International Journal of Forestry and Crop Improvement
Volume **6** | Issue 2 | December, 2015 | 116-122 | ■Visit us : *www.researchjournal.co.in*
e ISSN-2230-9411

**RESEARCH ARTICLE**

DOI: 10.15740/HAS/IJFCI/6.2/116-122

# Effect of seasoning on sprouting of stem cutting and their survival in threatened medicinal important plant, *Commiphora wightii* (Arn.) Bhan.

R.N. KULLOLI, SURESH KUMAR, S.K. JINDAL AND MANJIT SINGH

**ABSTRACT :** *Commiphora wightii* (Arn.) Bhan. known as Indian bdellium is a large shrub of family Burseraceae. Its oleo-gum resin is known to be anti-inflammatory, antirheumatic, hypocholesterolmic, hypolipidemic, and antifertility agent. In order to extract more oleo-gum resin it has been overtapped in past, killing its natural populations thus prompting IUCN to keep it in 'Data Deficient category'. Its *ex-situ* conservation through seed as well as vegetative propagation has met with variable success. Seasoning of stem cuttings for a duration that ensures more sprouting and consequent survival was, therefore, aim of this study. Cut stem cuttings kept for 0, 1, 2, 3, 4 and 5 days and treated with IBA (5000 ppm) revealed that maximum root biomass (0.56 g), maximum number of shoots (6) and length of shoots (49.50 cm) was found in five days seasoned stem cuttings. After 27 months of plantation maximum survival was found in four and five days seasoned stem cuttings (50% each) cuttings. Collar diameter (1.75 cm) was maximum in five day seasoned stem cuttings. Maximum plant height (119.75 cm) was in four days seasoned cuttings followed by five days seasoned cuttings (96 cm). Thus, four to five days of seasoning in the month of August emerged most optimum for sprouting of stem cuttings and their subsequent survival in field plantation.

**KEY WORDS :** *Commiphora wightii*, Collar diameter, IUCN, Survival, Seasoning

**HOW TO CITE THIS ARTICLE :** Kulloli, R.N., Kumar, Suresh, Jindal, S.K. and Singh, Manjit (2015). Effect of seasoning on sprouting of stem cutting and their survival in threatened medicinal important plant, *Commiphora wightii* (Arn.) Bhan. *Internat. J. Forestry & Crop Improv.*, **6** (2) : 116-122.

**ARTICLE CHRONICAL :** Received : *10.09.2015;* Revised : *13.11.2015;* Accepted : *25.11.2015*

## INTRODUCTION

Existing population of *C. wightii* are continuously declining in abundance and extent of occurrence due to its overexploitation for getting more and more oleo-gum resin which has high medicinal value. Deeper and more cuts in its stem have killed this plant. Its regeneration from seeds is poor in nature (Kumar and Shankar, 1982). It has been successfully propagated through stem cuttings of 25 cm length and 1 cm thickness (Mertia and Nagarajan, 2000; Chandra *et al.*, 2001 and Kumar *et al*., 2002). Earlier, one-meter long and 10 mm thick woody stem cuttings were reported suitable for raising of *Commiphora wightii* (Dalal and Patel, 1995), thus, requiring a large number of plant material for propagation.

**MEMBERS OF RESEARCH FORUM**

**Address of the Correspondence** : **R.N. KULLOLI,** Central Arid Zone Research Institute, JODHPUR (RAJASTHAN) INDIA Email: r.kulloli@gmail.com

**Address of the Coopted Authors : SURESH KUMAR,** Division of Integrated Land Use Management and Farming Systems, Central Arid Zone Research Institute, JODHPUR (RAJASTHAN) INDIA Email: sk_ecology@yahoo.co.in

**S.K. JINDAL,** Division of Plant Improvement Propagation and Pest Management Plant Genetics Division, Central Arid Zone Research Institute, JODHPUR (RAJASTHAN) INDIA Email: jindal53@yahoo.co.in

**MANJIT SINGH,** Directorate of Mushroom Research, Chambaghat, SOLAN (H.P.) INDIA Email: directordmr@gmail.com

Indole-3-butyric acid (IBA) is most widely used auxin for rooting in stem cuttings and to increase the success percentage of cuttings (Al-Saqri and Alderson, 1996). However, effect of seasoning on rooting is poorly understood. Less is also known about the effect of ambient conditions on stem cutting when these will give maximum sprouting as also best survival in the field.

In view of this, an experiment was carried out to see effect of different duration of seasoning on sprouting and survival of rooted stem cuttings of *C. wightii* in field.

## EXPERIMENTAL METHODS

An experiment was conducted to study effect of seasoning on rooting, root traits, biomass production and success in the field establishment. 100 Stem cuttings from healthy *C. wightii* plants of same genetic stock were collected. Each cutting was 20 cm long and 1.0-1.5 cm thick. Cuttings were taken in first week of months of August-2009 and spread out under shade of green house with diffused light to callus for different durations from 0 to 5 days. After seasoning treatment lower tip of cuttings were dipped in 5000 ppm IBA solution prepared in 70 per cent alcohol. These treated cuttings were put for rooting in polybags containing rooting mixture of a clay, sandy soil and FYM (1:2:1) and kept under diffused light in nursery for rooting. At regular interval, watering was done and rooting data recorded. In first week of October-2010; 10 rooted cuttings were planted in field to study survival and data of growth parameters like height, collar diameter, mortality were recorded at regular intervals. At the same time from above treatments, four each rooted cuttings were taken for biomass analysis. Observations of mean values of all parameters like number of shoots, length of shoots, diameter of shoots, number of primary roots, length of primary roots, number of secondary roots, length of secondary roots, diameter of secondary roots, root biomass and shoot biomass were recorded. For biomass roots and shoots were dried in oven at $80^0$ C till constant weight achieved.

## EXPERIMENTAL RESULTS AND ANALYSIS

Evidently, longer the duration of seasoning, more was the swelling of tissues at the cut end of the stem cuttings. Maximum root biomass (0.56 g) was recorded in five days seasoned stem cuttings followed by four days

**Table 1 : Different root and shoot traits of rooted cuttings (avg. of four saplings) of *C. wightii* seasoned for different days**

| Days of seasoning | No. of shoots | Avg length of shoot (cm) | Avg dia. of shoots (cm) | No. of prim. roots | Length of prim. root (cm) | Avg dia. of prim. roots (cm) |
|---|---|---|---|---|---|---|
| 0 | 5.25±2.06 | 17.14±6.95 | 0.26±0.02 | 11.75±3.50 | 12.45±13.62 | 0.11±0.030 |
| | 3-7 | 7.73-23.83 | 0.24-0.28 | 8-16 | 2.9-32.5 | .09-0.14 |
| 1 | 6.00±1.41 | 16.58±4.44 | 0.32±0.03 | 8.50±2.65 | 4.98±2.79 | 0.13±0.05 |
| | 5-8 | 13.50-23.13 | 0.30-0.35 | 6-12 | 2.20-8.50 | 0.07-0.17 |
| 2 | 4.75±1.71 | 14.53±4.36 | 0.28±0.03 | 14.00±9.63 | 8.38±8.53 | 0.10±0.04 |
| | 3-7 | 8.83-19.37 | 0.25-0.32 | 3-26 | 2.50-20.70 | 0.06-0.14 |
| 3 | 4.25±0.96 | 26.78±9.27 | 0.33±0.05 | 8.25±5.32 | 16.48±12.24 | 0.17±0.04 |
| | 3-5 | 18-39.80 | 0.27-0.38 | 4-16 | 7.40-34.50 | 0.12-0.22 |
| 4 | 3.75±1.71 | 28.96±15.94 | 0.36±0.14 | 6.00±4.76 | 18.13±6.06 | 0.21±0.06 |
| | 2-6 | 12.50-46.83 | 0.23-0.55 | 3-13 | 12-26.50 | 0.16-0.30 |
| 5 | 6.00±2.45 | 49.50±8.01 | 0.41±0.11 | 4.25±2.22 | 35.73±9.27 | 0.28±0.04 |
| | 3-8 | 39-58.50 | 0.28-0.56 | 2-7 | 23.50-46 | 0.22-0.31 |
| AVG | 5 | 25.58 | 0.33 | 8.79 | 16.02 | 0.17 |
| C.D. (P=0.05) | 2.64 | 13.14 | 0.12 | 7.9 | 14.1 | 0.07 |

*Table 1 : Contd.....*

*Table 1 : Cont....*

| Days of seasoning | No. of sec. roots | Length of sec. root (cm) | Avg dia. Sec. root (cm) | Root biomass (g) | Shoot biomass (g) |
|---|---|---|---|---|---|
| | 8.00±3.61 | 2.60±0.80 | 0.03±0.02 | 0.11±0.05 | 0.91±0.46 |
| 0 | 5-12 | 1.8-3.4 | 0.02-0.06 | 0.06-0.17 | 0.27-1.27 |
| | 4.50±0.71 | 9±6.92 | 0.04±0.01 | 0.06±0.05 | 1.15±0.46 |
| 1 | 4-5 | 0.03-0.05 | 0.03-0.05 | 0.02-0.12 | 0.86-1.83 |
| | | | | 0.08±0.04 | 0.93±0.55 |
| 2 | 0.00 | 0.00 | 0.00 | 0.04-0.13 | 0.45-1.71 |
| | 2.67±1.15 | 12.67±7.65 | 0.07±0.04 | 0.18±0.12 | 1.98±1.08 |
| 3 | 2-4 | 8-21.50 | 0.04-0.13 | 0.06-0.35 | 1.24-3.57 |
| | 7.67±8.08 | 16.40±3.76 | 0.13±0.01 | 0.39±0.35 | 4.03±3.6 |
| 4 | 3-17 | 12.50-20 | 0.11-0.15 | 0.13-0.92 | 0.84-8.97 |
| | 5.00±2.58 | 20.48±10.37 | 0.10±0.04 | 0.56±0.21 | 8.56±3.97 |
| 5 | 2 8 | 5.50 28.90 | 0.08 0.16 | 0.33 0.83 | 4.31 12.47 |
| AVG | 3.50 | 8.12 | 0.05 | 0.23 | 2.93 |
| C.D. (P=0.05) | 6.09 | 10.65 | 0.06 | 3.37 | 0.26 |

seasoned (Fig 1). While, it was minimum in one day seasoned (Table 1). In case of shoot biomass of rooted stem cuttings in the month of August 2009, as number of days of seasoning increases shoot biomass increases. Maximum shoot biomass (8.56 g) was produced (Fig 2) in five days seasoned stem cuttings (Table 1).

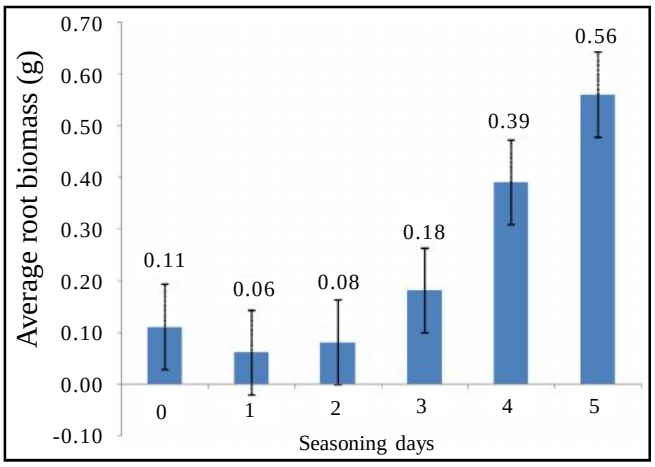


**Fig. 1 : Effect of callusing treatment on root biomass production**

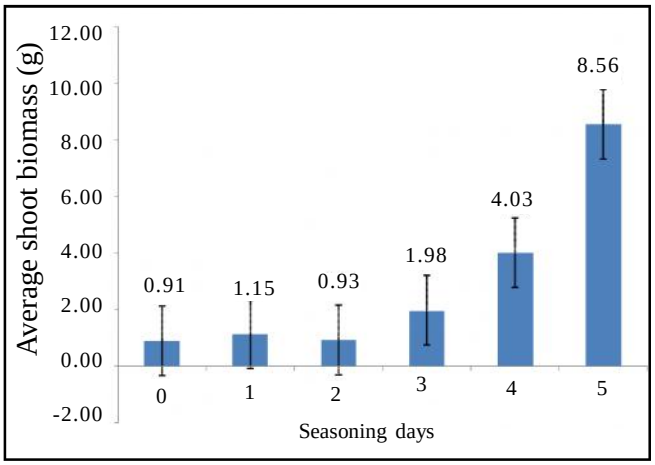


**Fig. 2 : Effect of callusing treatment on shoot biomass production**

Values for all traits of rooted stem cuttings seasoned for four to five days were higher than the other rooted stem cuttings (Table 1). Maximum number of shoots (6) and length of shoots (49.50 cm) were in five days seasoned stem cuttings while minimum shoot length (14.53 cm) in two days seasoned stem cuttings in which secondary roots were absent (Table 1). Though numbers of primary roots were maximum in case of zero day seasoned cuttings (11.75), length of primary roots were

less as compared to four and five day seasoned cuttings. Similar trend was found in case of secondary roots.

After 27 months of plantation of these rooted stem cuttings in field, maximum height was attained in four days seasoned cuttings (119.75 cm) followed by five days seasoned cuttings (96 cm, Table 2). Two days seasoned cuttings showed minimum height (53.50 cm). Similar trend was observed in case of two days seasoned stem cuttings for collar diameter (1.35 cm) and survival (20%). Collar diameter was maximum in five days seasoned cuttings (Table 3). But survival in field was recorded maximum in four and five days seasoned cuttings (50% each) followed by zero and three day's seasoned stem cuttings (30% each), while it was absent in two days seasoned cuttings (Table 4).

These results suggest that cuttings rooted in the month of August and seasoned for four and five days showed more survival in the field and these plants had more height and collar diameter. Again cuttings rooted in the month of August and callused for four to five days showed more shoot and root biomass. May be this could be the reason for more survival of cuttings rooted in the month of August and seasoned for four to five days, because biomass was also produced more which helps plants to grow vigorously giving more chances of survival in field conditions. Similar results in yellow cedar were reported by Karlson (1974 and 1981); Raimondi and Kermode (2004); Bonner and Karrfalt (2008) led to the development of yellow-cedar planting seedlings produced by rooted cuttings.

Season, timing or period of the year in which cuttings are taken can play an important role in rooting (Bassuk and Howard, 1981). In propagating deciduous species, hardwood and semi-hardwood cuttings can be taken during the dormant season when buds are not active and before buds start to force out in the rainy season. There

**Table 2 : Average height of *C. wightii* plants raised from cuttings seasoned for different days**

| No. of seasoning days | After 1 month | After 6 months | After 17 months | After 21 months | After 27 months |
|---|---|---|---|---|---|
| 0 | 19.80 | 23.75 | 40.63 | 47.90 | 60.75 |
| | 3.5-33.5 | 9-34 | 9-74 | 17-75 | 30-107 |
| 1 | 16.78 | 22.75 | 46.06 | 50.50 | 60.40 |
| | 3.5-39 | 4.5-34 | 13-77 | 25-78 | 40-80 |
| 2 | 22.28 | 20.83 | 45.50 | 44.00 | 53.50 |
| | 12-29.2 | 18-22.5 | 21-84 | 40-51 | 37-70 |
| 3 | 24.99 | 21.36 | 70.20 | 75.70 | 71.20 |
| | 11.6-36.3 | 6.5-47 | 45-93 | 40-94 | 44-120 |
| 4 | 54.25 | 58.95 | 85.10 | 86.30 | 119.75 |
| | 30-87 | 34-88.5 | 84-110.5 | 84-1132 | 113-168 |
| 5 | 57.60 | 60.33 | 80.58 | 82.20 | 96.00 |
| | 33-68 | 43-102 | 45.5-117.5 | 47-115 | 45-130 |

**Table 3 : Average collar diameters of *C. wightii* plants raised from cuttings seasoned for different days**

| No. of seasoning days | After 1 month | After 6 months | After 17 months | After 21 months | After 27 months |
|---|---|---|---|---|---|
| 0 | 0.34 | 0.28 | 1.02 | 1.11 | 1.36 |
| | 0.18-0.56 | 0.11-0.46 | 0.75-1.30 | 0.77-1.35 | 1.02-1.89 |
| 1 | 0.27 | 0.28 | 1.12 | 1.10 | 1.52 |
| | 0.14-0.41 | 0.21-0.33 | 0.90-1.37 | 0.87-1.29 | 1.35-1.72 |
| 2 | 0.35 | 0.29 | 0.94 | 1.07 | 1.35 |
| | 0.27-0.43 | 0.25-0.31 | 0.59-1.40 | 0.76-1.32 | 1.14-1.55 |
| 3 | 0.37 | 0.32 | 1.28 | 1.20 | 1.44 |
| | 0.31-0.47 | 0.21-0.43 | 1.01-1.62 | 0.92-1.69 | 1.08-1.81 |
| 4 | 0.52 | 0.54 | 1.35 | 1.35 | 1.71 |
| | 0.34-0.70 | 0.35-0.94 | 0.91-1.67 | 1.01-1.62 | 1.66-1.78 |
| 5 | 0.55 | 0.61 | 1.19 | 1.24 | 1.75 |
| | 0.40-0.81 | 0.32-0.93 | 0.72-1.58 | 0.79-1.53 | 0.87-3.13 |

is an optimal period for rooting many species, which is necessary to maximize the rooting process (Arnand and Herbalein 1975 and Hartmann *et al.*, 1997). Davis (1984) observed a vivid seasonal change in shoot production and rooting in *Ficus pumila*. Heavy flushing was also observed during the rainy periods, a time of intense vegetative growth, which may tend to increase rooting percentage. Cuttings do not root normally in the dry season, however, rejuvenated shoots may still have superior root development probably because of higher food reserves and other rooting co- factors. Evans (1992), contended that probably the best time to take cuttings from the field is at the beginning of the rainy season. Stem cutting method for plant production in *C. wightii* has been studied by several workers (Shah *et al.*,1983; Dalal *et al*.,1989; Singh *et al*., 1989; Mertia and Nagarajan, 2000; Kasera and Chawan, 2001 and Yadava, 2011) as a means to conservation. Their study reports various growth regulators, season and method of collection and planting of cuttings, for improved establishment and growth. As many as nine published studies (Table 5) report use of IBA in sprouting stem cuttings of *C. wightii*. These researchers reported IBA concentrations of 10-5000 ppm in which stem cuttings were given either pulse treatment as quick dips or soaked lower portion of cuttings in IBA solution for durations ranging from 5-10 minutes or even a lower IBA dose (50-100 ppm) through injection (Table 5). In view of such divergent treatments, when there is no single agreed concentration of IBA, prevailing IBA concentration of 5000 ppm as quick dip in its nursery raising was followed in this work.

Rathore (1984) had also observed the enhanced rooting in Kiwifruit with IBA application. Maximum number of primary, secondary and average root number in *Pyrus pyrifolia* L. were recorded at 5000

**Table 4 : Survival per cent of *C. wightii* plants raised from rooted cuttings seasoned for different days**

| No. of seasoning days | After 1 month | After 6 months | After 17 months | After 21 months | After 27 months |
|---|---|---|---|---|---|
| 0 | 100 | 90 | 40 | 30 | 30 |
| 1 | 100 | 90 | 10 | 10 | 10 |
| 2 | 100 | 90 | 0 | 0 | 0 |
| 3 | 100 | 70 | 30 | 30 | 30 |
| 4 | 100 | 100 | 80 | 60 | 50 |
| 5 | 100 | 90 | 50 | 50 | 50 |

**Table 5 : IBA treatments of stem rooting of *C. wightii* reported by different worker**

| Sr. No. | Hormone | Duration | Results | Authors |
|---|---|---|---|---|
| 1. | 50 and 100 ppm IBA | Injected with syringe | Maximum number of roots produced | Mishra, 2011 |
| 2. | 1000, 2000, 3000, 4000 and 5000 ppm IBA | - | 2000 ppm IBA concentration most effective for rooting of cuttings of 5-6 mm diameter and 6-10 inch long | Rai *et al*., 2011 |
| 3. | 100, 200, 500 and 1000 ppm IBA | 10 min dipping | 200 ppm IBA best for rooting in cuttings of 0.25- 0.50 cm diameter and 20-25 cm long | Tripathi *et al*., 2014 |
| 4. | 10, 50, 200, 300 and 500 ppm IBA | 10 min dipping | 500 ppm IBA best for rooting in cuttings of diameter < 0.25 cm and 6-10 cm long (micro cuttings) | Tripathi *et al*., 2014 |
| 5. | 100, 200, 500 and 1000 ppm IBA | 10 min dipping | 200 ppm IBA concentration is optimum for rooting of stem cutting of 0.25-0.50 cm diameter and 15-20 cm long | Mishra and Kumar, 2014 |
| 6. | 500, 1000, 1500, 2000, 2500 and 3000 ppm IBA | Quick dip method ( 5 seconds) | 1500 and 2000 ppm IBA effective in softwood cuttings 25 cm long | Kumar *et al.*, 2006 |
| 7. | 2000, 4000 and 6000 ppm IBA | 5 min dipping | 4000 ppm IBA effective rooting in hardwood cuttings 20 cm long | Bandi *et al.*, 2012 |
| 8. | 200, 300, 400 and 500 ppm IBA | - | 300 ppm IBA for cuttings of 6-10 mm thick and 15-20 cm long | Dhar, 2011 |
| 9. | 5000 ppm IBA | Quick dip method | 20-30 cm long and 1.5-2.0 cm diameter stem cuttings dipped and taken out | Jindal *et al*., 2005 |

ppm IBA up to certain concentration (Khalon and Singh, 1981). Hitchcock and Zimmerman (1940) also observed that, auxin treatment results in high percentage rooting and the development of more roots per cutting. Apparently, the movements of boron (B), nitrogen (N), zinc (Zn) and potassium (K) to the rooting zone as observed by Blazich *et al.* (1983) is enhanced by auxin treatment. In most of the naturally vegetatively propagated species, adventitious root formation is there without any need for hormone treatment, while others require different growth regulators usually auxin (Syros *et al*., 2004). Auxins (IAA and IBA) are widely used as it induces root formation by breaking root apical dominance induced by cytokinin (Cline, 2004). Pretreatment with IBA and NAA increased both rooting and sprouting in Jatropha (Kochhar *et al*., 2008).

Thus, it can be concluded that for large scale multiplication of *C. wightii,* its stem cuttings should be treated with hormone and should be kept for rooting in the month of August with four to five days callusing treatment.

**Acknowledgement :**

We are greatful to Director, CAZRI for providing necessary facilities for this work. The authors also thank National Medicinal Plant Board, Govt. of India, New Delhi for financial support.

## REFERENCES

AL-Saqri, F. and Alderson, P.G. (1996). Effects of IBA, cutting type and rooting media on rooting of *Rosa centifolia*. *J. Hort. Sci.,* **71**:729-737.

Arnand, V.K. and Herbelein, G.T. (1975). Seasonal changes and effect of auxin on rooting in stem cuttings of *Ficus infectoria*. *Pla. Physic.*, **34** : 330 – 334.

Bandi, B., Parmar, B.R., Parmar, S.B. and Parmar, K. (2012). Effect of auxins on shoot and root growth in an endangered medicinal plant guggal [*Commiphora wightii* (Arnt.) Bhand.]. *J. Hort. Sci.,* **7**(2) : 211-213.

Bassuk, N.L. and Howard, B.H. (1981). Seasonal rooting changes in the apple hardwood cuttings and their implications to nurserymen. *Comb. Proc. Internat. Plant Prop. Soc.*, **30** : 289 – 293.

Blazich, F.A., Wright, R.D. and Schanffer, H.E. (1983). Mineral nutrition status of "Convexa" holly cuttings during intermittent mist propagation as influenced by exogenous auxin application. *J. Amer. Soc. Hort. Sci.,* **109**:350 – 355.

Bonner, F.T. and Karrfalt, R.P. (2008). The woody plant seed manual.Ag Handb. 727. US for Serv. WASHINGTON, D.C.

Chandra, R., Kumar, D. and Jha, B.K. (2001). Rooting behaviour of stem cuttings of *Commiphora wightii* (Indian Bdellium). *J. Trop. Med. Plants* , **2** : 269- 274.

Cline, M.G. (2004). Execution of the auxin replacement apical dominance experiment in temperate woody species. *Ame. J. Bot.*, **87**(2): 182-190.

Dalal, K.C. and Patel, M.A. (1995). "Guggal," In: Chadha, K. L. and Gupta, R. (Ed) *Adv. Hort.,* **11**- *Medicinal and Aromatic Plants*, Malhotra Publishing House, pp. 491-501, NEW DELHI, INDIA.

Dalal, K.C., Patel, M.A., Upadhyay, N.V., Patel, D.H., Patel, R.B., Hirpara, B.V., Patel, C., Patel, P.B. and Gupta, R. (1989). Germplasm Collection and Therapeutic, Botanical, Agricultural, Chemical, and Clinical Aspects of the Endangered Indigenous Plant, Guggul *Commiphora wightii* (Arn.) Bhandari- a Status cum Review Report, In: Presentation of Tribal Data: Eighth Workshop of All India Coordinated Research Project on Medicinal and Aromatic Plants, pp. 67-79, Faizabad (U.P.) INDIA.

Davis, F.T. (1984). Shoot RNA, cambial activity and IBA effectively in seasonal rooting of juvenile and mature *Ficus pumila* cuttings. *Physiol. Plant.*, **62** : 571-575.

Dhar, B.P. (2011). Biology, cultivation and conservation of Guggulu [*Commiphora wightii* (Arnt.) Bhand.] In Abstracts and Souvenir of National workshop on "Conservation and Sustainable Utilization of Commiphora wightii (Guggal)" organized by Forest Department Govt. of Gujarat,15th- 16th Sept., Gandhinagar, GUJARAT, INDIA.

Evans, J. (1992). *Plantation forestry in the tropics.* 2nd Ed. Pergamon Press, Oxford – London, N.Y., Paris 236 pp.

Hartmann, H.T., Kester, D.E., Davies, F.T. and Geneve, R.L. (1997). Plant propagation principles and practices. Prentice hall ENG. Cliffs, New Jersey 07632 pp. 276 -391.

Hitchcock, A.E. and Zimmerman, P.W. (1940). Effects obtained with mixture of root- inducing hormones and other substances. *Contrib. Boyce Thomp. Inst.*, **11**:143 – 160.

Jindal, S.K., Singh, M. and Singh, D. (2005). Guggul- A therapeutic shrub. In: Narain P, Singh M, Khan M S, Kumar S (Ed.) Shrubs of Arid Zone. 55-59pp.

Karlson, I. (1974). Rooted cuttings of yellow cedar. Vancouver. British Columbia BCFS Int. Res. Note 66:5p.

Karlson, I. (1981). Propagation of Alaska yellow-cedar (*Chamaecyparis nootkatensis* (D.Don) Spach) by rooted cuttings for production planting. *Internat. Plant Propagator's Soc.*, **31** : 112-116.

Kasera, P.K. and Chawan, D.D. (2001). Cultivation and evaluation of medicinal plants under desert conditions of North-west India. Final Technical Progress Report, ISMH Project, J. N. Vyas University, Jodhpur, pp. 65.

Khalon, P.S. and Singh, S. (1981). Effect of IBA on the juvenile and adult cuttings of pathernakh *(Pyrus pyrifolia* L.). *Haryana J. Hort. Sci.,* **10**(1): 36-41.

Kochhar, S., Singh, S.P. and Kochhar, V.K. (2008). Effect of auxins and associated biochemical changes during clonal propagation of the biofuel plant- *Jatropha curcas*. *Biomass & Bioenergy,* **32** : 1136-1143.

Kumar, D., Jha, B.K. and Chandra, R. (2002). Response of auxin and planting time on the regeneration of stem cuttings of *Commiphora wightii* (Indian Bdellium). *J. Trop. Med. Plants,* **3** : 253-258.

Kumar, S., Mathur, M., Jain, A.K. and Ramawat, K.G. (2006). Somatic embryo proliferation in *Commiphora wightii* and evidence for guggulosterone production in culture. *Indian J. Biotechnol*., **5**:217–222.

Kumar, S. and Shankar, V. (1982). Medicinal plants of the Indian desert: *Commiphora wightii* (Arnott). *Band. J. Arid Envion.,* **5**: 1-11.

Mertia, R.S. and Nagarajan, M. (2000). Successful rooting in cuttings of *Commiphora wightii* (Arnott) Bhandari. *Ann. Arid Zone,* **39** (1): 87-88.

Mishra, D.K. (2011). Vegetative multiplication of *Commiphora wightii* (Arnt.) Bhand. through air layering techniques and its comparative performance in arid condition. In: Pandey C.N, Sharma DK, Sampat AC (Ed.) Abstracts and Souvenir of National Workshop on Conservation and Sustainable Utilization of *Commiphora wightii* (Guggul) at Gandhinagar, Gujarat 15th-16th Sept., 2011.

Mishra, D.K. and Kumar, D. (2014). Clonal propagation in *Commiphora wightii* (Arnt.) Bhand. *J. Forest & Environ. Sci.,* **30** (2) : 218-225.

Rai, C.P., Tiwari, S.K., Jha, R.K. and Pandey, A. (2011). Mass multiplication through stem branch cutting of *Commiphora wightii* an important medicinal plant. In: Pandey C.N, Sharma DK, Sampat AC (Ed) Abstracts and Souvenir of National Workshop on Conservation and Sustainable Utilization of *Commiphora wightii* (Guggul) at Gandhinagar, Gujarat 15th-16th Sept., 2011.

Raimondi, N. and Kermode, A.R. (2004). Seedling growth and establishment in natural stands of yellow-cedar (*Chamaecyparis nootkatensis*) seedlings derived from the use of modified seed dormancy-breaking treatments. *New-Forests,* **27**: 55-67.

Rathore, D.S. (1984). Propagation of chinese gooseberry from stem cuttings. *Indian J. Hort.,* **43**(3&4): 237-239.

Shah, R.R., Patel, D.B., Patel, D.H. and Dalal, K.C. (1983). Hormonal effect on germination of guggal cuttings. *Indian Drugs,* **20** (11): 435-437.

Singh, P., Sharma, M.L. and Mukherjee, S. (1989). Effect of indole butyric acid on sprouting in plant cuttings in *Commiphora wightii* (Arnott) Bhandari. *Indian Drugs,* **26** : 515-516.

Syros, T., Yupsanis, T., Zafiriadis, H. and Economou, A. (2004). Activity and its forms of peroxidases, lignin and anatomy, during adventitious rooting in cuttings of *Ebenus cretica* L. *J. Plant Physiol.,* **161**: 69-77.

Tripathi, A., Shukla, J.K., Gehlot, A. and Mishra, P.K. (2014). Standardization of cloning in *Commiphora wightii*. *Adv. For. Sci. Cuiaba.,* **1**: 19-25.

Yadava, B.B.L. (2011). *Commiphora wightii* (Gum-Guggul) Present Status in India: An Overview. *Herbal Tech. Industry,* **8** (1): 24-28.