NON-DESTRUCTIVE HARVESTING PRACTICES OF *TERMINALIA ARJUNA* (ARJUNA), *PHYLLANTHUS EMBLICA* (AONLA) AND *ANDROGRAPHIS PANICULATA* (KALMEGH)

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Introduction

Since time immemorial, people have utilized plant resources to cure their various ailments. In recent years there has been tremendous increase in interest of plant based medicines worldwide. Conservative estimates put the monetary value of Medicinal and Aromatic Plant (MAP) related global trade at more than US $ 60 billion (GoI, 2000). India has rich biodiversity of medicinal plants, which plays an important role in human life. A recent survey in India found that more than 960 medicinal plants are in use in the manufacturing and processing sectors and 178 plants were predominantly traded (Ved and Goraya, 2007). The forests of central India are depository of several valuable medicinal plants. Collection and sale of non-timber forest produce (NTFPs), including medicinal plants, from its vast forest resources has a significant bearing on the socio-economic fabric of Madhya Pradesh and Chhattisgarh as it forms an important source of livelihood for the tribal population of the states (Pandey and Shukla, 2006). An annual consolidated trade worth Rs. 525 crores in respect of the 'nationalized' and the 'non-nationalized' NTFPs has been reported from the state of Chhattisgarh for the year 2006-07 (CGMFP Federation Survey Report, 2006).

Wild plant resources are used throughout the world by subsistence communities for daily needs, as well as to generate income. However, increased demand and commercialization of NTFP resources frequently leads to over utilization, resulting in a decline of resource and the livelihoods (Peters, 1999). At present, 90% collection of medicinal plants is from the wild. This activity generates about four million mandays employment (both part and full time) annually. About 70% of wild collections involve destructive harvesting; many plants have become endangered/ vulnerable/ threatened. In the process, the principles of sustainability which were intrinsic part of traditional systems got overlooked. Moreover, medicinal plants are collected without paying attention to the stage of maturity. They are stored haphazardly for longer period under unsuitable conditions resulting in deterioration of quality.

The major issues related to unsustainable wild-collection include: lack of knowledge about sustainable harvesting rates and practices and lack of legislative and policy guidance. Other important reasons responsible are: ignorance, quick returns for the produce and greedy collection. Furthermore, the lack of security of tenure, a situation commonly encountered in state-controlled forests, often results in such adverse ecological impacts like damage during harvest and suppressed regeneration (Momberg *et al.*, 2000). All these factors contributed to the need for conservation and sustainable use of wild medicinal plants on one hand and to achieve the optimum quality of produce on the other. The basic idea behind sustainable harvesting is that a biological resource should be harvested within limits of its capacity for self renewal. More than that, the manner of its harvest should not degrade the environment in any way (Hamilton, 2005).

Keeping above facts into consideration the present study was conducted in the forest areas of Chhattisgarh with the objective to develop sustainable harvesting practices of three medicinally important plants of central India i.e. Arjuna (*Terminalia arjuna*), Aonla (*Phyllanthus emblica*) and Kalmegh (*Andrographis paniculata*).

Terminalia arjuna (Arjuna)

Terminalia arjuna Roxb. (family Combretaceae) is a large tree with fissured bark and numerous dropping branches. The tree is common throughout the greater part of Indian peninsula along rivers, streams, ravines and dry watercourses. Arjuna is a water loving species and typical of dry deciduous forests of central India. The tree prefers humid, fertile loam and red lateritic soils. It grows in low land to hilly areas and can tolerate half submergence for a few weeks. Its bark has been used in traditional Ayurvedic herbalism for generations, primarily as a cardiac tonic. Clinical evaluation of this botanical indicates that it can be beneficial in the treatment of coronary artery disease, heart failure, hypercholesterolemia, antibacterial, antioxidant, antimutagenic activities, febrifuge, anti-dysenteric, biliousness, sores, hepatic, congenital, venereal and viral

diseases (Dwivedi and Udupa, 1989). The active constituents include tannins, polyphenols and flavonoids. About 95 per cent of the Arjuna bark requirement is met from the wild and collected in a pattern that is not concomitant with sustainable harvesting practices. Harvesting commercial quantity of bark has also affected Arjuna population.

***Phyllanthus emblica* (Aonla)**

Phyllanthus emblica Linn. (family Euphorbiaceae) popularly known as Indian gooseberry. It grows naturally as an associate in tropical dry and moist deciduous forests in large parts of India and also cultivated in some parts. Its fruits are valued as rich source of vitamin C and are used extensively in all the Indian systems of medicine, including Ayurveda. The fruits are also consumed raw and widely used for number of other preparations including jam, pickles, jellies, candies, squash, shampoo, dyes, etc. (CSIR, 1952). According to *Charak* and *Sushrut Samhita* Aonla is the best among rejuvenative herbs, useful in relieving cough and skin diseases and the best among the sour fruits. Aonla fruits form an integral part of various herbal formulations including Triphala (three fruits) and the famous Chyawanprash, a general tonic for people of all ages, which improves mental and physical well being. It decreases serum cholesterol, binds heavy metals and is useful in jaundice. It is considered astringent, bitter, digestive, aphrodisiac, laxative, diuretic and tonic. It has been used in treating vomiting, haemorrhage, fever, cough, eye inflammation, ulceration, anorexia, emaciation, scurvy, diabetes, menorrhagia, leucorrhoea and toxicosis. It is also said to relieve thirst, burning sensations, impurity of the blood and to promote abundant hair growth and has been used for the treatment of common cold, cancer and heart diseases. Aonla fruit is a botanical raw drug used by the domestic herbal industry with present annual trade of 16000 tonnes (Ved and Goraya, 2007).

***Andrographis paniculata* (Kalmegh)**

Andrographis paniculata Nees. (family Acanthaceae) popularly known as Kalmegh has been used for centuries in Asia for the treatment of various ailments. In India it is found in the states of Madhya Pradesh, Chhatisgarh, Orissa, Maharashtra, Assam, Bihar, West Bengal, Uttar Pradesh., Tamil Nadu, Karnataka and Kerala. The fresh and dried leaves of Kalmegh and the juice extracted from the herb are the official drugs in Indian Pharmacopocia and are being prominently used in at least 26 Ayurvedic formulations. It is reported to possess astringent, anodyne, tonic and alexipharmic properties and is useful in dysentery, cholera, diabetes, influenza, bronchitis, piles, liver disorder, jaundice, hepatomegaly, skin disorder, fever, wounds, leprosy, sore throat, tonsillitis, osteodynea, menstrual disorder, hypertension and worm infestation (Jarukamjorn and Nemoto, 2008). *Panchang* (stem, leaf, flowers, seed and root) of the plant is used in various formulations of Indian system of medicine. The plant is bitter acrid, cooling, laxative, antipyretic, anti-inflammatory, expectorant, digestive and stomachic. The major active constituent is andrographolide, which is a diterpene lactone. The leaves contain the maximum active principle content while in the stem it is in lesser amount.

Material and Methods

Study site

The state of Chhattisgarh, India lying between 17°46' N to 24°8' N latitude and 80°15' E to 84°51' E longitude, has about 44 % of its geographical area (135,224 km^2) under forests and provides catchments to at least three main river systems i.e., *Mahanadi, Godavari and Indravati*. The state is divided into 3 agro-climatic zones namely, the Bastar Plateau, Northern hilly region, and plains of Chhattisgarh. Rainfall in this region occurs mainly during monsoon (July to September) with an average annual rainfall between 1200-1500 mm. The forests of the state fall under two major forest types, i.e., Tropical Moist Deciduous and Tropical Dry Deciduous and ecologically comprising of Sal (*Shorea robusta*) and miscellaneous forest.

Peoples' protected area (PPA) and multiple use forest area (Non PPA)

As a conservation strategy, the state of Chhattisgarh has conceptualized an adaptive and resilient forest management model of Peoples Protected Area (PPA) approach to involve local people in protection and conservation of valuable forest resources in resource-rich areas, with benefit sharing between collectors and Forest Department. The PPA envisages a proactive and people's friendly participation to ensure long term protection and maintenance of biological diversity and providing at the same time a sustainable supply of natural products and services to meet local community needs. The minimum area under each PPA is 5000 ha which people effectively protect against fire, grazing etc., while the non-PPAs are the multiple use natural forest areas having no control over anthropogenic activities. Species-wise location of experimental sites in Chhatisgarh Division is presented below :

S.No.	Species	Experimental site/forest division
1.	*Terminalia arjuna*	Dhamtari, Marvahi, Sarguja, Bilaspur
2.	*Phyllanthus emblica*	Dhamtari, Sarguja
3.	*Andrographis paniculata*	NWFP Nursery (TFRI, Jabalpur)

Experimental layout and methods of study

Terminalia arjuna

Different girth class of *T. arjuna* populations (15 trees per girth class at each site) were selected and experiments were laid out on randomized design for the extraction of bark. The selected four girth classes represent different age group populations. Bark harvesting was done from trees of different age group at different time intervals of the year by making longitudinal blazes of different sizes (45 cm – 1.20 m length and 15 – 45 cm width). Only healthy trees (no previous bark harvesting) were selected for the experiment. For each individual, bark was harvested from trunk up to 120 cm stem height. Based on above criteria, bark harvesting was experimented using following two methods:

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.

Each tree was individually tagged and re-visited at regular intervals (six months) to take observations on wound healing. The trees were also monitored for their general growth, survival and flower and seed production. The fresh and dry weights of the bark samples were recorded. Data on regeneration of bark (regrowth) was recorded at six monthly intervals. The bark's regenerative properties were determined by the time taken in bark regeneration. Two types of bark regrowth were observed, edge growth and sheet growth.

Phyllanthus emblica

The experiments were laid out in different sites located in Peoples Protected Areas (PPAs) and multiple use natural forests (Non PPAs) to standardize sustainable harvesting practices. Linear transects were used to sample the initial population (trees, saplings and seedlings). At each site 50 m x 50 m plots (0.25 ha) were randomly laid out with three replications in the PPAs as well as in Non PPAs. These transects were used to study the impact of fruit harvesting on sustainability. To find out sustainable fruit harvesting limit, four different harvesting intensities on the basis of per cent harvest i.e. H_1 (60% harvest), H_2 (70% harvest), H_3 (80% harvest) and H_4 (90% harvest) were selected. At the different sites, the plots were located in forests that have similar kind of management practices for fruit harvesting, protection, grazing, etc. Additionally, periodic regeneration surveys were used to quantify the initial density of seedlings and saplings in the populations being exploited. Transects were sampled once a year during December 2006-2009. All individuals in the quadrat were tagged; in addition, diameter at breast height (DBH) was measured for individuals greater than 1cm diameter. Stems less than 1cm diameter were considered as seedlings; stems with dia. (1 to 5cm) were considered saplings; and stem >5cm diameter were considered as trees. Sprouting stems (seedlings and saplings that have resprouted after being damaged due to fire, grazing, etc.) were also counted in the plots. Annual recruitment and mortality were calculated following the methods of Hall *et al.*, (1998) and Phillips (1998):

Annual recruitment (% per year)

$$R = ln\frac{[(No - Nd + Nt)/(No - Nd)]}{t} X\ 100$$

Where,

R is annual recruitment of plant

N_t is newly recruited trees in t years

N_O is initial number of trees

N_d is number of dead trees in t years

Aonla fruits were collected at different stages of maturity from selected locations to study the impact of harvesting time on quality of produce. To find out optimum harvesting time with regard to fruit quality, fruits were harvested at monthly intervals from September to January. Fifty fruits were collected in every month from each site for chemical analysis. Their fresh and dry weight was recorded. Incidences of anthropogenic pressure such as cuttings, lopping, grazing and browsing were observed in the experimental area. Current fruit harvesting strategies and techniques used by the people focused on maximizing the economic returns by adopting destructive methods of extraction such as lopping of branches and cutting of trees. The prevalent harvesting techniques used by the collectors have negative impacts on Aonla trees.

***Andrographis paniculata* (Kalmegh)**

Kalmegh seeds were sown in nursery and seedlings were planted in field at 30 cm x 30 cm and 45 cm x 45 cm spacing in first week of July 2006-2007. The crop was grown as per standard cultivation practices (Purohit and Vyas, 2004). Two harvesting methods i.e. destructive (uprooting) and Non-destructive (cutting) were compared. The herb was cut at 08-12 cm above the ground level at the time of initiation of flowering. Total three cuttings were obtained from a single crop. Leaves/plant material were collected and dried in shade for 7 days followed by grinding. The fine leaf powder samples were then used for andrographolide estimation. Regular observations were recorded on number of branches/tillers, herbage yield (foliage) fresh and dry from the experimental field.

Chemical analysis

Tannin content in Arjuna bark and Aonla fruits was estimated by Folin-Denis Method of Schanderi (1970), Sadasivam and Manikam (1996). The oxalic acid content in Arjuna bark was determined by using method of Bhatia *et al.*(1977). The ascorbic acid content in Aonla fruits was estimated by titrimetric method of Aberg (1958) and gallic acid by HPLC method (Charpentier and Cowles, 1981). Kalmegh plants were analysed for their active principle (andrographolide) content through HPLC (Pandey and Mandal, 2008).

Statistical analysis

In Arjuna, data on bark regrowth was statistically analysed by multivariate analysis of variance (MANOVA) whereas, in Aonla the variation in regeneration and recruitment in various harvesting intensities by two way analysis of variance (ANOVA) using Statistix PS DOS Version 2.0, NH Analytical Software (SX). Statistically best harvesting intensity was determined using Duncan's multiple range test (DMRT) by using SPSS (Statistical Package for the Social Sciences, Version 14.0). Significance of difference was defined at $P < 0.05$ level of significance. However, data on biomass yield of Kalmegh and chemical analysis of Arjuna bark, Aonla fruits and Kalmegh panchang was statistically analysed by one way ANOVA using SX software.

Results and Discussion

Terminalia arjuna

Bark regeneration with respect to harvesting methods, GBH and time taken for regeneration is presented in Table 1. Bark regeneration was represented as percentage observed at six months intervals. In GBH group 50-100 cm, the regeneration was highest (38.33±0.49) in method I during initial 6 month period. The regeneration completed within 24 months with about 95% bark recovery in 18 months only. In GBH group 101-150 cm, regeneration was highest in method I between 6-12 months and completing in 24 months. In higher GBH groups i.e. 151-200 cm and 201 cm-above, the regeneration was slow during initial 6 month period in both methods. However, in subsequent interval (i.e. between 6 -12 months) the recovery was faster and completing in 30 months period. Interaction of blaze size and bark regeneration period was significant. Highest average bark regeneration percentage was obtained in method I in 18 months period. Significant interaction between GBH, blaze size and regeneration period mean was observed and found maximum in 50-100 cm GBH group, Method I and in first 6 month of regeneration period.

The stage of bark recovery (re-growth) varied from tree to tree. Bark harvesting method I showed faster bark regeneration in all the GBH groups because in this method smaller 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 (Oven and Torelli, 1994). 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 of Delvax *et al.*, 2009 where they reported edge and sheet bark regrowth in some medicinal trees species of Benin, West Africa. Findings of studies conducted elsewhere indicated that some other factors like temperature, relative humidity and time of stripping influences wound healing in woody species (Morris *et al.*, 1989). In younger trees the bark regeneration was comparatively faster than the older trees. We did not observe any adverse trend on the overall development of tree. No tree was found to die after harvesting of bark. Arjuna showed remarkable bark re-growth in moist sites in comparison to drier sites.

Table 2 represents the chemical analysis of Arjuna bark samples. Maximum (11.83%) tannin content was found in sample collected from Kajalnadi, Jabarra, Dhamtari followed by 11.05% in Bharasong, Marvahi. The maximum (12.96%) oxalic acid content was found in sample of Bharasong, Marvahi followed by 12.46% in Kudurgarh, South Sarguja. Table-3 depicts variation of tannin and oxalic acid content in different parts of tree. It revealed that the trunk bark contains maximum (13.03%) amount of tannin and oxalic acid (18.56%). There was significant difference in the colour of original and regenerated bark. The regenerated bark was pale yellow or light pink whereas original bark was fleshy in colour. The original and regenerated bark samples were analysed for tannin and oxalic acid content and presented graphically in Fig. 1. Regenerated bark contained lower amounts of tannins (8.59%) and oxalic acid (8.56%) in comparison to original bark.

Phyllanthus emblica

The data pertaining to annual regeneration and recruitment of Aonla after harvesting the fruits as per treatments are presented in Table 4. In the year 2007, it was observed that the maximum mean value for annual regeneration was 46.65% in H_2 treatment (70% fruit harvesting) at Changari Dharpur, East Sarguja (PPA) site followed by 44.67% in H_1 treatment (60% harvest) at the same site and the minimum value 1.57% was observed in

H_4 treatment (90% harvest) at Jabarra, Dugali, Dhamtari (Non PPA). While in the year 2008, the maximum mean value for annual regeneration was 20.19% in H_1 treatment at Kudargarh, South Sarguja (PPA) site followed by 17.38% in H_2 treatment at Changari, Dharpur, East Sarguja (PPA) and minimum 2.49% was obseved in H_4 treatment (90% fruit harvest) at Jabarra, Dugali, Dhamtari (PPA) site. The annual recruitment in the year 2008 was maximum 37.45% in H_2 treatment followed by 36.78% in H_1 treatment at Changari, Dharpur, East Sarguja (PPA) site and minimum 1.22% was in H_4 treatment at Non PPA Jabarra, Dugali, Dhamtari site. While in the year 2009 maximum annual recruitment (13.97%) was in H_1 treatment at Jabarra Dugali (PPA) site and minimum (1.69%) in H_1 treatment at Non PPA Jabarra, Dugali, Dhamtari site. The annual regeneration and rate of recruitment varied among sites. Intensity of harvesting played significant role in regeneration and recruitment of Aonla. Statistically, H_2 treatment i.e. 70% harvesting intensity was found to be the best treatment as determined by Duncan's multiple range test (DMRT) however it is statistically at par with H_1 (60% harvesting intensity) treatment.

Table 5 represents the effect of harvesting time on quality of Aonla fruits. It has been observed that there was significant increase both in fresh weight and ascorbic acid content from September to January. The fresh weight showed gradual increase from 14.75 to 22.25g and ascorbic acid content also gradually increased from 198.24mg/100g to 675.50mg/100g. The tannin content was higher in the fruit samples harvested in October (6.68%) than samples harvested in January (4.75%). Gallic acid content was highest (128.35mg/100g) in the samples collected in the month of November. The results suggested that Aonla fruits attained maturity in the month of December - January, which may be the optimum harvesting time for this crop under tropical climatic conditions of Chhatisgarh.

Variations were found in size, weight, tannin, ascorbic acid and gallic acid content in the fruit samples of Aonla collected from various locations (Fig. 2). The highest Ascorbic acid content was found 534.66 mg/100 g in Dharpur, East Sarguja followed by 487.63 mg in Kudurgarh, Sarguja. The minimum fruit weight was found 231.89 mg in Sankara, Dhamtari followed by 444.89 mg in Dugali, Dhamtari. The highest content of gallic acid was recorded 54.18 mg in Kokar, Kanker followed by 46.14 mg in Kudurgarh, Sarguja and minimum was found 17.7 mg in Dharpur, East Sarguja.

Over harvesting is a major cause for poor regeneration of Aonla in the state. The areas with higher harvest intensity showed poor regeneration. Murali and Hegde (1997) reported deficient natural regeneration under the trees which were over harvested for fruits. They suggest that regulated fruit harvest should be done leaving some fruits on the tree for regeneration. The high permissible sustainable harvest (70%) of the Aonla fruits as found in the present study suggests that the population can be maintained without any decline as a result of fruit harvest. Emanuel *et al.* (2005) reported that 92% fruits of *Sclerocarya birrea* could be harvested without impacting the current population in the South African lowveld. There was significant variation in the seedling size class in different years. This fluctuation in seedling abundance may be reflection of variation in fruit production which varies from year to year. It is essential to point out here that every year is not a good fruit year and therefore it is difficult to prescribe universal harvest limits of Aonla fruits. There is decline in number of fruiting trees and average fruit production per tree in the state. There are also incidences of destructive fruit harvest. Overall there is reduction in fruit production of Aonla in the state, with high harvest intensity. The current harvesting levels of the fruits seem to have negative impact on population of Aonla. Our findings are in accordance with the findings of Avocevou-Ayisso *et al.* (2009).

Sinha and Bawa (2002) found that populations of *P. emblica* and *P. indofischeri* are more sensitive to destructive harvesting (for example, lopping of branches) than fruit harvest. They found that such harvesting technique reduce fruit production in the following year for these species. Cutting of primary branches to harvest fruits has deleterious effect on fruit productivity in subsequent years. Murali and Hegde (1997) and Setty *et al.* (2008) suggested regulated harvesting to ensure perpetual regeneration of *P. emblica* in the moist evergreen and moist deciduous forests of South India.

The study revealed that harvesting time plays very important role in maintaining the sustainability because only mature fruits produce viable seeds. If the fruits are harvested at right maturity stage i.e. December-January, they will produce viable seeds. Even small quantities of fruits (10-20%) were found sufficient for regeneration. The study also suggests that anthropogenic pressures other than harvest could be responsible for difference in regeneration between protected and unprotected areas, which are managed under similar harvest intensities. Grazing and fire may be the reasons for poor regeneration. In protected areas where more than 5 fruited Aonla trees are available in 50 m x 50 m area, 10-20 % Aonla fruits were found sufficient for regeneration.

Table 1

Arjun bark regeneration percentage in respect to GBH, blaze size and time.

GBH group (cm)	Blaze width	Bark regeneration percentage				
		6 months	12 months	18 months	24 months	30 months
50-100	¼	38.33±0.49	31.34±0.58	25.04±0.46	5.12±0.41	-
	⅓	31.66±0.41	28.34±1.01	25.56±0.51	14.36±0.53	-
101-150	¼	30.12±0.57	35.06±0.39	26.68±0.17	9.05±0.41	-
	⅓	23.33±0.28	32.33±0.29	26.05±0.06	18.33±0.21	-
151-200	¼	23.33±0.68	32.66±1.86	26.87±0.63	11.56±0.29	6.25±0.31
	⅓	16.66±0.18	31.66±0.55	24.23±0.46	18.25±0.34	9.36±0.44
201-above	¼	15.25±0.35	29.56±0.32	24.52±0.17	25.12±0.31	8.25±0.28
	⅓	13.33±0.48	25.98±0.24	23.58±0.32	24.25±0.18	13.32±0.25

Results expressed as mean±SD (n=5)

Critical Differences and Standard Error of means of variable factors.

	GBH means	Regeneration Period means	Blaze size means	Interaction of GBH and regeneration period means	Interaction of GBH and blaze size means	Interaction of blaze size and regeneration period means	Interaction of GBH, Blaze size and regeneration period means
(C.D.) 0.05%	2.51	2.16	NS	4.34	NS	3.07	NS
S.E.	1.24	1.08	NS	2.16	NS	1.53	NS

Table 2

Tannin and oxalic acid content and bark characteristics of Arjuna bark.

Location	Date of collection	GBH tree (cm)	Blaze size (cm)	Fresh weight (kg)	Dry weight (kg)	Wt/ cm^2 (gm)	Moisture %	Tannin %	Oxalic acid %
Kajalnadi, Jabarra, Dhamtari	20.10.06	116	30X60 - 45X45	2.74	0.94	0.42	64.91	11.83	12.03
Jadkun Nala, Jabarra	14.12.06	127	23X36 - 45X45	1.95	0.85	0.73	57.15	7.48	12.09
Bendra Nala, Jabarra	14.12.06	236	60X60 - 70X70	5.7	2.32	0.71	58.69	6.89	12.26
Bhaironsang, Marvahi	18.10.06	149	30X60 - 45X45	2.56	1.01	0.53	55.37	11.05	12.97
Kundrugarh, South Sarguja	12.12.06	212	60X60 - 60X75	1.85	0.78	0.29	57.55	8.57	12.46
	CD			2.46	9.0	-	7.83	1.49	-
	SE			1.07	3.9	-	3.39	6.48	-
	Significance at 0.05%			S	S	NS	S	S	NS

Table 3

Tannin and Oxalic acid content in bark of different parts of Arjuna.

Tree part	Blaze size (cm)	Bark wt. per cm^2	Tannin %	Oxalic acid %
Trunk	35 X 60	0.532	13.03	18.56
Branch	30 X 15	0.356	8.56	15.54
Twig	30 X 10	0.125	6.23	7.04

Table 4

Regeneration and annual recruitment status of Phyllanthus emblica.

Site	Harvesting level (%)	Initial no. of plants in 2006	Regeneration of plants (%)		Annual recruitment of plants (%)	
			2007	2008	2008	2009
Non PPA, Jabarra, Dugali, Dhamtari	H_1 (60)	20.8	4.67±0.46 ^{a}	4.39±1.98 ^{a}	2.28±0.14 ^{a}	1.69±0.57 ^{a}
	H_2 (70)	19.2	7.17±2.23 ^{b}	8.66±1.04 ^{b}	3.55±1.04 ^{b}	2.75±0.18 ^{b}
	H_3 (80)	17.2	2.64±0.97 ^{c}	10.31±2.21 ^{c}	1.29±0.56 ^{c}	3.8±0.93 ^{c}
	H_4 (90)	17.8	1.57±1.73 ^{c}	5.42±1.26 ^{ab}	1.22±0.61 ^{d}	1.75±0.53 ^{d}
PPA Jabarra - Dugali, Dhamtari	H_1 (60)	33.66	11.66±0.78 ^{a}	13.97±3.34 ^{a}	5.47±0.16 ^{a}	13.97±3.32 ^{a}
	H_2 (70)	31.33	15.94±2.25 ^{a}	11.07±1.28 ^{b}	7.25±1.09 ^{b}	11.17±1.34 ^{ab}
	H_3 (80)	36	11.08±1.19 ^{a}	9.46±0.15 ^{bc}	4.32±0.97 ^{ab}	9.47±0.14 ^{b}
	H_4 (90)	41	12.38±0.27 ^{b}	2.49±4.78 ^{c}	5.74±0.03 ^{ab}	2.49±4.79 ^{c}
PPA Changari, Dharpur, East Sarguja	H_1 (60)	22	44.67±6.74 ^{a}	12.17±1.01 ^{a}	36.78±5.38 ^{a}	5.66±0.45 ^{a}
	H_2 (70)	14	46.65±8.13 ^{a}	17.38±4.68 ^{b}	37.45±5.85^{a}	7.94±2.07 ^{b}
	H_3 (80)	22.5	25.53±6.79 ^{b}	7.19±2.52 ^{c}	22.16±4.95^{b}	3.45±1.11 ^{c}
	H_4 (90)	17.5	23.72±8.07 ^{b}	6.26±3.17 ^{c}	20.27±6.28 ^{b}	3.02±1.41 ^{c}
PPA Kudurgarh, South Sarguja	H_1 (60)	18	43.78±11.85 ^{a}	20.19±3.71 ^{a}	35.82±9.24 ^{a}	8.88±1.40 ^{a}
	H_2 (70)	17.75	19.8±5.11 ^{ab}	17.06±1.49 ^{a}	17.94±3.40 ^{b}	8.09±0.85 ^{a}
	H_3 (80)	17.75	23.45±2.53 ^{bc}	12.81±1.51 ^{b}	18.51±2.99 ^{b}	5.98±0.64 ^{b}
	H_4 (90)	13.5	21.05±4.22 ^{c}	9.71±3.69 ^{c}	18.74±2.84 ^{b}	4.61±1.61 ^{b}

a, b, c - Mean values within each column followed by different letter differ significantly and the values with same letter are not significantly different at $p<0.05$.

Table 5

Effect of harvesting time on quality of Phyllanthus emblica fruits.

Harvesting time	Fresh weight (gm)	Ascorbic acid (mg $100gm^{-1}$)	Tannin %	Gallic acid (mg $100gm^{-1}$)
September	14.75±0.82^{a}	198.24±1.63 ^{a}	5.25± 1.02 ^{a}	25.48±1.55 ^{a}
October	15.50±3.27^{a}	360.15±8.16 ^{b}	6.68±2.45 ^{a}	43.45±1.63 ^{b}
November	19.85±1.63 ^{b}	402.25±1.47^{c}	5.65±2.45 ^{a}	128.35±4.08 ^{c}
December	20.45± 0.98 ^{bc}	595.45±8.23 ^{d}	5.25±0.82 ^{a}	125.25±4.08 ^{d}
January	22.25±1.51 ^{d}	675.50± 8.25^{e}	4.75±0.61 ^{a}	75.65±1.76 ^{e}

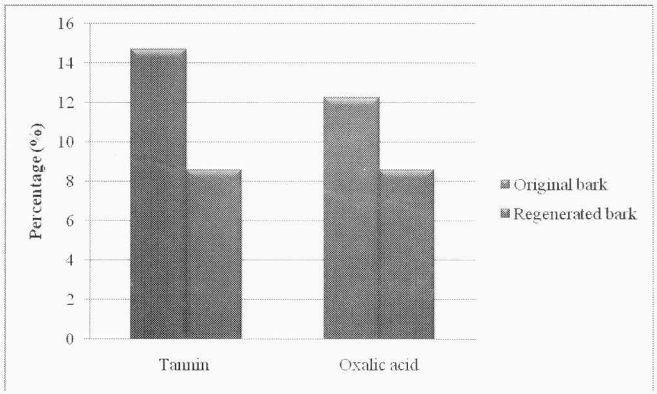
a, b, c - Mean values within each column followed by different letter differ significantly and the values with same letter are not significantly different at $p<0.05$.

Table 6

Influence of harvesting techniques on biomass yield and andrographolide content of Kalmegh.

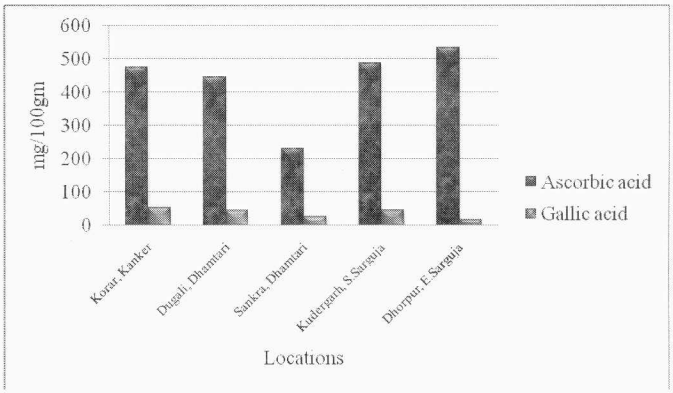
Harvesting techniques	Spacing	Number of branches/tillers		Herbage Biomass		
		Main crop	Ratoon crop	Fresh weight (gm)	Dry weight (gm)	Andrographolide content (%)
Destructive	30x30 cm	07	-	61.92	19.24	1.67
	45x45 cm	09	-	58.50	17.80	1.87
Non-destructive	30x30 cm	06	16	154.6	49.54	1.95
	45x45 cm	08	19	170.79	51.56	1.98
SE ±				3.783	1.006	-
CD at 5 %				48.07	12.79	NS

Fig. 1



Tannin and oxalic acid contents of original and regenerated Arjuna bark

Fig. 2



Ascorbic acid and Gallic acid content of *Phyllanthus emblica* fruits.

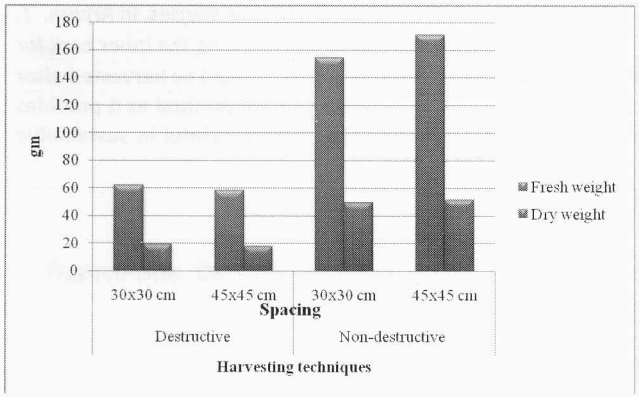
However, in unprotected areas less regeneration was observed even more than 20% fruits were left for regeneration. For proper dispersal and to maintain sustainability, mature seeds should be dispersed in the forest area. These practices may be helpful for the sustainable management of the species. These are also useful in providing quality raw material to the pharmaceutical industry on sustainable basis.

***Andrographis paniculata* (Kalmegh)**

The data pertaining to influence of harvesting technique on biomass yield and andrographolide content were presented in Table-6. Fresh and dry weights were found maximum when Kalmegh was harvested following non-destructive methods (170.79 gm and 51.56 gm, respectively) and minimum in destructive harvesting practices (58.50 gm and 17.80 gm, respectively). Based on cumulative yields of total biomass, crop harvested non-destructively yielded more than those of the destructive harvesting method. Fresh and dry foliage yield was found affected by harvesting techniques. In second crop (ratoon), number of branches/tillers was more than the initial crop. The total herbage yield was more in second crop (ratoon).

Andrographolide content varied from 1.67 to 1.98 % in Kalmegh harvested by different methods. Raina *et al.* (2007) conducted a study and also reported variation of andrographolide content in dry leaves from 1.14% to 2.60% amongst their collections. The maximum andrographolide (1.98 %) was found in the crop planted at spacing of 45 cm x 45 cm and harvested by non-destructive methods. However, minimum andrographolide content (1.67 %) was found in the crop harvested by destructive methods. There was no significant difference found in androgrpholide content among first and ratoon crop. Cut method (sustainable harvesting) is superior to destructive harvesting method since it improves natural regeneration of the herb. This harvesting practice can be used for sustainable development of Kalmegh. Fig 3 revealed the effect of harvesting techniques on biomass yield of Kalmegh. Sustainable harvesting technique will be very useful in the forest areas where the Kalmegh was available earlier but due to destructive harvesting the population has decreased. By non-destructive harvesting technique root stock of Kalmegh can be preserved in the forest areas.

Fig. 3



Influence of harvesting techniques on biomass yield of Kalmegh.

Conclusion

Increased demand of herbal products has accelerated over exploitation of valuable medicinal plants by unscientific and destructive manner. If the resource is managed sustainably by adopting sustainable harvesting practices it can fulfill the raw material demand of pharmaceutical industry and also provide opportunities for rural people to engage in income generating activities. Extractions of medicinal plants, if done on sustainable basis can provide an alternative to sustainable supply and conservation of valuable medicinal plants resources. The following are the species wise findings of our study.

In Arjuna tree, ¼ part of the mature bark from total girth of the tree should be harvested. Only outer and middle bark should be removed leaving the inner bark for regeneration. Re-harvesting of bark can be done after two years by removing opposite quarters of trunk bark rather than girdling the trees. Bark should be harvested longitudinally, not all over the circumference of trunk and branches. Field observations suggest that the bark gatherers may harvest bark selectively from the larger trees available. The bark should not be harvested during rainy season.

Aonla fruits should be harvested in the proper season, at the proper maturity stage in a non-destructive and sustainable manner. For sustainable harvesting the fruits should be harvested after maturity i.e. in the month of January and ideally 20% fruits are left for regeneration. If it is difficult to leave 20% fruits on every tree, at-least 10% fruiting trees should be left for regeneration purpose. It has been observed that if 10 or more fruiting trees are present in 1 ha, 10% fruits left on the trees are enough for optimum regeneration. The fruits should be harvested during December- January when they become dull greenish-yellow from light green. At this stage fruits accumulate maximum ascorbic and gallic acid. Study revealed that the status of fruits yield per tree was better in PPAs than in multiple use forest areas as PPAs are subjected to comparatively less biotic disturbances. As against this, the current practice of premature fruit harvesting which is damaging trees was found to be rampant in natural forests. This appears to support better natural regeneration in PPAs than in the adjoining natural forest.

In Kalmegh, results showed a significant difference in the yield of the herb in relation to harvesting techniques. Cut method (non-destructive method) was found to be superior and has an edge over the uprooting (destructive harvesting method) since it improves natural regeneration of the herb. Thus non-destructive harvesting practice proves to be a tool for sustainable development of Kalmegh. This technique will be very useful in the forest areas where Kalmegh was available earlier but due to destructive harvesting the population has decreased. By sustainable harvesting technique root stock of Kalmegh can be preserved in the forest areas. It will lead to increase in the availability of Kalmegh in the forest areas. Summarizing the results, it may be concluded that sustainable harvesting technique provides more herbage of better quality in comparison to destructive harvest on sustainable basis.

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SUMMARY

In recent years the demand of medicinal plants has grown exponentially because of accelerated local, national and international interest, the latter notably from western pharmaceutical industries. Increased market demand resulted in unscientific collection which has put numerous species at the verge of extinction. Non-destructive harvesting is suggested as a way to conserve the medicinal plant resources and provides quality planting material to the pharmaceutical industry. Keeping above into consideration, a study was conducted in Chhattisgarh to develop non-destructive harvesting practices of important medicinal plants. The paper gives an account on

non-destructive harvesting practices of *Terminalia arjuna* (Arjuna: bark), *Phyllanthus emblica* (Aonla: fruit) and *Andrographis paniculata* (Kalmegh: herb/panchang). This is the first study on development of non-destructive harvesting practices of above species. In Arjuna, $^{1}/_{4}$ or $^{1}/_{3}$ of the mature bark of total girth of the tree should be stripped by removing only outer and middle bark leaving the inner bark for regeneration. The length of blaze/strip can be upto 1.20 meter depending upon girth of the trees. Aonla fruits should be harvested after maturity and nearly 10-20% fruits should be left for regeneration. Kalmegh plants should be harvested by cut method as it provides quality herb vis-a-vis improves natural regeneration. Developed non-destructive harvesting practices will be helpful in sustainable management and utilization of medicinal plant resources.

Key words : Medicinal plants, Non-destructive harvesting, Arjuna, Aonla, Kalmegh.

टर्मिनेलिया अर्जुना (अर्जुन) *फायलैन्थस एम्बिलका* (आंवला) और *एण्ड्रोग्राफिस पैनिकुलाटा* (कालमेघ) की अविनाशकारी कटाई विधियाँ

ए.के. पाण्डेय व डी.सी. कोरि

सारांश

विगत वर्षों में औषध पादपों की मांग स्थानीय राष्ट्रीय और अन्तर्राष्ट्रीय दिलचस्पी में त्वरित वृद्धि होने के कारण, विशेषत: विदेशी औषध-निर्माण उद्योगों के फलस्वरूप बहुत अधिक बढ़ गई है। इस बाजारी मांग का परिणाम इनका अवैज्ञानिक ढंग से संग्रहीत किया जाना हुआ जिसने बहुरंगीय पादप जातियों को विलुप्ति के कगार पर ला दिया है। औषध पादप संसाधनों का संरक्षित करने तथा औषध-निर्माण उद्योग को अच्छी गुणवत्ता वाली रोपण सामग्री उपलब्ध कराने के उपाय स्वरूप इनकी अविनाशकारी कटाई विधि सुझायी जा रही है। उपर्युक्त आवश्यकता को ध्यान में रखते हुए कुछ महत्वपूर्ण औषध पादपों की अविनाशकारी कटाई विधि विकसित करने के लिए छत्तीसगढ़ में यह अध्ययन संचालित किया गया। इस अभिपत्र में *टर्मिनेलिया अर्जुना* (अर्जुन की छाल), *फायलैन्थस एम्बिलका* (आंवला फल) और *एण्ड्रोग्राफिस पैनिकुलाटा* (कालमेघ (बटी/पचांग)) की अविनाशकारी कटाई करने की विधि का ब्यौरा दिया गया है। उपर्युक्त पादपजातियों की अविनाशकारी कटाई विधि विकसित करने का यह पहला अध्ययन है। अर्जुन में उसकी कुल परिधि की 1/4 या 1/3 वयस्क छाल ही उतारी जानी चाहिए जिससे उसकी बाहरी और बीच की छाल रहे तथा अन्दर वाली छाल पुर्नजीवित होने के लिए यथावत् छोड़दी जाए। काट की लम्बाई वृक्ष की परिधि पर ध्यान देते हुए 1.20 मी. तक की पट्टी रखी जा सकती है। आँवले के फल उनके प्रौढ़ हो चुकने के बाद ही काटे जाने चाहिए तथा लगभग 10-20% फल पुनर्जनन हेतु वहीं लगे छोड़ दिए जाने चाहिए। कालमेघ पादपों का पौधा काटकर निकालना चाहिए क्योंकि ऐसा होने से गुणवत्ता वाली बूटी प्राप्त होने के साथ-साथ प्राकृतिक पुनर्जनन में भी सुधार होता है। ऐसी विकसित अविनाशकारी कटाई विधियां औषध पादपों संसाधनों का लम्बे समय तक प्रबन्ध करते रहने और उनके उपयोग में भी सहायक रहेंगी।

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