ORIGINAL ARTICLE

Sustainable bark harvesting and phytochemical evaluation of alternative plant parts in *Holarrhena antidysenterica* R. Br. Sans (Kutaj)

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Holarrhena antidysenterica R. Br. Sans (Kutaj) belonging to family Apocyanaceae is a small tree or shrub. Its bark is used as an astringent, anthelmintic, stomachic, febrifuge, diuretic, and also useful in piles, dyspepsia, chest infections, amoebic dysentery, and other gastric disorders. Increasing demand and destructive harvesting of bark has led to the depletion of this valuable medicinal tree. A study was conducted to standardize sustainable harvesting practices of stem bark and suitability of alternative plant parts. Different bark harvesting methods were experimented. In these methods tree girth was divided into three or four equal parts and the bark was extracted from one part and harvesting was done by removing longitudinal strips from the main trunk of the tree. Alternate/opposite strips were also experimented in younger/thinner trees. The harvested bark samples and different plant parts like twig bark, wood, flowers and leaves were analysed for tannins, total phenols, total alkaloids and total flavonoids. Phytochemical analysis revealed that the active ingredients in trunk bark were comparatively higher, i.e., total phenols (7.51±0.12%), total flavonoids (0.19±0.09%), total alkaloids (2.25±0.06%), and tannins (8.61±0.10%) than other plant parts studied. Strip harvesting was found to be the best method for harvesting and by this method the bark can be harvested on sustainable basis after every 18 months. Bark should be harvested by removing only outer and middle bark leaving the inner bark for regeneration.

Key words: Alternative plant parts, bark harvesting, *Holarrhena antidysenterica*

INTRODUCTION

Medicinal plants, since times immemorial, have been used in virtually all cultures as a source of medicine. About three quarter of the world's population relies on plants and plant extracts for their healthcare. India represented by rich culture, traditions, and natural biodiversity, offers a unique opportunity for researchers.[1] India is sitting on a gold mine of well-recorded and well practiced knowledge of traditional herbal medicine. The past decade has witnessed a tremendous resurgence in the interest and use of medicinal plant and herbal products. Herbal medicine is still the mainstay of about 75–80% of the world population, mainly in the developing countries, for primary health care because of better cultural acceptability, better compatibility with the human body and lesser side effects. However, the last few years have seen a major increase in their use in the developed world. The forest areas have been the source of medicinal plants and herbs over centuries. This position cannot be sustained further because on one hand the area under forests has been steadily shrinking while on the other hand requirement of medicinal plants and herbs has been increasing steeply. This has resulted in unscientific over exploitation of medicinal plants from forests. The problem is further compounded by unsustainable harvesting and marketing of plants that adversely affect the livelihood of millions of people dependent on medicinal plants.

Access this article online	
Quick Response Code:	Website: www.greenpharmacy.info
	DOI: 10.4103/0973-8258.85166

Tree bark is a commonly used traditional medicine in the world.[2] The growing demand for medicinal bark, commercialization, and destructive harvest techniques pose a major threat to high demand forest species. Also, a large percentage of especially rural communities still use traditional medicines, with the most valued medicines harvested from natural forest.[3] Considering the importance of the medicinal plant industry and the dependence of communities on traditional medicines, the uncontrolled, destructive harvesting of tree bark[3-5] from natural forest is a growing concern. Good collection practices are necessary for the long term survival of wild populations and their habitats. Medicinal plant materials need to be collected in a proper season to ensure the best possible quality of both the starting material as well as

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Received: 23-03-2011; **Accepted:** 10-06-2011

the finished product.[6] It is necessary that the harvesting practices employed should be non-destructive. In India, the demand of *Holarrhena antidysenterica* is 1000-2000 MT annually.[7] Excessive bark harvest affects availability of *H. antidysenterica* (Kutaj) population in the forest areas of central India. The species has decreased alarmingly due to illegal logging and unsustainable harvest of bark. Keeping the view in to consideration a study was conducted for sustainable harvesting of *H. antidysentrica* (Kutaj) bark in Tropical Forest Research Institute, Jabalpur, M. P.

H. antidysenterica (commonly known as Kutaj) belonging to family Apocyanaceae, is a small tree or shrub. It is found in Asia, Africa, Madagascar, India, and Philippines. This tree grows throughout India up to an altitude of 4,000 ft. and often gregariously found in deciduous forests, open waste lands and is especially abundant in the sub-Himalaya tract.[8] *H. antidysenterica* is up to 13 m in height, with milky latex, its bark peels off in flakes and is grey to pale brown in color. The leaves are shiny on the upper surface, dull and hairy on the lower, opposite, subsessile and elliptic. The flowers are white, in terminal corymbose cymes; the fruits are cylindrical, dark grey with white specks and occur in pairs; the seeds are light brown and 0.5–1.5 cm in size. Around 30 alkaloids have been isolated from the plant, mostly from the bark. These include conessine, kurchine, kurchicine, holarrhimine, conarrhimine, conaine, conessimine, iso-conessimine, conimine, holacetin, and conkurchin.[9]

Leaves, barks, and fruits of Kutaj are useful in various diseases. However, bark is the most useful part and used as an astringent, anthelmintic, antidontalgic, stomachic, febrifuge, antidropsical, diuretic, in piles, colic, dyspepsia, chest infections, and as a remedy for skin and spleen diseases. A hot decoction of the drug is used as a gargle in toothache.[10] It is a well-known drug for amoebic dysentery and other gastric disorders.[11] Till now the bark is being harvested by cutting down the entire tree and chopping the main stem and branches and removing the entire bark from the existing tree. The bark exploitation has caused serious damage to wild populations, including trees inside the forests.

Destructive Harvesting Practices

The demand of Kutaj bark is increasing worldwide, which led to the depletion of this valuable resource of medicinal plants. Present harvesting methods of medicinal plants from forests involve mostly destructive practices. Destructive methods of harvest include stripping of tree completely for its bark or cutting it to facilitate harvest. The medicinal plants in which bark is useful part are under more threat as the bark from the trees is extracted by making blazes in the tree trunk. The only possible way to meet this increasing demand is by harvesting the bark in such a way that it should not affect the health and growth of trees. It is therefore desirable to standardize the sustainable harvesting practices through scientific experimentation.

Sustainable Harvesting Practices

Sustainable use has been defined as the use of components of biological diversity in a way and at a rate that does not lead to long term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

Sustainable harvesting is possible with various safeguards and methods. Generally, protection from fire and grazing, nurturing the young regeneration, regulating extraction, popularizing different uses of medicinal plants as some steps for sustainable harvesting of medicinal plants. Systems for sustainable bark harvesting largely depend on the response of the target species to bark stripping. The volume of bark that could be harvested under different harvest prescriptions and scenarios would largely depend on the growing stock and growth of the target species, bark characteristics (especially bark thickness), and the rate of bark regrowth after harvesting. Different forest and woodland species react differently to bark stripping, both in terms of wound closure and susceptibility to insect and fungal attack. Systems for the sustainable harvesting of bark for medicinal use should thus be species specific. Strip harvesting to ensure a sustainable supply of medicinal bark is thus only a harvest option for those species that recover after bark stripping through sheet or edge development. Key aspects to a harvest system for strip harvesting include strip width and length, harvest rotation, minimum diameter of harvest trees, percentage of the trees in the population to be exposed to bark stripping, and the number and rotation of strips on selected trees.

MATERIALS AND METHODS

Study Areas

Study areas were selected in the state of Madhya Pradesh, Chhattisgarh, Maharashtra, and Odisha. Surveys were conducted in different forest areas of the states to select Kutaj growing areas. Populations of selected species were identified with the help of local people and forest officials. Experiments were laid out for standardization of sustainable harvesting of selected species in different forest areas of Balaghat, Bodala (M.P.); Harishankar (Odisha); Bilaspur, Keochi, Raigarh (Chhattisgarh) and Chandrapur, Nasik (Maharastra). Randomized design with three replications was used to lay out the experiments. Trees of different age group and girth size were selected for laying out the experiments. Care was taken not to include trees with pollarded crown, broken branches, or those infected with fungi and insects.

Methodology

Bark harvesting

Three methods of bark harvesting were studied.

- Method I: Tree girth was divided into four equal parts and the bark was extracted from one part.
- Method II: Tree girth was divided into three equal parts and the bark was extracted from one part.
- Method III: Strip bark harvesting conducted by removing longitudinal alternate/opposite strip on the main trunk of the tree.

Chemical Analysis

The harvested bark samples and plant parts were brought to the laboratory for chemical analysis. The harvested samples were dried under shade. The fresh and dry weights of the bark were recorded. The dried bark samples were ground into coarse powder and used for chemical analysis. Bark and other plant parts were quantified for the estimation of active chemical ingredients, i.e., total phenols, total alkaloids, tannins, and total flavonoids content. Total phenols in the samples were estimated by Folin-Ciocalteau method,[12] total alkaloids by Magnesium Oxide method,[13] tannins by Folin-Denis method,[14] and for estimation of total flavonoids, aluminum chloride colorimetric technique was used.[15]

Statistical Analysis

Data on recovery and quality characteristics of Kutaj bark were analyzed statistically using multivariate ANOVA and variation in the quality characteristics of different plant parts were tested by one way ANOVA using (Statistical Package for the Social Sciences (SPSS), Version 14.0) and values of $P \leq 0.05$ were taken to imply statistical significance. Statistically best harvesting method and season were determined using Duncan's Multiple Range Test (DMRT) by SPSS. Means were calculated from seven replications and results were expressed as the mean±SD.

Observations

Data on regrowth (regeneration of bark) was recorded half yearly. The bark's regenerative properties were determined by the time taken to regenerate the bark. The stage of bark recovery varied from tree to tree. The physical appearance of bark regrowth was recorded. Two types of bark regrowth were observed, i.e., edge growth and sheet growth. Insect and fungal attack incidences were also recorded.

RESULTS AND DISCUSSION

Bark regrowth was represented as regeneration percentage observed at six months intervals. In girth at breast height (GBH) group 10–40 cm bark regeneration percentage was faster in method III, i.e., strip harvesting (45.62±0.49%) followed by method II (41.35±0.36%) during initial 6 months period. Similar trends were observed during consecutive period and complete regeneration was achieved within 18 months after harvest. With respect to 41–80 cm and 81–120 cm GBH group similar bark regeneration pattern was observed. In all the GBH groups bark regeneration were faster by harvesting method III followed by method II and I completing in 18 months. Bark regeneration percentage with respect to GBH, bark harvesting methods and time taken for regeneration is represented in Table 1.

Significant difference in bark regeneration was observed with respect to different harvesting season. The data revealed that the bark regeneration was faster when the harvest was done in the month of March followed by December, irrespective of girth classes. In smaller girth classes, i.e., 10–40 cm and 41–80 cm bark regeneration was faster than 81–120 cm girth and completing bark regeneration in 18 months. The affect of harvesting season on bark regeneration in Kutuj is represented in Table 2.

The data revealed significant variation in total phenols and tannins with regard to different GBH groups. Total phenols were found maximum (9.21±0.32%) in 81–120 cm GBH group in March followed by 8.61±0.25% in 41-80 cm GBH group in March and minimum (3.12±0.05%) in 10-40 cm GBH group in June. Total flavonoids were found maximum (0.30±0.08%) in 81–120 cm GBH group in March followed by 0.29±0.11% in 41–80 cm GBH group in March and minimum (0.05±0.01%) in 10–40 cm GBH group in June. Tannins were

Table 1: Bark regeneration percentage with respect to GBH, blaze size, and time in *Holarrhena antidysenterica*

GBH group (cm)	Method	Bark regeneration %		
		6 months	12 months	18 months
10–40	I	40.33±1.25b	44.27±1.14c	14.78±0.82a
	II	41.35±0.36b	46.64±0.20b	11.51±0.09b
	III	45.62±0.49a	48.86±0.51a	5.63±0.06c
41–80	I	35.33±0.47c	41.66±1.24c	25.66±1.69a
	II	39.25±1.69b	45.15±0.34b	15.09±0.23b
	III	41.93±0.26a	47.62±0.41a	9.76±0.35c
81–120	I	32.47±0.17c	37.85±0.37c	29.53±0.64a
	II	35.24±0.45b	40.57±0.74b	23.87±0.43b
	III	39.85±0.73a	46.27±0.64a	13.57±0.27c

Mean values within each column for a Girth at breast height (GBH) group followed by different letters differ significantly at $P \leq 0.05$

found maximum (9.89±0.05%) in 81-120 cm GBH group in March followed by 9.74±0.17% in 41–80 cm GBH group in March and minimum (4.89±0.04%) in 10–40 cm GBH group in June. Total alkaloids content was observed maximum (3.11±0.10%) in 81–120 cm GBH group in March followed by 2.96±0.09% in 41–80 cm GBH group in March and minimum (1.11±0.07%) in 81–120 cm GBH group in June. Total phenols, total flavonoids, tannins, and total alkaloids content of *H. antidysenterica* bark are presented in Table 3.

On analyzing different plant parts for total phenols, total flavonoids, tannins and total alkaloids content it was found that they were maximum (7.51±0.12%, 0.19±0.09%, 8.61±0.10%, and 2.25±0.06%) in trunk bark followed by leaves (3.18±0.05%, 0.07±0.02%, 3.80±0.07%, and 1.21±0.03%) and minimum in flowers (0.12±0.02%, 0.02±0.01%, 0.26±0.02%, and 0.11±0.02%). It clearly indicates that all phytochemical contents were having more concentration in trunk bark in comparison to other plant parts as represented in Table 4.

The results revealed that bark regeneration was faster in younger and middle aged trees which corroborates with the findings that trees of *Pseudocedrela kotschyi* had similar pattern, i.e., medium sized trees (21–30 cm dbh) had a faster bark recovery than the other studied dbh classes.[16]

Strip harvesting (method III) showed faster bark regeneration in all the GBH groups in both the species because in this

Table 2: Seasonal variation in bark regeneration of *Holarrhena antidysenterica*

GBH group (cm)	Harvesting season	Bark regeneration %		
		6 months	12 months	18 months
10–40	March	43.59±0.29a	48.23±0.54a	7.98±0.09d
	June	30.25±0.54c	45.63±0.52b	23.96±0.10a
	September	40.56±0.63b	44.65±0.23c	15.63±0.53b
	December	41.63±0.23b	45.96±0.12b	11.98±0.36c
41–80	March	41.86±0.52a	47.96±0.37a	9.89±0.09d
	June	30.21±0.23d	46.63±0.68b	23.12±0.12a
	September	34.79±0.48c	46.53±0.57b	18.63±0.16b
	December	38.64±0.52b	45.67±0.42c	15.63±0.21c
81–120	March	38.98±0.89a	45.79±0.77a	14.96±0.15d
	June	29.23±0.46d	42.63±0.23c	27.85±0.62a
	September	31.97±0.50c	41.52±0.41d	25.76±0.34b
	December	35.48±0.61b	43.52±0.35b	20.65±0.53c

Mean values within each column for a GBH group followed by different letters differ significantly at $P \leq 0.05$

Table 3: Total phenols, total flavonoids, tannins and total alkaloids content in *Holarrhena antidysenterica* bark

GBH group (cm)	Harvesting season	Total phenols %	Total flavonoids %	Tannins %	Total alkaloids%
10–40	March	6.48±0.12a	0.16±0.08a	7.65±0.16a	2.36±0.05a
	June	3.12±0.05c	0.05±0.01c	4.89±0.04c	1.13±0.01c
	September	3.54±0.09d	0.09±0.03d	5.45±0.07d	1.49±0.01d
	December	4.86±0.15b	0.14±0.05b	6.98±0.12b	2.11±0.03b
41–80	March	8.61±0.25a	0.29±0.11a	9.74±0.17a	2.96±0.09a
	June	4.25±0.12c	0.11±0.02c	5.28±0.10d	1.21±0.05c
	September	4.96±0.17c	0.19±0.08c	6.98±0.13c	1.85±0.09c
	December	7.63±0.21b	0.24±0.14b	7.54±0.20b	2.46±0.12b
81–120	March	9.21±0.32a	0.30±0.08a	9.89±0.05a	3.11±0.10a
	June	4.65±0.08d	0.05±0.02d	6.12±0.08c	1.11±0.07c
	September	6.52±0.14c	0.15±0.07c	6.21±0.11c	2.05±0.15b
	December	8.04±0.13b	0.21±0.05b	7.98±0.09b	2.86±0.06b

Mean values within each column for a GBH group followed by different letters differ significantly at $P \leq 0.05$

Table 4: Total phenols, total flavonoids, tannins and total alkaloids content in different plant parts of *Holarrhena antidysenterica*

Samples	Total phenols %	Total flavonoids %	Tannins %	Total alkaloids %
Trunk bark	7.51±0.12a	0.19±0.09a	8.61±0.10a	2.25±0.06a
Leaves	3.18±0.05b	0.07±0.02b	3.80±0.07b	1.21±0.03a
Twig bark	0.34±0.07c	0.05±0.03bc	0.59±0.05c	0.78±0.06b
Wood	0.15±0.03cd	0.03±0.01c	0.83±0.06c	0.23±0.04b
Flowers	0.12±0.02d	0.02±0.01c	0.26±0.02c	0.11±0.02b

Mean values followed by different letters differ significantly at $P \leq 0.05$

method only small portion of bark was removed, resulting in smaller wound. Moreover, bark regeneration was also faster during initial 6 months due to plant wound closure mechanisms that occur during initial few months after wounding.[17,18] In trees of higher girth classes and large blazes the size of wound is bigger resulting in more exposed surface area, which takes long time to recover. In first 6 months after harvest mostly edge growth was observed during bark regeneration process there after both edge and sheet growth were observed that are in accordance to the findings that were reported edge and sheet bark regrowth in some medicinal trees species of Benin, West Africa.[19] This could be explained by a higher hormonal activity stimulated by stress in order to restore water conductivity and thus to close the wound as soon as possible.[20]

Bark regrowth varies with site differences, season and microclimate. It is reported that bark regrowth varied with site differences, season, and microclimate.[21] It also reported that response to bark stripping could be affected by season of harvesting and this varies between species.[22,23] The affect of harvesting season on bark regeneration showed that the bark regeneration was faster if when the bark was harvested in the month of March. However, the bark regeneration was slower when the bark was harvested in the month of June. Phytochemical content showed remarkable increase with increase in girth of the tree, i. e., it is higher in older trees and lower in younger trees. It is reported by some other researchers that the chemical composition of *Pinus radiata* trees varied significantly with the age of tree.[24] It is also reported that the percentage of total alkaloids in *H. antidysenterica* varies with age and girth of plants.[10] It is reported that there is direct relationship of tannin and oxalic acid content with the age of *T. arjuna* trees.[25] The present study revealed that on the basis of quality of the bark with respect to their phytoconstituents, the bark harvested in the month of March has higher concentration of constituents as compared to the bark harvested in the month of June. Therefore ideal time for bark harvesting to get quality produce is from February to March for the species.

CONCLUSIONS

H. antidysenterica (Kutaj) bark can be obtained on sustainable basis if the bark is harvested through non-destructive harvesting techniques and sufficient time is allowed between two successive harvests for the plant to regenerate new bark. Bark should be harvested longitudinally, not all over the circumference of trunk and branches. In younger trees having GBH less than 30 cm bark should be extracted by removing 5–6 cm wide strips from the main trunk of the tree. For sustainable harvest, strip harvesting should be done on the tree trunk. Only outer and middle bark should be removed leaving the inner bark for regeneration. Sustainable bark harvesting can be done after every 18 months by extracting opposite strip of the trunk bark. Sustainable bark harvesting techniques should be practiced in order to conserve and sustainably utilize the resources.

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How to cite this article: Pandey AK, Yadav S, Sahu SK. Sustainable bark harvesting and phytochemical evaluation of alternative plant parts in *Holarrhena antidysenterica* R. Br. Sans (Kutaj). Int J Green Pharm 2011;5:107-12.

Source of Support: Nil, **Conflict of Interest:** None declared.