

Effects of Harvesting Intensities on Fruit Production and Regeneration of *Emblica officinalis* Gaertn. in a Semi-Evergreen Forest of Manipur, India

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Abstract The fruit production and regeneration status of *Emblica officinalis* was studied under two harvesting regimes during 2015-16 in a semi-evergreen forest of Manipur. The fruit production varied significantly ($p > 0.05$) between harvesting regimes and years, attaining higher values in low harvesting regime than high harvesting regime, in line with other growth attributes which contributed to fruit production. A relatively higher proportion of trees were found moderated and highly damaged in high intensity harvesting than the low intensity harvesting stand. Lower annual mortality rate (6.89%) coupled with an increased recruitment (21.52%) in the low harvesting stand resulted in better regeneration although both stands had same pattern of seedlings>saplings>trees. The results were further supported by increase soil organic carbon and available

N and K in low intensity stand in bringing better regeneration.

Keywords *Emblica officinalis*, Harvesting intensity, Regeneration, Seed production, Soil characteristics.

Introduction

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn.) belongs to the family Phyllanthaceae, a native to tropical South-East Asia particularly the central and southern Indian region. In North East India it is found distributed mainly in the states of Manipur, Mizoram, Meghalaya and Tripura. Famous for its nutritional value, the fruits of this tree have established itself as a common ingredient in the ancient Indian medicinal practice of Ayurveda. Its potential is so versatile that most of the pharmaceutical and cosmetic industries have a product specially designated for this species. Besides these benefits, the tree also finds a place in the heart of the Hindu and Meitei community of Manipur due its mythological significance. Over exploitation in term of fruit harvest owing to growing demand may result in reduced quality and quantity of fruit production in this species (Pandey and Bhargava 2014). The heterogeneity in edaphic features and forest understory micro environments may affects seedling performance, subsequent community composition and the potential for species co-existence (Bharali et al. 2012).

Aonla starts fruiting from the month of Octo-

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ber and matured by the end of December. In natural forest, immature extraction of fruits reduces both the quality of quantity of fruits per plant in the corresponding years (Mishra and Kotwal 2007). Harvesting intensities and techniques are reported to affect re-growth dynamics of many non-timber forest products species (Pandey and Shackleton 2012). The effects of fruit harvesting on population stability requires a longer study and a modelling approach to determine the threshold harvesting levels (Venter and Witkowski 2013). Impact of non-timber forest product extraction may affect the regeneration potential of a forest stand (Varghese et al. 2015, Gaoue et al. 2017). There have been some studies on impact assessment of Aonla fruit collection, prospects of sustainable harvest and regeneration elsewhere (Mishra and Kotwal 2010). The fruit harvesting for Aonla, is recommended not to be allowed before November and some fruits should be left on the plant for future regeneration (Prasad et al. 2008). The forest dependent people in and around Ngariyan hill range have been collecting various non-timber forest products including Aonla for their livelihood and the method they employ for harvest is mostly by lopping, pollarding and felling (Laishram and Sahoo 2018), causing threat to the survival of species. Nevertheless quality fruit production increased yield and better regeneration can help meet the growing demand of this species in the region. However, no study hitherto has been carried out to relate the effect of harvesting intensities and anthropogenic disturbances on fruit production and regeneration potential of *Embllica officinalis* and therefore, the present study was aimed at evaluating (a) fruit production and (b) regeneration status as affected by harvesting intensities and edaphic factors.

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Materials and Methods

Study site

The study was carried out in two forest stands located at Laimaton and Zoujangtek in Ngariyan hill

range of Senapati district of Manipur during 2015-2016. The former site was relatively less disturbed in terms of lopping and felling and harvesting intensity was 60% (herein referred as mildly disturbed (MD) and low harvesting intensity) and the later was highly disturbed, harvesting intensity high (>90%) based on visual observation (herein referred to as highly disturbed (HD)). In each site, 10 permanent plots or quadrates of 0.1 ha (each 100 m long and 10 m wide) were established randomly with a minimum distance of 5 km for regeneration and fruit production studies.

Regeneration survey

Each plot was sampled once a year and all the individuals in the quadrate was tagged and numbered. The initial population belonging to seedlings, saplings and trees were counted from each plot and their density was estimated. Sprouting stems (seedlings and saplings that have re-sprouted after being damaged due to fire, grazing) was also been counted in the plots. Annual mortality and recruitment was calculated following Hall et al. (1998) such that : (a) annual mortality (as per cent per year), M , is $\ln [(N_0 - N_d) / N_0] / t \times 100$, where N_0 is initial number of trees, and N_d is number of dead trees in t years; and (b) annual recruitment (per cent per year), R , is $\ln [(N_0 - N_d + N_r) / (N_0 - N_d)] / t \times 100$, where N_r is the number of newly recruited trees in t years. The seedlings and saplings were encountered during the survey were divided into different categories. The seedling population was divided into three categories (i) short seedlings with <10 cm height (ii) medium seedlings with >10.0 cm to 20.0 cm height and (iii) tall seedlings with >20.0 cm to 30.0 cm height. The sapling population was divided into two categories (i) young saplings (>30.0 cm height but <10.0 cm cbh) and (ii) old saplings (>10.0 cm to 30.0 cm cbh) and those saplings (>30 cm dbh) was considered as tree. The regeneration status of *E. officinalis* was determined based on population size of seedlings, saplings and adults (Laishram and Sahoo 2018). The regeneration status was considered as good regeneration if seedlings>sapling>adults, fair regeneration if seedlings >or = saplings ≤ adults and poor regeneration if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults). If a spe-

cies was only present in adultform, it was considered not regenerating and whenever a species was found only either in seedling or sapling stage without any adult individual, it was treated as new or new arrival.

Fruit production and extent of tree damage during harvesting

Twenty fruit bearing tree species were marked for studying the fruit production in both forest stands for two consecutive years. Appearance of dull greenish yellow or rarely brick red was taken as an indication of maturity. Intact fruit only were counted whereas the aborted fruits were not included in determining fruit production. Fruits were counted in mid-November, just before maturation or at the beginning of maturation. During this period of maturation predation of fruits starts on the tree itself, necessitating their estimation to be done on the tree at the initial stage of maturation to represent total fruit production including those lost to predation during the maturation phase. The fruit production for each tree was estimated as follows : (a) Total fruit production per tree = Average number of sub-branches \times average number of fruits per sub-branch. (b) Fruit production ha^{-1} = Average number of fruit tree $^{-1}$ \times Number of *Emblia* trees ha^{-1} .

For each tree, mean number of inflorescences per branch was calculated from a sample of 10 branches and mean number of fruit per inflorescences was calculated from a sample of 50 inflorescences. The data, for each dbh class, each stand and each year, were statistically treated using co-efficient of variance to test the effect of each of these factors. The extent of damage to the Aonla trees (i.e., lopping, pollarding and felling of trees) was recorded. The tree damage was categorized into four types : (i) not damaged, (ii) moderately damaged, (iii) highly damaged, and (iv) completely felled trees. Trees with 25—50% of branches lopped were recorded in the moderately damaged category and more than 50% lopped was put in the highly damaged category.

Soil analysis

Soil samples were collected from 5 sampling points

randomly in each of the 10 established permanent plots at two forest sites from three soil depths (0—10, 10—20, 20—30 cm) using a soil corer (diameter 6.3 cm and length 30 cm). All the samples for a given depth and forest stand was subsequently bulked to make a composite sample and then placed in sterilized polythene bags and brought to the laboratory. The composite samples were passed through 2 mm sieve to remove large stones and roots and packed in an air-tight polythene bag separately for each depth for further analysis. Soil pH was determined by a digital pH meter taking 1 : 2.5 suspension of fresh soil and distilled water (Anderson and Ingram 1993). The analysis of the macro elements like C, N and H and micro elements like K, Mn, Al, As and Mo in soil was done in CIL (Central Institutional Laboratory) of Mizoram University. Soil texture of different depth class was determined by using hydrometer method (Bouyoucos 1962). All analysis were done by using three replicates for each site and depth.

Data analysis

Data collected in the study were analyzed using Microsoft Excel 2007 version. Analysis of variance (ANOVA) and LSD post-hoc test were performed to test for significant differences among variables.

Results and Discussion

Effect of harvesting intensities/ disturbance on fruit production

E. officinalis had significantly higher ($p < 0.05$) stand density in mildly disturbed than the highly disturbed stand, so also the basal area of the species. The proportion of seedlings contributing to total stand density of *E. officinalis* was significantly higher ($p < 0.05$) in mildly disturbed stand than the highly disturbed stand. However, the population density of seedling was higher ($p < 0.05$) in highly disturbed than the density in mildly disturbed stand (Table 1). The average number of fruit per tree varied between years and between stands. The average number of fruit production was significantly ($p < 0.01$) higher in mildly disturbed than the highly disturbed stand and was true for both the years. Other growth attributes such as average number of main branches tree $^{-1}$, average

Table 1. Regeneration status (number ha⁻¹ ± SEM, n = 10) of *Emblica officinalis* in two forest stands of Manipur. LHI-low harvest intensity (60%), HHI-high harvest intensity (>90%).

Life stage of <i>Emblica officinalis</i>	Mildly disturbed/LHI		Highly disturbed/HHI	
	Population ha ⁻¹	Percentage	Population ha ⁻¹	Percentage
Seedling ha ⁻¹ (stems < 10 cm cbh)	147.00 ± 17.07	41.41	113.00 ± 14.30	48.92
Sapling ha ⁻¹ (stems 10-30 cm cbh)	118.00 ± 11.53	33.24	76.00 ± 13.68	32.90
Tree ha ⁻¹ (stems > 30 cm dbh)	90.00 ± 13.58	25.35	42.00 ± 9.64	18.18
Stand density (stem ha ⁻¹)	355.00 ± 37.25		231.00 ± 32.06	
Basal area ha ⁻¹	0.44 ± 0.06		0.25 ± 0.05	

number of sub-branches was also relatively higher in mildly disturbed than the highly disturbed stand (Table 2). The fruit production, mortality and recruitment were all influenced by the site condition and intensity of harvest (Table 3.). The number of trees showing different degree of damage also differed with respect to the two stands, more number of trees found without any damage or with partial damage in the mildly disturbed forest stand while a significantly ($p < 0.05$) higher number of trees were reported to be heavily damaged in highly disturbed forest stand (Table 4). This trend of damage to the trees was similar in both the years and was obviously related to the harvest of Aonla by the people surrounding the forests. The number of felled trees too was significantly higher ($p < 0.05$) in highly disturbed stand than the mildly disturbed stand.

Effect of harvest intensities/disturbance on regeneration

The higher seedling recruitment rate in mildly disturbed forest stand compared to highly disturbed site

in the present study was probably was related to higher soil moisture in the former than the latter. Both forest stands nevertheless showed good regeneration and in general showed population density in the order of seedlings>saplings>trees. Maximum number of seedling (<10 cm cbh ha⁻¹) and sapling (10-30 cm cbh ha⁻¹) were found in the mildly disturbed stand. The greater number of species under seedlings and saplings than the trees indicates the species is of advanced regeneration type. Higher number of seedlings and sapling and tree density in mildly disturbed stand than highly disturbed stand may be availability of favorable micro site in the former than later. The small scale disturbance that occurs in mildly disturbed forest stand might have increased a small heterogeneity of forest floor (Blanchet et al. 2013) producing a variety of micro sites that favors the co-existence of numerous tree species. Lower density of seedling and sapling of Aonla in the highly disturbed stand than mildly disturbed stand could also be due to low seed bank density as a result of unfavorable environment leading to lesser seedling recruitment.

Table 2. Year-wise variation in fruit production (number/plant) of *Emblica officinalis* in two forest stands (± SEM, n= 10) of Manipur. LHI-low harvest intensity (60%) , HHI-high harvest intensity (>90%).

Parameters	Mildly disturbed/LHI		Highly disturbed / HHI	
	2015	2016	2015	2016
Number of fruit bearing trees ha ⁻¹	90.0 ± 13.58	96.00 ± 13.92	42.00 ± 9.63	49.00 ± 11.87
Number of main branches tree ⁻¹	3.2 ± 0.33	3.20 ± 0.33	3.00 ± 0.29	3.00 ± 0.29
Number of sub-branches tree ⁻¹	13.0 ± 1.01	13.00 ± 1.01	13.20 ± 1.24	13.20 ± 1.24
Number of fruits sub-branch ⁻¹	68.6 ± 5.40	56.10 ± 4.22	52.20 ± 5.21	41.30 ± 4.03
Number of fruits tree ⁻¹ ha ⁻¹	896.2 ± 103.2	725.50 ± 76.2	698.00 ± 111.2	556.60 ± 90.8
Number of fruit production ha ⁻¹	80869 ± 17436	71443 ± 15085	27661 ± 8461	25309 ± 730

Table 3. Analysis of variance (ANOVA-2 way fixed effect model) on fruit production and regeneration of *E. officinalis* due to site and year.

Variables	Stand F ratio	P value ($\alpha=0.05$)	Year F ratio	P value ($\alpha=0.05$)
Stand density	6.36717	0.02125		
Basal area	5.51687	0.03046		
Fruit production	14.52527	0.00052	0.20418	0.65408
Mortality	5.30085	0.02721	0.02309	0.88008
Recruitment	0.8254	0.36965	0.81189	0.37355

The annual rate of recruitment and mortality of trees, saplings and seedlings of Aonla varied between the sites. Annual mortality rate was higher in highly disturbed stand and lower in mildly disturbed stand; the mortality rate was almost three times in highly disturbed stand compared to mildly disturbed stand (Table 5). This was true in both the years of study. Annual recruitment rate of the species, similarly was higher in the highly disturbed stand than the mildly disturbed stand, however, the survival per cent was better in the mildly disturbed stand. The concomitant increase in basal area and density in Aonla in mildly disturbed stand seems to be related to a decrease in the incidence of fire and of anthropogenic disturbances at the Ngariyan forest of Senapati district of Manipur. For some tree species, the mean annual mortality rate of 2.64% calculated for the forest gradient are within the range of 2-3% per year reported for tropical forests (Oliveira et al. 2014) and deciduous forests as well as for other semi-deciduous seasonal forests and gallery forests (Carvalho and Felfili 2011, Oliveira and Felfili

Table 4. Incidence of tree damage (Number of individuals ha⁻¹ \pm SEM, n=10) of *Embluca officinalis* during the study period in two forest stands of Manipur. LHI-low harvest intensity (60%), HHI-high harvest intensity (>90%).

Parameters	Mildly disturbed/LHI		Highly disturbed/HHI	
	2015	2016	2015	2016
Trees ha ⁻¹	90.00 ± 13.58	96.00 ± 13.92	42.00 ± 9.64	49.00 ± 11.87
Trees showing no damage	72.00 ± 10.93	69.00 ± 10.79	28.00 ± 7.86	37.00 ± 7.00
Trees showing moderate damage	11.00 ± 3.79	17.00 ± 3.00	8.00 ± 2.00	9.00 ± 1.79
Trees showing high damage	7.00 ± 2.13	10.00 ± 2.11	6.00 ± 2.21	8.00 ± 2.49
Felled trees	8.00 ± 3.59	14.00 ± 3.71	22.00 ± 4.42	32.00 ± 5.12

2008). The mortality rate observed ranged from 1.47-2.8% in low intensity harvest stand to 5.50-7.74% in high intensity harvest stand (Table 5), are also comparable to that reported in more recent studies of semi-deciduous seasonal forests (Silva and Araujo 2009) and gallery forests (Machado and Oliveira-Filho 2010). The variation in mortality rates over time can be related to factors such as climatic stresses (Zhang et al. 2017), longevity of the species that compose the community, anthropogenic disturbances and succession stage of the forest and compared to these values the present value of annual mortality in Aonla is very high, obviously due to high scale of human disturbances in Ngariyan forest of Manipur. In general, the rates of mortality and recruitment increased did not vary between the two successive measurement periods in the present

Table 5. Records of annual recruitment and annual mortality of *Embluca* in two forest stands of Manipur. \pm SEM, n = 10. LHI-low harvest intensity (60%), HHI-high harvest intensity (>90%).

Parameters	Mildly disturbed/LHI		Highly disturbed/HHI	
	2015	2016	2015	2016
Initial number of trees ha ⁻¹	90.00 \pm 13.58	96.00 \pm 13.92	42.00 \pm 13.28	49.00 \pm 15.49
No of recruitment (Nr) ha ⁻¹	5.00 \pm 2.24	7.00 \pm 2.13	9.00 \pm 3.14	6.00 \pm 2.21
No of dead trees (Nd) ha ⁻¹	3.00 \pm 1.53	6.00 \pm 2.21	5.00 \pm 2.24	8.00 \pm 2.91
Annual mortality (M%)	1.47 \pm 0.36	2.80 \pm 0.89	5.50 \pm 1.23	7.74 \pm 1.12
Annual recruitment (R%)	2.43 \pm 0.36	3.25 \pm 0.96	9.45 \pm 1.20	5.93 \pm 1.79

Table 6. Physico-chemical properties of soil at the two forest sites. \pm SEM, n =3, SL-Sandy loam, OC-Organic carbon, LI-low harvest intensity (60%), HI-high harvest intensity (>90%).

Soil parameters Textural class	Mildly disturbed/ LHI			Highly disturbed/High HHI		
	0-10 cm SL	10-20 cm SL	20-30 cm SL	0-10 cm SL	10-20 cm SL	20-30 cm SL
Soil pH	4.87 \pm 0.01	4.84 \pm 0.01	4.83 \pm 0.01	4.84 \pm 0.01	4.83 \pm 0.01	4.82 \pm 0.01
OC (%)	7.47 \pm 0.005	6.85 \pm 0.005	6.55 \pm 0.004	6.45 \pm 0.004	6.34 \pm 0.004	6.34 \pm 0.003
N (%)	0.41 \pm 0.004	0.38 \pm 0.003	0.36 \pm 0.001	0.35 \pm 0.001	0.34 \pm 0.002	0.34 \pm 0.004
H (%)	1.89 \pm 0.003	1.86 \pm 0.003	1.85 \pm 0.004	1.87 \pm 0.001	1.87 \pm 0.003	1.86 \pm 0.001
K (ppm)	0.88 \pm 0.003	0.66 \pm 0.02	0.59 \pm 0.01	0.71 \pm 0.01	0.69 \pm 0.003	0.61 \pm 0.002
Al (ppm)	0.19 \pm 0.003	0.25 \pm 0.005	0.31 \pm 0.004	0.24 \pm 0.002	0.25 \pm 0.001	0.25 \pm 0.003
As (ppm)	0.12 \pm 0.005	0.12 \pm 0.005	0.22 \pm 0.003	0.15 \pm 0.004	0.17 \pm 0.003	0.17 \pm 0.001
Mn (ppm)	0.94 \pm 0.004	0.65 \pm 0.003	0.58 \pm 0.01	0.72 \pm 0.005	0.61 \pm 0.003	0.59 \pm 0.001
Mo (ppm)	0.98 μ \pm 0.005	0.99 μ \pm 0.003	1.03 μ \pm 0.03	0.99 μ \pm 0.01	1.01 μ \pm 0.001	1.03 μ \pm 0.003

study. For the semi-evergreen forest and the gallery forest, the imbalance in favor of mortality, the decrease in density and the increase in basal area suggest a process of self-thinning in the tree community. In the Ngariyan hill range, however, the positive balance in favor of recruitment and the increases in density and basal area indicate that this vegetation formation is in the construction phase in mildly disturbed stand, which is favored by the decrease in the occurrence of fire and other anthropogenic disturbances. Among the seedlings and sapling classes, short seedlings exhibited higher density in the first census in mildly disturbed than the highly disturbed stand while the young saplings were reported to be of higher densities in the 2nd census in both the stands. Between the two censuses, there were minor changes in the floristic composition of both the sites.

In the both the forest stands, the Aonla trees were of similar age and no variation with respect to these reproductive phenological events were observed in the present study. However, it was noticed that the fruiting trees with greater girth had more number of branches and bore more fruits. It is generally accepted that tall trees with large crowns which receive a lot of light, produce maximum fruits. Tall individuals may offer more foraging opportunities and thereby increased chances of pollination and also increased protection from predators of flowers and fruits (Kula et al. 2014). Higher number of fruit bearing species and high number of fruits per sub-branches of Aonla were reported in mildly disturbed

stand, obviously related to lesser degrees of human interference in this stand.

Effect of physico-chemical properties on fruit production and regeneration

In the present the soil type of mildly disturbed and highly disturbed stand was sandy loam of textural class. The soil parameters like organic carbon, available nitrogen, available hydrogen, potassium, manganese and molybdenum decreased from upper to lower depth in both the forest stands while reverse was the case with other micro elements like aluminium and arsenic in both the forest stands (Table 6). The differential fruit production in the sites could be related to soil edaphic conditions and nutritional status. The pH in both the sites though did not vary significantly; there was a tendency of increase potassium, arsenic and manganese in the highly disturbed forest stand than mildly disturbed stand. The lesser fruit production in the highly disturbed stand could be due to lower soil moisture and nutrient stress. Higher fruit drop in Aonla has been related to moisture and nutrient stress in other studies too (Abhijith et al. 2018). Increase in soil organic carbon in the mildly disturbed forest stand than highly disturbed forest stand must have increased the biological properties of soil, thereby showing better regeneration. The available N and K were also relatively higher in the mildly disturbed soil than highly disturbed soil. Several studies (Singh et al. 2012, Abhijith et al. 2018) suggest the important role played by various micronutrients like zinc and boron in en-

hancing fruit yield and increase in fruit weight through the process of translocation of carbohydrates and photosynthates. On the otherhand, deficiency of boron and other micronutrients in the soil can cause necrosis and fruit drop, reducing the fruit quality (Abhijith et al. 2018). Nitrogen have been reported to increase vegetative growth and female flowers while phosphorus increase sex ration, initial fruit set and fruit retention and increase yield (Singh et al. 2012).

Conclusion

The study revealed that the fruit production and regeneration are affected by fruit harvest intensities and anthropogenic pressure coupled with soil chemical properties. Fruit production and annual mortality values were higher in the low harvest stand compared to the high harvest stand; however, long term studies are needed to determine threshold harvesting levels for quality and quantity fruit production and optimum regeneration.

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