.08 ^{f}
CPT-3	16.91 ^{m}	8.36 ^{h}	158.03^{l}	21.03 ^{h}
CPT-4	21.46 ^{d}	9.50 ^{ef}	255.00 ^{fg}	25.92 ^{c}
CPT-5	17.07 ^{lm}	8.96 ^{g}	184.50 ^{jk}	23.19 ^{f}
CPT-6	21.04 ^{def}	9.17 ^{fg}	200.37 ^{ijk}	28.22 ^{a}
CPT-7	17.50 l	8.32 ^{h}	179.07 ^{kl}	19.45 ^{i}
CPT-8	23.35 ^{b}	10.58 ^{b}	356.23 ^{a}	24.64 ^{d}
CPT-9	20.72 ^{fgh}	9.48 ^{ef}	203.90 ^{ij}	27.22 ^{b}
CPT-10	18.80 ^{k}	8.93 ^{g}	220.13 ^{hi}	22.36 ^{g}
CPT-11	22.60 ^{c}	11.64 ^{a}	296.73 ^{bc}	24.08 ^{de}
CPT-12	21.30 ^{de}	11.51 ^{a}	223.23 ^{hi}	23.31 ^{f}
CPT-13	19.36 ^{j}	9.22 ^{fg}	288.03 ^{bcd}	22.33 ^{g}
CPT-14	18.71 ^{k}	9.84 ^{de}	223.00 ^{hi}	21.39 ^{h}
CPT-15	19.87 ^{ij}	10.53 ^{b}	285.20 ^{bcde}	20.86 ^{h}
CPT-16	22.48 ^{c}	10.51 ^{b}	273.83 ^{cdef}	25.67 ^{c}
CPT-17	20.38 ^{ghi}	9.17 ^{fg}	223.83 ^{hi}	23.28 ^{f}
CPT-18	21.14 ^{def}	10.11 ^{cd}	303.27 ^{b}	23.67 ^{ef}
CPT-19	20.29 ^{hi}	10.02 ^{cd}	261.67 ^{efg}	25.33 ^{c}
CPT-20	22.40 ^{c}	9.75 ^{de}	303.07 ^{b}	23.61 ^{ef}
CPT-21	18.52 ^{k}	9.87 ^{cd}	238.27 ^{gh}	25.78 ^{c}
CPT-22	20.46 ^{gh}	11.36 ^{a}	258.73 ^{fg}	25.47 ^{c}
Mean	20.49	9.87	253.22	23.77
CD $_{(0.05)}$	0.55	0.30	21.94	0.63

Analyzed data also showed that there was significant difference among the 22 CPTs of *T.ciliata* collected across six districts of sub-tropical and sub-temperate Jammu region for all seed traits. Seeds collected from CPT-1 (Manthal, Udhampur) recorded maximum seed length with wings of 20.89 mm and the minimum value (12.80 mm) was observed in the seeds collected from CPT-5 (Sahar, Kathua).

Table 3: Variation in seed traits among the CPTs of *T. ciliata*

CPTs	Seed length (mm)		Seed width (mm)		100 seed weight (g)
	With wings	Without wings	With wings	Without wings	
CPT-1	20.89 ^{a}	5.73 ^{bc}	4.52 ^{def}	2.88 ^{ab}	0.33 ^{ab}
CPT-2	14.27 ^{kl}	5.68 ^{bc}	3.55 ^{jk}	2.50 ^{cde}	0.25 ^{gh}
CPT-3	15.19 ^{hi}	5.45 ^{bcd}	4.30 ^{efg}	2.66 ^{bcd}	0.19 ^{ij}
CPT-4	16.68 ^{e}	5.77 ^{b}	4.31 ^{efg}	2.67 ^{bcd}	0.25 ^{gh}
CPT-5	12.80 ^{m}	5.33 ^{cde}	3.84 ^{ij}	2.50 ^{cde}	0.18 ^{jk}
CPT-6	16.56 ^{ef}	5.73 ^{bc}	3.93 ^{hi}	2.43 ^{cde}	0.23^{h}
CPT-7	13.79 ^{l}	5.52 ^{bcd}	4.34 ^{ef}	2.60 ^{bcd}	0.15^{k}
CPT-8	19.27 ^{b}	6.31 ^{a}	5.29 ^{a}	2.72 ^{bc}	0.35^{a}
CPT-9	15.60 ^{gh}	5.80 ^{b}	4.46 ^{ef}	2.93 ^{ab}	0.29 ^{cde}
CPT-10	16.07 ^{fg}	5.57 ^{bc}	4.32 ^{ef}	2.68 ^{bcd}	0.29 ^{cdef}
CPT-11	18.17 ^{c}	6.47 ^{a}	5.10 ^{ab}	3.13^{a}	0.27 ^{efg}
CPT-12	15.02 ^{ij}	5.62 ^{bc}	4.89 ^{bc}	2.49 ^{cde}	0.28 ^{defg}
CPT-13	14.38 ^{k}	5.12 ^{de}	3.41 ^{k}	2.15^{e}	0.28 ^{cdefg}
CPT-14	14.79 ^{ijk}	4.98 ^{e}	3.99 ^{ghi}	2.71 ^{bcd}	0.22 ^{hi}
CPT-15	18.57 ^{c}	5.78 ^{b}	4.82 ^{bcd}	2.44 ^{cde}	0.25 ^{fgh}
CPT-16	19.28 ^{b}	6.39 ^{a}	4.63 ^{cde}	2.50 ^{cde}	0.31 ^{bcd}
CPT-17	16.36 ^{ef}	5.75 ^{bc}	4.50 ^{def}	3.21^{a}	0.30 ^{bcde}
CPT-18	17.36 ^{d}	6.47 ^{a}	4.19 ^{fgh}	2.41 ^{cde}	0.30 ^{bcde}
CPT-19	15.60 ^{gh}	5.47 ^{bcd}	4.56 ^{de}	2.61 ^{bcd}	0.31 ^{bc}
CPT-20	17.59 ^{d}	5.79 ^{b}	4.55 ^{de}	2.37 ^{de}	0.30 ^{bcde}
CPT-21	14.51 ^{jk}	5.59 ^{bc}	4.38 ^{ef}	2.71 ^{bcd}	0.25 ^{gh}
CPT-22	18.49 ^{c}	6.51 ^{a}	5.13 ^{ab}	2.73 ^{bc}	0.36^{a}
Mean	16.42	5.77	4.41	2.64	0.27
CD $_{(0.05)}$	0.54	0.43	0.33	0.35	0.04

However, seed length without wings ranged from 4.98 mm to 6.51 mm. Minimum value was exhibited by CPT-14 (Surinsar, Jammu) and maximum value of 6.51 mm was recorded in CPT-22 (Kathanu, Rajouri). Whereas, seed width with wings ranged from 2.15 mm (CPT-13; Kaink, Jammu) to 5.29 mm (CPT-8; Kannoh, Kathua). Seeds collected from CPT-17 (Mehari, Reasi) recorded maximum value (3.21 mm) of seed width without seed wings and the least value (2.15 mm) for seed width without seed wing was found in CPT-13 (Kaink, Jammu). The analysis showed significant differences among the genotypes for 100 seed weight with maximum 100 seed weight was registered in CPT-22 (Kathanu, Rajouri; 0.36 g) and. On minimum value (0.15 g) was exhibited from the seeds collected from CPT-7 (Girnari, Kathua) (Table 3).

It is clear from the results that the nature and extent of observed variations for traits under consideration was large. The variations observed, might have occurred due to climatic and microclimatic conditions as this species grows over the wide range of climatic conditions. Similar results have been reported by Roy *et al.* (2004) [9] in *Pinus roxburghii*, Fredrick *et al.* (2015) [3] in *Faidherbia albida* and Shu *et al.* (2012) [13] among the provenances of *Magnolia officilnalis*. Rao *et al* (2008) [10] found the significant differences for seed length and 100 seed weight in *Jatropha curcas*. Uniyal *et al* (2003) [14] reported significant variation between population of *Grewia optiva* that could have been the consequences of disparity in the environmental conditions, like water, nutrients or light, to which parental plants were subjected during growing season. Similar results were also reported by Singh *et al* (2006) [12] which revealed that the variation in seed size (seed length, seed breadth) and 1000 weight of *Celtis australis* is due to the different environments at the geographic origins.

It is concluded that fruits and seeds collected from 22 CPTs of *T. ciliata* in Jammu region showed significant difference among them in most of the fruit and seed traits and therefore, these CPTs may be used for further genetic improvement programme in the species. CPTs *viz.* CPT-1, CPT-11, CPT-12, CPT-22, and CPT-6 with large sized fruits with more number of seeds can be used for commercial raising of quality planting material.

Conclusion

This is the first study of phenotypic variation in seed traits among populations of *T. ciliata* trees in Jammu and Kashmir. This study provides baseline information for the domestication of *T. ciliata*. It has highlighted fruit trait variation between the populations of the species in the subtropical and intermediate zones of Jammu, identified tree-to-tree variation, and relationships between some key traits, thereby defining some ideotypes. However, there is a need to study genetic variation parameters to understand the genetic contribution to the observed phenotypic variation. In addition, it is worth implementing progeny tests to estimate realized heritability values and associated genetic gains together with genetic correlations in fruit and seed traits.

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