GENETIC IMPROVEMENT, PROPAGATION AND CONSERVATION EFFORTS FOR *TECOMELLA UNDULATA*, A FLAGSHIP TIMBER SPECIES OF THE DRYLANDS- A REVIEW

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Abstract

Tecomella undulata (Local name-Rohida) which belongs to the family Bignoniaceae is a socially acceptable and economically valuable tree species of the arid regions and native to the Indian subcontinent. It is a well-known multipurpose tree species that has been over exploited for timber and medicines from its natural habitat. As a result, most Rohida genetic resources have already been depleted in the wild habitat. Therefore, to conserve the species tree improvement programmes are underway in different organisations. Under tree Improvement research on Rohida, work has been majorly carried out on reproductive biology, selection of candidate plus trees, establishment of progeny trials, vegetative propagation, and diversity studies using molecular markers. The report consolidates the status of the work on tree improvement and propagation of this important tree species done so far.

Keywords: ***Conservation, Molecular markers, Phenology, Progeny trials, Propagation***

I. INTRODUCTION

Bignoniaceae family is characterized by woody stem, opposite, compound leaves and zygomorphic flowers. The family is comprised of about 112 genera and 725 species, usually distributed in the tropical and subtropical parts of world[1].The family is represented by 15 genera and 40 species in India, mostly occurring in western and southern parts whereas ,few in Himalayas [2],[3]

Tecomella undulata locally known as Rohida or Rohitaka belongs to this family and is regarded as the flagship species of the arid region according to Forest Survey of India (2001) and Indian Council of Forestry Research and Education [4]. It is one of the co-dominant medium sized tree species in the arid forest of Rajasthan and ranked high position for its timber quality amongst the indigenous tree species of desert regions of Shekhawati and Marwar in Rajasthan [5].

Unfortunately, this species has become victim of over exploitation for its high-quality timber and medicinal values because of which it has been put into the class of “threatened” in Rajasthan province of India [6], [7], [8]. Moreover, United Nations Environment Programme (UNEP) and World

Conservation Monitoring Centre (WCMC) Nairobi, Kenya, both have also included Rohida into "Indeterminate- Category 1" list of threatened plants to emphasize its status and suggests measures for conservation of such an important tree species [9]. Similarly, Red data book compiled by Hussain [10] also determine the threatened status of native plants of Karachi and reported that out of 135 species, eight species including Rohida were threatened.

The wood obtained from the tree is tough, strong and durable. It takes a fine polish hence highly valued for engraved furniture, carvings, turnery and toys and an excellent source of firewood and charcoal [11]. The wood is prized equal to Teak thus the name '*Marwar* Teak' of Rajasthan [12], [13], [14]. The tree has occupied a reputed position of having valuable medicinal properties in both folk and classical streams of indigenous medicinal systems. Bark of the tree is used for the treatment of syphilis, eczema, enlarged spleen, gonorrhea, leucoderma and liver disease and also used in many ayurvedic preparations [15]. Various studies have shown that it has significant anticancer [16], hepatoprotective [17], analgesic [18] and antibacterial [19], antifungal, antitermite activities.

The major disadvantage of the species is that it is slow growing and this result in a slow return of the breeding efforts. Since the species has become a victim of over exploitation for timber and medicinal purposes, an attempt has been made to review and consolidate the information available on tree improvement and propagation research done and to suggest future prospective for Rohida so as to conserve and managed such an important species of arid region.

A. Historical evolution

Existence of *Tecomella undulata* is mentioned in the major Sanskrit epics of ancient India, Mahabharata. Mahabharat is divided into eighteen parvas out of which Sabha parva (The Book of Assembly Hall), Vana parva (The Book of the Forest) and Udhyoga parva (The book of the Effort) mention the existence of the Rohitaka tree. Chapter 29 of Sabha parva Book II of Mahabharat (2:29:4) mentions that the kings whom Nakula subjugated, set out from Khandavaprastha for the west. He first assailed the mountainous country called Rohitaka (Rohtak) that was dear unto (the celestial generalissimo) Kartikeya. Similarly , Chapter 174 of Book III of Mahabharata, Vana Parva describes that while wandering about with contentment in (the vicinity of) the Dvaita Forest, Kurukshetra, Saraswati river, Pandavas saw the holy fig, the rudaraksha, the rohitaka, the cane and the jujube, the catechu, the sirisha, the bel, the inguda, the karira, pilu and sami trees growing on the bank of this river. Further chapter 19 of Book V of Mahabharat, Udyoga Parva describes about the region called Kuru-Jangala, and the forest of Rohitaka [20].

B. Distribution

Tecomella undulata (Sm.) Seem is an economically important plant species that originated in India and Arabia [21]. Population of this species is restricted to the drier parts of the Arabia, southern Pakistan and northwestern India up to an elevation of

1200 meters [22]. It is also recorded in the Sindh regions and Baluchistan in Pakistan. In India, it occurs naturally in Maharashtra, Gujarat, Rajasthan, Punjab, Haryana states out of which major population is mainly found to occur in southern Haryana and western parts of Rajasthan. In other states its population is scanty and very rare. In Rajasthan, it is distributed throughout the districts of Barmer, Jaisalmer, Jodhpur, Jhunjhunu, Jalore, Pali, Ajmer, Nagaur, Bikaner, Churu and Sikar [23], [24].

C. Ecological descriptions

This species is widely adapted to the arid regions [25], [26] and occurs on flat and undulating areas including ravines and hilly slopes. It can tolerate drained loamy to sandy loam soil with a pH ranging from 6.5 to 8.0. The species thrives very well on stabilized sand dunes, which experience extreme low (0°C to −2°C) and high temperatures (48°C to 50°C)[27]. It can grow in the areas of scanty rainfall almost as less as 150 to 500mm annually. It acts as a keystone species for afforestation due to its drought, frost, fire resistant properties. It is also accepted as agroforestry tree species in the Thar Desert of Rajasthan for its higher survival rates even in extreme drought conditions [27]. A large population of this species is found in the agricultural lands and can be observed growing in community land, and orans (forestland) in association with *Prosopis cineraria, Capparis decidua, Zizipus spp, Salvadora spp* [28]

D. Phenological observations in Tecomella undulata

Tecomella undulata is near to evergreen tree species and defoliate completely for a very short period if at all happen. Leaf-fall starts from beginning of November and carries up to March end. Three different flower colors are observed in *T. undulata* i.e. yellow, orange to dark-orange and red (Fig.1). Tree flowers from late November and continues up to the April end. In general, the duration of flowering is more in yellow flowered trees than the trees with other colors. Peak flowering has been reported between February end to mid-March (i.e. 9 to 19 days).

Figure 1: Three different morphotypes of *Tecomella undulata* (Yellow, Red and Orange)

However, the total flowering duration varies from 59-103 days for the individual tree and 135 days for the whole population [29]. Asynchronous type of flowering is observed in the species [30]. Fruit formation starts in February and fruits are ready for harvest in the last week of March. Setting of fruit varies from 0.64% from selfing to 3.94% from cross pollination, indicating presence of self-incompatibility in the species [29]. Studies of [29] and [8] indicated that only about 4-6% of flowers form fruits. Fruits harvested per tree vary from 11 to 143 and number of seeds per fruit varies from 58.7 to 135 seeds per fruit. Length and width of the pods varies significantly from 18.6cm to 26.2cm and 9.0mm to 10.7mm [31]. One thousand seed weights ranges from 6.0g to 10.4g. The seeds of this species varied greatly in their length and width ranging from 16.7 mm to 22.2 mm and 8.3 mm to 9.3 mm respectively (Table 1) [31].

E. Pollination

The species has been reported as cross pollinated in behavior. Variable dark color flower in Rohida and nectar collected at the base of the flower inside the corolla attracts the birds or other insects for pollination [29]. In *Tecomella undulata*, anthesis occurs between 6:00 am to 12:00 Noon and 5:00 am to 1.00 pm followed by dehiscence about an hour later [8] and [30].A wide range of pollen fertility has also been reported in this species, where pollen fertility ranges from 91.2% in orange flowers to 98% in yellow flowers [30].

TABLE 1: - Month wise representation of phenology of *Tecomella undulata*

Parameter Month and Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Seed Ripening	×	×	Yes	Yes	Yes	Yes	×	×	×	×	×	×
Pod Ripening	×	Yes	Yes	Yes	×	×	×	×	×	×	×	×
Flowering	Yes	Yes	Yes	Yes	×	×	×	×	×	×	Yes	Yes
Leaf Initiation	×	Yes	Yes	Yes	Yes	Yes	×	×	×	×	×	×
Leaf Fall	Yes	Yes	Yes	×	×	×	×	×	×	×	Yes	Yes

[8] recorded the pollen fertility as 96%, where the sub-spheroidal pollen measuring 78.14 × 69.9 showed maximum germination and pollen tube length observed in 10% sucrose solution supplemented with 0.005% boric acid. The stigma remains receptive up to 24-30 of anthesis. The nectar robbing is also observed in Rohida which is the result of the ability of some floral foragers to steal nectar without effecting pollination [32]. The flowers are entomophilous and ornithophillous in nature and honeybees and Martin birds are the major pollinators in *T. undulata* [30] and [8].

F. Selection of candidate plus trees and establishment of trials

The regeneration rates of Rohida in natural surroundings is quite low, therefore alternative propagation methods are considered beneficial in large scale multiplication, improvement and conservation of its elite clones. Sexual method of propagation through seeds has limitation as often essential superior qualities or plus traits of a mother plant fails to get transmitted to the selected young ones and progeny also lack the uniformity and resemblance to mother tree [33].

The ripening of pods starts at the month of mid-February and are available for collection from March to April. On an average, a capsule contains 234 seeds [34]. The number of seeds varies from 70000 to 120000 to a kilogram and approximately 5000 plants can be expected from one kilogram of seeds [35]. Seed viability is greatest immediately post-harvest and has reported to decline to zero after one year [36]. Artificially it could be propagated by directly sowing the seeds in polythene bags containing the mixture of sand, soil and FYM, placed properly under the shaded mother beds. The germination capacity of the seed has been reported to be between 26 to 46 percent from the seeds collected from unknown sources [37]. However, studies carried out at AFRI from the fresh seeds collected from the selected CPTs gave an average of 66% germination in nursery beds when grown in the month of May under 50% shade condition [31]. Seeds sown vertically at a depth of 1.5 to 2.0 cm sprouted within two to three days. Freshly harvested seeds germinated well, hence seed dormancy was not observed during the study. Depending upon the source of collection, the seeds of the plant remain viable for about 12-18 months. Gibberellic Acid treatment to the seeds from 1 ppm to 50 ppm promoted the germination up to 80% [38].

Since, the species show three distinct morphotypes (Yellow, Orange and Red) therefore seed germination with respect to different flower colors was also recorded. Variation in seed germination with respect to different flower colors of the trees ranged from 73.22% (yellow flowered tree seeds) to 61.62 % (red flowered tree seeds). Orange colored flowers shown seed germination of 64.86%. Based on the survey conducted in Rajasthan it was observed that orange and yellow color flower plants are in majority in most of the sites whereas red flower plants are comparatively lower in frequency [31].

For effective tree improvement programme, knowledge

of genetic variability existing in plants and patterns of change of genetic parameters over time is necessary. Establishment of provenance trial is the first step for any improvement programme. Provenance trial results are useful in selecting its growing areas for CPTs selection and assessing overall genetic variability. In the year 1992 the provenance trial of this species was established at Arid Forest Research Institute, Jodhpur with 13 seed sources from Rajasthan. The provenances from Bhaislana region of Jaipur District and Sunderpur Bir of Sikar District grew best [39].

A criterion of selecting CPTs is designed according to commercial exploitation of a tree species. In case of trees, major criteria are based on yield and quality of wood. Main trunk, secondary and even tertiary branches (having diameter >30 cm) of *T. undulata* are used for various wood products. Present used CPTs selection criteria and methodology for the species have been developed and derived from FAO guidelines and method used by different organizations [40] and [41]. Canker formation is serious problem in Rohida trees and lead to loss of productivity in terms of quality wood yield. Canker formation is higher in trees having girth range from 80 cm onwards. The maximum percentage (18.65 %) of cankers was reported in the trees having girth range above 121 cm [42]. Therefore, selection of trees having no symptoms of canker is important criteria in Rohida. In 1992, [41] identified 24 CPT's from Jodhpur and Barmer districts and laid down the progeny trial of *T. undulata* comprising of 11 progenies in 1983 and evaluated the changes in the growth parameters and tree height over six years in 1989. They reported that the components of variance tend to stabilize after fourth year of growth, therefore, selections done prior to this may not be rewarding. Low values of heritability and genetic gains from family and single tree selection suggested the need for other selection procedures for higher genetic gains for tree height. Under the tree improvement programme of *T. undulata* initiated at AFRI, Jodhpur, 86 CPT's were selected from Barmer, Jaisalmer, Bikaner, Nagaur, Sikar, Churu, Jalore, Pali and Jodhpur of Rajasthan (Fig.2).

Figure 2: Identified candidate plus trees of *Tecomella undulata*

TABLE 2: Growth performance of multilocational trials of *Tecomella undulata* established in 2008 and 2013-14

Growth performance of trial	Mean Avg. Height in 2018 (cm)	Mean Avg. Girth in 2018 (cm)	Best performing progeny
Jodhpur (2008)	236	4.45	CPT No-37 from Jodhpur (Ht-276cm, Girth-6.6cm)
Bikaner (2008)	128	1.92	CPT No-27 from Barmer (Ht-156cm, Girth-2.6cm)
Jodhpur (2013)	122	1.71	CPT No-36 from Pali (Ht- 180cm, Girth-3.2cm)
Jhunjhunu (2014)	42.53	0.48	CPT No-25 from Churu (Ht- 75.5cm, Girth 0.78cm)

To assess the performance of the selected trees, multilocational half-sib progeny trial of 40 progenies (Barmer, Jaisalmer and Jodhpur) and 36 progenies (Nagaur, Sikar, Churu, Jalore, Pali and Bikaner) were established in 2008at Jodhpur and Bikaner also and in 2013-14 at Jodhpur and Jhunjhunu district of Rajasthan (Table 2).

Performance of the growth was recorded for all the progeny trials. The 11-year-old trial existing at Jodhpur performed well compared to Bikaner trial with 87% of survival at Jodhpur and 58% at Bikaner. Average height of plants at Jodhpur was 236 cm and at Bikaner it was 128 cm. Similarly, an average collar diameter of plants at Jodhpur was 4.45cm whereas at Bikaner was 1.92 cm respectively. The progeny of CPT-37 (Jodhpur) gave the best growth at Jodhpur attaining the height of 276 cm with collar diameter of 6.6 cm whereas the progeny of CPT-27 (Barmer) gave best growth at Bikaner with height of 156 cm and collar diameter of 2.6 cm. Similarly, growth data were also recorded for the trials established in 2013 and 2014 which showed an average height of 122 cm and collar diameter of 1.71 cm at Jodhpur and height of 42.53 cm and collar diameter of 0.48 cm at Jhunjhunu. The progeny of CPT No-36 from Pali (Ht 180 cm, Girth 3.2 cm) performed best at Jodhpur site where as the CPT No-25 from Churu attaining the Height of 75.5 cm and Girth of 0.78 cm performed best at Jhunjhunu district.

G. Vegetative propagation:

The use of biotechnology on trees has opened up new possibilities for rapid mass multiplication of existing stocks of germplasm, as well as conservation of important plants/plant parts [43], [44], [45], [46] and [47].

Once the superior or elite trees are identified they need to be propagated by clonal methods to produce identical trees comprising the same genetic constitution as of the parent material. Clonal propagation also assures the uniformity and desirability of the elite characters. This method is broadly classified into two groups- conventional (macropropagation) and contemporary (micropropagation) methods. Conventional methods of vegetative propagation of tree species are in practice in many species with the beginning of forestry as a science. These methods now also termed as macropropagation and

include propagation by vegetative cuttings (root, stem and leaf), grafting, air-layering etc. Modern technologies came into existence in 1960 and recently application at commercial scale is also been demonstrated in certain plant species. They are mainly *in vitro* techniques (Plant Tissue Culture) also termed as micropropagation. Reports are available on regeneration for the conservation and better management of such an important plant species of an arid region. But efficient plant production through clonal propagation methods for *T. undulata* tree is still lacking.

1. Macropropogation

Macropropogation is used routinely and still preferred for tree species over micropropagation because of cost effectiveness, requirement of semi-skilled manpower and simple infrastructure. Very little published research work is available on macropropagation of *T. undulata.* In 2010, [48] reported very high success rate in rooting (about 80%). They studied the effect of IBA and NAA on the rooting of Rohida stem cuttings in the late winter and late autumn. Rooting was found to be seasonal and the response to auxin was uneven between the seasons. Both NAA and IBA had significant effect on rooting. In the late winter rooting was better than the stem cutting harvested in the late autumn. During the first period, the application of NAA at the concentration of 0.3% resulted in 82.9 and 89.4% rooted cuttings *via* semi-hardwood and hardwood cuttings, respectively, whereas 4% IBA resulted in 80.6 and 81.7% rooted cuttings *via* semi-hardwood and hardwood cuttings, respectively.

Further in 2011, at AFRI, Jodhpur, macropropagation studies were done to observe the effects of auxin (IBA), container type, potting mix, wax coating, differently managed tree, different thickness, season, genotype and different position of stem cutting in a tree canopy. In this IBA was not found suitable for rooting. Stem cuttings with 0.2 – 2.0 cm thickness were tried and best result was observed in the cuttings with 1.0 to 1.4 cm thickness. Late winter (January to March) was the best period for root initiation (15 %). No rooting response was observed during July to December months. Among the 4 different genotypes viz. Tree no. 9, 12, 17 and 21, highest sprouting (99 %), root primordial formation (48.1 %) and rooting (10.4 %) was observed in tree no.9, which was significantly different from other three genotypes (Table 3) [49]

Data analysis resulted that upper portion of the branch collected from middle crown of the tree canopy rooted 33.3% maximally. Stem cuttings collected from this tree also produced flower buds and flowers in the mist-polyhouse itself (Table 4) [49]. This phenomenon was not observed in any other tree. It appears that flowering is also associated with rooting response in this tree. However, these rooted plants did not produce flowers after one year.

TABLE 3: Effect of stem cutting collected from different trees on sprouting and rooting response. [49]

Genotype	Number of Stem Cuttings	Sprouting %±SE	Primordia %±SE	Rooting %
Tree No 09	45×3	99±7.4	48.1±4.3	10.37
Tree No 12	45×3	93±2.2	7.4±2.2	0.74
Tree No 17	45×3	92±2.3	4.4±1.8	0.74
Tree No 21	45×3	97±1.4	5.9±2.0	0.74

TABLE 4: Effect of stem cutting collected from different locations in the crown of a tree no.9 on rooting response. [49]

Crown Portion	Nos. Cuttings	Rooting % in branch portions SE			All
		Upper	Middle	Lower	
Top crown	45	6.7±6.7	13.3±9	0	6.7
Middle crown	45	**33.3**±12	13.3±9	6.7±6.7	17.8
Bottom crown	45	0	20.0±10	0	6.7

2. *Micropropagation*

Advance micropropagation technique offers several advantages over macropropagation technique, such as, faster multiplication, regeneration of plants throughout the year, elimination of viruses through shoot tip culture, selection of normal clonal variants and preparation of artificial seeds through somatic embryogenesis. Advantages of tissue culture technique in forestry have been emphasized by several authors [50]. However, progress in micropropagation of tree species is still has limited success and only few tree species can be propagated at commercial scale. Micropropagation of *T. undulata* is still difficult particularly due to unpredictability of adventitious rooting. Therefore, there is a need for improvement in shoot multiplication and long-term sub culturing and for better knowledge of root induction in this species.

First report on standardization of *T. undulata* protocol was carried out Rathore [51] by using seedlings and mature trees as source of explants. Shoot induction from mature (25-year-old) and seedling explant was found best on Murashige and Skoog's (MS) medium supplemented with 0.05 mg/l IAA and 2.0 mg/l BA at 31°C after 2-3 weeks when kept at 43 µE m−2 s−1 photon flux density and a 12-h/day photoperiod. Maximum 79 % of bud break was achieved in the month of August-September. The *in vitro* shoots were multiplied by sub culturing on fresh MS medium containing IAA (0.01 mg/l) and BA (1.0 mg/l) within 3 weeks at 26 ± 2°C and 36 µE $m^{-2}s^{-1}$ photon flux density. Isolated shoots were rooted by culturing on half strength MS liquid medium containing IBA (2.5 mg/l) for 48 h and then transferred to hormone-free half strength MS medium. About 60 % of in vitro produced shoots were rooted.

In continuation of this, many researchers attempted for regeneration of *Tecomella undulata* and succeeded to induce shoots from various explants from mature plants [52], [53], [54], [55] and [56]. [53], 1993 reported 30 % rooting on one-third strength modified woody plant basal medium supplemented with 0.3 mg/l indole butyric acid (IBA) or NAA.

By taking the seedlings derived explants like cotyledonary nodes on various medium for growth, many researchers were successful in developing regeneration protocol for *T. undulata*[57], [58], [59], [60], [61].

In 2013, [62] from AFRI, Jodhpur studied the rooting ability of mature trees of *T. undulata* through microprogation. They refined its *in vitro* propagation using nodal segments from mature trees. Results shows that the *in vitro* shoot cultures can be established throughout the year but the most favorable months for bud break (75%) was January and February on Murashige and Skoog (MS) medium supplemented with 0.54 µM NAA and 8.8 mm IBA. Correlation studies on different classes of shoot length and rooting revealed that the rooting percentage increases with the increase in shoot length and shoots less than 2.5 cm long does not root at all. The rooted plantlets were successfully hardened followed by flowering which was recorded in tissue culture plants for two consecutive years.

By taking the combinations of various pant growth regulators and nitrogen sources, studies were carried out by [63] and [64]. Patel and Patel in 2013 studied the effects of different concentrations and combinations of plant growth regulators (PGRs) on callus induction using internodal segments [63] and leaf segments [65] of *Tecomella undulata* (Sm) Seem. In 2017, Chauhan and Rathore [64] studied the effects of different concentrations of NH_4NO_3, KNO_3, NH_4NO_3 X KNO_3 and glutamine on its proliferation stage cultured on MS media as nitrogen sources. The highest shoot length and multiplication was obtained with combination of NH_4NO_3 X KNO_3 (10.31 mM X 9.40 mM) with low hyperhydricity (10.3%). It was reported that the MS N combination was superior to any single N source for proliferation and growth of shoots.

Various others studies with respect to development of protocol for genetic transformation and use of nanoparticles was carried out in the species. In 2009, Aslam [66] optimized a protocol for genetic transformation of Rohida from cotyledonary node tissue using *Agrobacterium tumefaciens* strain GV2260 harboring binary vector pBinAR containing osmotin and *nptII* gene under control of CaMV35S promoter. This was the first report on the transformation of *T. undulata.* The effective concentration of selectable marker antibiotic used for screening of transformants was 85.97 µM in shooting media and 42.98 µM in rooting media.

Further in 2012, [67] evaluated the effects of silver nanoparticles (SNPs) at different concentrations ranging from 5 to 80 mg I^{-1} alone or in combination with 6-benzyl-amino-purine (BAP) and indoleacetic acid (IAA) on growth properties of *T. undulata* in aseptic condition. Adding of SNPs in MS medium increased the mean number of fresh shoots per explants

(MNFS/E), the percentage of explants producing shoots (PEPS). SNP's also increases plant survival, due to its action on ethylene blockage. At the concentration of 0.1 mg $l^{-1,}$ TDZ increased the bud proliferation (two buds per explants), however higher concentration inhibited growth and, in some cases, caused death of the explants.

In 2016, [68] synthesised the silver nanoparticles (AgNPs) of Rohida using aqueous extract at 60 °C in orbital shaking incubator. The variation in pH values and colour changes were observed within few minutes during reduction of silver nitrate (0.1 to 1 mM final concentration) in presence of plant extract and the capping of synthesized stable silver nanoparticles. The stability of biogenic silver nanoparticles was monitored through zeta potential measurement and surface properties and size of the nanoparticles were studied through scanning electron microscopy and atomic force microscopy.

H. Genetic diversity study using molecular markers

Genetic diversity is characterized by differences in composition or frequency of genes or alleles among individuals in a species or its population. Before designing any forest conservation programme, understanding of the current diversity status of forest genetic resources is essential [69]. Populations with genetically diverse species have better survival compared to the populations having more individuals but with the limited genetic variations. A number of economically important forest tree species are under threat due to human pressures and the extent of reduction in population size provides an indication of the extent of loss of diversity [70] and a narrowing of genetic base. The advent of molecular marker techniques, bioinformatics and the use of geographical information system (GIS) are helping to develop better methods to survey, sample and assess the genetic diversity as already predicted by [71]. An array of population genetic studies had indicated that genetic diversity is structure that various levels of ecosystem in a kind of genetic architecture, knowledge of which is important in developing *in situ* conservation strategies [72]. Genetic variations are measured either through testing the characters through progeny tests or through genetic markers at DNA expression level (protein profile, Isozyme profile and even repetitive DNA markers like Scot DNA level (DNA markers). Moreover, little information is available with respect to genetic diversity studies for *T. undulata* using morphological and molecular markers.[73] assessed the genetic diversity of *T. undulata* (Sm.) using eight AFLP markers. They investigated the genetic diversity and phenetic relationship among 42 plants collected from different regions of India. Results of their study revealed high level of genetic diversity in *T. undulata* accessions, which is attributing to its outcrossing nature, yet the study would be interesting if they would have categorized the samples based on flower color. The AFLP analysis produced 338 bands of which 243 (72%) were polymorphic with an average of 42 bands per assay, which indicate a high multiplex ratio for AFLP techniques.

Further in 2011, [13] studied the taxonomical and ecological study in the species to find out genetic diversity at

intra-specific level. Three different morphotypes of Rohida i.e. yellow, red and intermediate colored petals accompanied by variations in color of sepals and seeds were identified. SDS PAGE of total proteins from seeds revealed distinct and consistent variations in banding patterns among the three morphotypes studied. Eight bands were found to be common to all the three morphotypes. One band was absent in the red morphotype and was present in orange and red morphotypes. These distinct characters suggest that the third morphotype with intermediate flower colour (orange) might be an intraspecific hybrid of the two morphotypes.

In 2017 [74], carried out the fingerprinting in the species using 22 SCoT primers which generated 294 amplicons of 100 to 3000 bp size, of which 212 (71.6%) were polymorphic. Average polymorphism information content (PIC), Nei's diversity index (H) and Shannon index (I) were found to be 0.54, 0.22 and 0.36, respectively. Dendrogram generated using unweighted pair-group method with arithmetic mean (UPGMA) divided the 108 accessions into 5 clusters while 2 accessions out grouped.

In 2018 [75] investigated the genetic variability of *T. undulata* in western Rajasthan using RAPD, ISSR and rDNA markers. The UPGMA dendrogram separated the samples into 13 (RAPD) and 11(ISSR) clusters with one outlier. The single distinct amplicon (~650 bp) of 5.8S gene region showed a uniform nucleotide length of 163 bp for the conserved 5.8S rDNA region while length variations were observed in ITS-1 (223 to 226) and ITS-2 (238 to 242) regions. Furthermore, the phylogram divided the 23 samples into 5 major clusters.

Recently, at AFRI, Jodhpur, genetic variability of *T. undulata* in Rajasthan was analyzed using RAPD and ISSR markers by taking the large number of uniform samples with flower colour identity. Polymorphism of 97.03% was observed with RAPD markers which are efficiently more compared to ISSR (89.13%) among the 120 samples belonging to 12 populations. The percent variability within and between populations varied among ISSR (58 and 42) and RAPD (69 and 31) markers. The *UPGMA* dendrogram divided the samples into 2 major clusters in both the marker system conserving the few populations which can be used further for genetic improvement of the species.

II. CONCLUSION AND FUTURE PERSPECTIVES

Tecomella undulata is a species of well drained soils with low water retention capacity and poor nutrient availability but responded well to increased water availability for growth. Literature survey has shown that this plant is an important timber yielding species of arid region and has immense medicinal uses in different systems of medicine. Multipurpose uses of this tree have over exploited the species for timber, medicines and fodder which categorized the species as endangered. Conservation and propagation of *T. undulata* is of utmost importance as populations seem to be declining. Since, the tree is very slow growing and no suitable method for vegetative propagation for rapid multiplication of elite trees is

available therefore seeds from improved quality are of utmost importance for extensive plantation of this species. Research on establishment of Seed production areas, seed orchard, reproducible clonal techniques, juvenility markers, clonal trials and pollen biology are to be initiated for its better conservation, sustainable utilization and genetic improvement. For this, long term and focused approach is required to achieve the deliverables. Reports are available on regeneration for the conservation and better management of such an important plant species of an arid region. But efficient plant production through clonal propagation methods for *T. undulata* tree is still lacking. However, tissue culture protocol remains ineffective due to lack of reproducible rooting methods. Therefore, there is a need of improvement in shoot multiplication and long-term sub culturing and better knowledge of root induction in this species. There is also need to explore the mineral accumulation capacity of the species for its use in afforestation on a wide range of soil conditions. Furthermore, use of nano particles can also be explored in enhancing and improving the micro-propagation protocols for quality planting material. Advanced tools and techniques of biochemistry and molecular biology could be utilized in refining natural systems of classification and establishing phylogenetic relationships among the morphologically similar or disputed taxa. The above said attempts should be taken up to save this species from further exploitation owing to its increasing demand for timber and pharmacological industries.

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