Sprouting shoot biomass dynamics associated with traditional fire in the oak forest stand of Manipur, North East India

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Sprouting shoot biomass of five tree species in the oak forest was measured at the end of the first and second year with different stump diameter and height (cm), and site quality (unburnt and burnt). The influence of stump diameter and height, shoot diameter, number of survived shoots and total leaf area on shoot biomass production is significant ($P < 0.001$). The net primary productivity of sprouts of these tree species is in the following order: *Lithocarpus dealbata* (15.29 kg stump^{-1} yr^{-1}) > *L. fenestrata* (7.05 kg stump^{-1} yr^{-1}) > *Castanopsis tribuloides* (6.68 kg stump^{-1} yr^{-1}) > *Quercus griffithii* (6.19 kg stump^{-1} yr^{-1}) > *Q. serrata* (2.28 kg stump^{-1} yr^{-1}). The treatment factor (site quality) also has significant effect on the sprouting shoot biomass production ($P < 0.05$). The value of Durbin–Watson statistics was found to be 1.75 (close to 2), so that the fitted adjusted regression is useful to predict the pattern of biomass in the present study.

Keywords: Net primary production, oak species, shoot biomass, sprouts, traditional fire.

IN Manipur, the oak forest represents the climax forest vegetation and its distribution ranges from 180 to 2750 m amsl[1]. Most of the information on biomass dynamics and production in the oak forest is available from the temperate regions of the world[2–4], but few studies have been reported from India[5–7]. However, in Manipur, North East India, the climax oak forest stand is being replaced by the scrub forest due to various biotic pressures, such as felling of trees for timber, fuel wood, and slash and burning for shifting cultivation. The oak forest tree species are known for their resprouting nature after fire as a life-history trait[8–10]. These species are able to persist when fires are frequent because the time needed to grow new shoots, flowers and set seeds is often short[11]. It has wide ecological amplitude and magnitude of recovery through sprouting in various ecosystems of the world is widely observed for forest wood resources[12,13]. The short-rotation forestry, particularly the coppice system, is of interest for three principal reasons: (i) as an alternative use for the land taken out of agricultural production; (ii) as a feedstock for energy and industry, and (iii) as a means to sequester carbon dioxide[14,15]. Furthermore, they have a positive impact on biodiversity, nutrient capture and carbon circulation in the soil–plant atmosphere system[16,17]. The short-rotation forestry of fast-growing oak coppice shoot management is also important for sericultural and fuel-wood resources[18]. Therefore, the present study was undertaken to understand the traditional fire treatment on sprouting shoot biomass production in the oak forest stand and also to develop a useful regression model to predict aboveground shoot biomass production through independent variables such as site quality, stump diameter and height, total leaf area, shoot diameter and number of survived shoots.

The study site, i.e. Lambui hills, Ukhrul District, Manipur, NE India lies at 25°01′N lat. and 94°02′E long., a distance of 65 km from Imphal city and at an altitude of 1470 m amsl. The present oak forest was located at the transition between sub-tropical and temperate regions[19] and was dominated by five tree species, viz. *Lithocarpus dealbata*, *Lithocarpus fenestrata*, *Quercus griffithii*, *Quercus serrata* and *Castanopsis tribuloides*. The climate of the area is monsoonic with warm moist summer and cool dry winter. The mean maximum temperature varies from 16.49°C (January) to 29.32°C (August), and mean minimum temperature from 2.94°C (January) to 15.2°C (August), with average annual rainfall of 1484 mm.

We hypothesized that diameter at breast height (DBH) variation of the tree species might affect the sprouting characteristics. A pilot survey in the selected oak forest stand based on trees of 10 DBH sizes (cm), two each of the five different species selected, indicated 460 as the adequate sample size after taking 15 quadrates of 10 × 10 m size randomly in the study site.

$$n = \frac{Z\alpha^2 s^2}{e^2},$$

where n is the sample size, $Z\alpha^2$ the standard variate value at α level = 1.96 at ($\alpha = 0.05$), s the standard deviation = 17.77, and e the margin of error to the mean = 5% to the mean value ($\bar{x} = 32.79$).

Subsequently, the tree species were harvested randomly at various heights up to a maximum of 120 cm in the first week of January 2005. The study area was divided into two sites, viz. unburnt and burnt. At the end of January, the traditional system of fire (slash and burning) was employed after 15 days of harvesting. During the process of traditional fire the entire litter and twigs were burned completely, except for small branch and wood biomass. The number of samples (N) has been calculated on different class intervals for different variables, i.e. stump diameter (cm), stump height (cm), survived shoot, etc.

The following variables were recorded at the end of the first and second growing seasons: average shoot diameter and height, total leaf area, number of survived shoots and

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biomass of sprouts in the unburnt and burnt sites. The total biomass of each individual sprout was estimated on dry weight basis (105°C, 72 h)[20]. The regression model was developed on the second-year data of biomass.

Shoot biomass as the dependent variable is to be explained by independent variables: stump diameter and height (cm), site quality, total leaf area (m^2), shoot diameter (cm) and number of survived shoots. In the univariate analysis of shoot biomass production one-way ANOVA was performed to compare means of various class intervals of different variables. The same independent variables were also used for the regression model to predict biomass production. A binary dummy variable (0 and 1) was adopted to quantify the site quality (unburnt and burnt). Statistical treatment of the study was performed through SPSS V.13.

The average sprouting shoot biomass according to stump diameter and height (cm), number of shoots, number of survived shoots, shoot diameter class (cm) and total leaf area (m^2) for five oak tree species is given in Table 1. The sprouting shoot biomass increased from the lowest stump diameter class (< 10 cm) to the stump diameter of 40–50 cm and then decreased in the next higher stump diameter class > 50 cm ($P < 0.01$). These variables have significant effects on biomass production ($P < 0.001$) and its correlation was also at $P < 0.001$. The remaining parameters showed maximum shoot biomass at the highest class interval ($P < 0.01$). The effect of site quality on shoot biomass production was insignificant ($P > 0.05$; Figure 1). Student Newman–Keuls (SNK) test identifies homogenous subsets of means that are not different from each other, of different class intervals of different variables ($P > 0.05$).

In the first and second year, the mean shoot biomass values of the five tree species were significantly significant. Shoot biomass was maximum in *L. dealbata* and minimum in *Q. serrata* (Table 2). The net primary productivity of the sprouting shoot was maximum in *L. dealbata* (15.29 kg stump^{-1} yr^{-1}), followed by *L. fenestrata* (7.05 kg stump^{-1} yr^{-1}), *C. tribuloides* (6.68 kg stump^{-1} yr^{-1}), *Q. griffithii* (6.19 kg stump^{-1} yr^{-1}) and *Q. serrata* (2.28 kg stump^{-1} yr^{-1}). The sprouting shoot biomass of burnt site (21.02 ± 2.14 kg stump^{-1} yr^{-1}) was higher than the unburnt site (16.78 ± 1.40 kg stump^{-1} yr^{-1}; Figure 1). However, this variation in biomass was statistically insignificant ($P > 0.05$).

Biomass production is explained in relation to stump diameter and height (cm), number of sprouting shoots, number of survived shoots, shoot diameter and total leaf area (m^2) through multiple regression (Table 3). This adjusted multiple regression has been fitted after scanning and diagnosing the problem of multicollinearity. The cutoff value of correlation coefficient is taken as 0.6.

The fitted regression model is as follows: The amount of biomass (kg) = –24.76 + 3.78 site quality (kg) + 0.01 stump height (cm) – 0.01 stump diameter (cm) + 0.16 total leaf area (m^2) + 2.64 shoot diameter (cm) + 8.23 number of survived shoots.

A step-wise regression analysis involving the number of survived shoots, leaf area, shoot diameter and site quality was conducted to explain the variability in biomass (Table 4).

The amount of biomass (kg) = –24.65 + 8.27 number of survived shoots + 0.16 total leaf area (m^2) + 2.63 shoot diameter (cm) + 3.80 site quality (kg).

The regression explains 54% ($R^2 = 0.543$) variation in biomass. Out of the six parameters considered, leaf area, shoot diameter, number of survived shoots and site quality showed significant relationships. However, number of survived shoots was the most influencing factor on biomass production ($t = 12.75$, $P < 0.001$).

In the present study, sprouting shoot biomass production and its net primary productivity were maximum in *L. dealbata* and minimum in *Q. serrata* in both unburnt and burnt site. This may be due to maximum number of survived shoots, larger leaf area and greater shoot diameter size among the five oak tree species, and also showed significant correlation ($P < 0.001$). A similar relation between biomass and leaf area index (LAI) has been found in various studies[21,22]. It has also been reported that LAI, total leaf area (tLA) per shoot and specific leaf area (SLA) must be the most important determinants of aboveground woody biomass production[23]. The sprouting shoot biomass production for all five oak tree species increased up to 40–50 cm and then decreased in > 50 cm. The increase of shoot biomass up to 40–50 cm diameter size depicts juvenile to adult phase of the plant, and its maximum physiological performance[24]. In the last three decades, a number of workers have also reported that the sprouting success decreases with increasing parent diameter, possibly due to the inability of bud to breach the thick bark associated with larger trees or inability of the sprouts to produce enough photosynthate to keep the larger root alive[25–27]. The decrease in sprouting shoot biomass in > 50 cm diameter size may be due to increase in tree age with the number of dormant buds[28,29]. The sprouting shoot biomass production increases with stump height classes. This may be due to increase in the number of sprouting shoots with stump height classes[30]. This positive effect of stump height on shoot biomass production is directly related to the increase of bud bank surface vertically[31].

The variation of shoot biomass production is directly influenced by the number of sprouting shoots and of survived shoots at the end of the second year. Their survival rates are also different with different diameter and stump height classes[27]. As the height and diameter increase, the number of sprouting shoots also increases, and ultimately survival and biomass also increase. Thus, the sprouting shoot biomass also increases with the increase in total leaf area[32]. This positive effect may be due to more leaf area related to a significant increase in shoot diameter,

Table 1. Sprouting shoot biomass according to diameter class (cm), height class (cm), number of shoots, number of survived shoots, shoot diameter class (cm) and total leaf area (m^2) for five oak tree species

Diameter class (cm)	N	Mean biomass (kg per stump)	Height class (cm)	N	Mean biomass (kg per stump)	Survived shoot	N	Mean biomass (kg per stump)	Shoot diameter (cm)	N	Mean biomass (kg per stump)	Leaf area (m^2)	N	Mean biomass (kg per stump)
< 10	25	3.79 ± 1.02	< 20	50	8.73 ± 1.19	< 5	88	4.43 ± 0.76	< 2	12	0.63 ± 0.18	1.00	74	3.11 ± 0.38
10–20	83	9.77 ± 1.04	20–40	73	14.90 ± 2.25	5–10	145	10.72 ± 0.74	2–4	84	4.67 ± 0.56	2.00	162	11.03 ± 0.82
20–30	90	20.50 ± 2.454	40–60	74	16.82 ± 2.43	10–15	67	18.28 ± 1.80	4–6	173	16.17 ± 1.23	3.00	76	19.56 ± 1.77
30–40	91	19.55 ± 2.43	60–80	81	19.08 ± 2.75	15–20	47	34.26 ± 3.68	6–8	103	33.76 ± 3.87	4.00	43	44.08 ± 4.78
40–50	63	28.73 ± 5.12	80–100	61	21.75 ± 3.02	20–25	25	43.42 ± 6.54	8+	29	32.52 ± 4.71	5.00	46	48.22 ± 7.09
> 50	44	25.84 ± 3.87	100–120	62	32.26 ± 5.59									
r		0.269**			0.243**			0.602**			0.381**			0.55**
F		7.532***			5.558***			47.33***			22.02***			51.92***
SNK test		*P*, (i, ii) = 0.223			*P*, (i–iv) = 0.098			*P* (i, ii) = 0.146			*P*, (i, ii) = 0.650			*P*, (i) = 1.000
		P, (i–iv) = 0.740			*P*, (ii–v) = 0.422			*P*, (ii, iii) = 0.081			*P*, (ii–iv) = 0.680			*P*, (ii) = 1.000
		P, (iii–vi) = 0.241						*P*, (iv) = 1.000			*P*, (iv–v) = 1.000			*P*, (iii) = 1.000
					P, (vi) = 1.000			*P*, (v) = 1.000						*P*, (iv, v) = 0.274

N, Sample size; *r***, Significant at 1%; *F****, significant at 0.01%; SNK test, Student Newman–Keuls test.

Table 2. Sprouting shoot biomass (kg per stump) and net primary productivity (kg per stump per yr) of five oak tree species

Species	First year biomass (kg per stump per yr)	N	Second year biomass (kg per stump)	N	Net primary productivity (kg per stump)
Lithocarpus dealbata	13.56 ± 1.30	98	28.85 ± 4.08	97	15.29
Lithocarpus fenestrata	11.45 ± 1.12	106	18.50 ± 1.84	105	7.05
Castanopsis tribuloides	10.56 ± 1.45	86	17.24 ± 2.60	79	6.68
Quercus griffithii	9.01 ± 1.17	49	15.21 ± 2.18	64	6.19
Quercus serrata	7.77 ± 1.06	54	10.05 ± 1.71	57	2.28
F	2.685*		5.74**		

N, Sample size; *Significant at 5%; **Significant at 1%.

Table 3. Adjusted multiple regression analysis of biomass production (kg per stump)

Covariate	Unstandardized coefficient β	Unstandardized coefficient SE	Standardized coefficient β	t	P	95% CI for β Lower bound	95% CI for β Upper bound
Constant	–24.760	3.441		–7.196	0.000	–31.524	–17.996
Site quality	3.784	1.824	0.072	2.074	0.039	0.197	7.370
Stump height (cm)	0.010	0.030	0.012	0.338	0.735	–0.048	0.068
Stump diameter (cm)	–0.014	0.070	–0.008	–0.200	0.841	–0.151	0.123
Leaf area (m^2)	0.157	0.019	0.326	8.061	0.000	0.118	0.195
Shoot diameter (cm)	2.641	0.474	0.209	5.571	0.000	1.709	3.573
Number of survived shoots	8.233	0.670	0.461	12.286	0.000	6.915	9.550

Model diagnostics: $F = 77.801$, $P = 0.000$; $R^2 = 0.543$, Durbin–Watson = 1.753.

Table 4. Stepwise regression of biomass production

Model	Predictor(s)	Unstandardized coefficient β	Unstandardized coefficient SE	Standardized coefficient β	T	P	95% CI for β Lower bound	95% CI for β Upper bound	Model test $F(P)$
1	(Constant)	–9.641	2.178		–4.426	0.000	–13.923	–5.359	226.14 ($P < 0.001$)
	Number of survived shoots	10.758	0.715	0.602	15.038	0.000	9.351	12.164	
2	(Constant)	–10.182	1.934		–5.265	0.000	–13.984	6.380	197.66 (< 0.001)
	Number of survived shoots	8.408	0.674	0.470	12.478	0.000	7.084	9.733	
	Leaf area (m^2)	0.189	0.018	0.392	10.404	0.000	0.153	0.224	
3	(Constant)	–23.065	2.910		–7.926	0.000	–28.786	–17.343	153.483 (< 0.001)
	Number of survived shoots	8.412	0.648	0.471	12.979	0.000	7.138	9.687	
	Leaf area (m^2)	0.152	0.019	0.317	8.205	0.000	0.116	0.189	
	Shoot diameter (cm)	2.664	0.463	0.211	5.756	0.000	1.754	3.573	
4	(Constant)	–24.655	2.995		–8.231	0.000	–30.543	–18.766	117.202 (< 0.001)
	Number of survived shoots	8.273	0.649	0.463	12.750	0.000	6.997	9.548	
	Leaf area (m^2)	0.157	0.019	0.326	8.424	0.000	0.120	0.193	
	Shoot diameter (cm)	2.625	0.461	0.208	5.692	0.000	1.718	3.531	
	Site quality	3.797	1.810	0.072	2.098	0.037	0.239	7.355	

Summary of models

Model	R	R^2	Adjusted R^2	Standard error of the estimate	Durbin–Watson
1	0.602	0.362	0.361	21.06	1.753
2	0.706	0.499	0.496	18.70	
3	0.733	0.538	0.534	17.98	
4	0.737	0.543	0.538	17.91	

which also enhances production[22,33]. The univariate analysis of site quality on sprouting shoot biomass production was insignificant ($P > 0.05$). This may be due to the irrespective effect of other factors when observing the effect of site quality. However, in multivariate analysis the treatment factor (site quality) was found to be significant ($P < 0.05$). This may be due to the controlling the joint linear effects of five selected parameters: stump

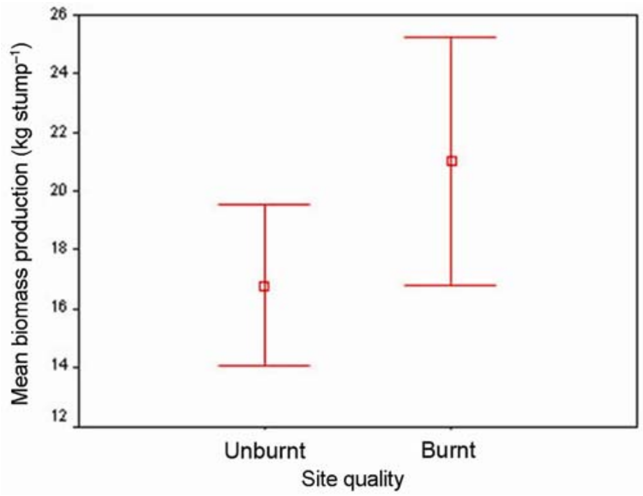

Figure 1. Mean biomass production (kg per stump) of shoot biomass with site quality (unburnt and burnt).

height, stump diameter, leaf area, shoot diameter and number of survived shoots. The increase of sprouting shoot biomass in the burnt site may be due to an immediate flash of readily available nutrient and also observed to increase in sprouting shoot growth in the burnt site[34,35]. Therefore, instead of site preparation and fertilization, traditional fire treatment could be the alternative for shoot biomass production in the oak forest stand in Manipur.

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Status of *Embelia ribes* Burm f. (Vidanga), an important medicinal species of commerce from northern Western Ghats of India

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***Embelia ribes* is a red-listed medicinal plant species that contains embelin, which has wide clinical applications. Its great demand in Ayurveda and the pharmaceutical industry (> 100 t/yr) has imposed tremendous pressure on natural populations from the Western Ghats of India. In this study, we have prepared a distribution map of *E. ribes* for the northern Western Ghats of Maharashtra. Issues regarding misidentification, adulteration and the status of its trade with respect to its population decline have been critically discussed.**

Keywords: Distribution map, *Embelia ribes*, population decline, trade.

INDIA has a rich repository of medicinal plant species (about 8000). More than 80% of the population of our country is dependent on medicinal plants for its primary health care[1]. India ranks second in terms of the volume and value of medicinal plants exported. Of the 960 traded medicinal plant species from India, 178 species are consumed in volumes exceeding 100 MT/yr (ref. 2). Less than 10% of the medicinal plants that are traded in the country are cultivated and about 90% are collected from the wild. These are often harvested in a destructive and unsustainable manner[3]. The biodiversity hotspot of the Western Ghats, which is ranked fifth in the world in its biological resources, harbours about 4000 species that are used in herbal drug formulations. Besides, several plant species from the Western Ghats are gaining international importance due to their newly identified pharmacological and curing properties. This has led to their indiscriminate harvest, severely threatening their existence. *Embelia ribes* Burm f., which possesses high trade potential, is one such species that needs immediate conservation attention.

E. ribes, popularly known as 'Vidanga' or 'Vavding' in Ayurveda, is a Red-listed species[4]. It yields embelin, and other highly valued secondary metabolites, which have a wide range of clinical applications (Table 1). It is a dioecious woody climber belonging to the family Myrsinaceae. It is sparsely distributed in the evergreen to moist deciduous forests of the Western Ghats and is now confined only to remnant forest pockets. *E. ribes* is listed in the 'Priority Species List' for cultivation by the National Medicinal Plant Board (http://nmpb.nic.in/index1.php?level=2&sublinkid=688&lid=246) and the Maharashtra State Horticulture and Medicinal Plant Board (MSHMPB)[5]. However, lack of knowledge about its distribution, poor natural regeneration and unknown propagation techniques has resulted in the lack of availability of 'quality planting material' (QPM) for promoting cultivation. Misidentification of this species coupled with the use of adulterants and substitutes has further aggravated the problem. It has been observed that *E. ribes* has been extensively wild-harvested, sometimes even from the protected areas (PAs). Due to the aforementioned reasons it has become essential to: (i) assess the current status and distribution of *E. ribes* from the northern Western Ghats (NWG) of Maharashtra; (ii) identify and map the existing populations of the species; (iii) assess the status of the trade of *Embelia* and (iv) give a comparative account with closely related alternative and adulterant species.

The NWG, popularly known as Sahyadri (15°30′–20°30′N lat., 73°–74°E long.) lies in Maharashtra. The vegetation here is more or less in the form of fragmented patches, in contrast to continuous stretches of forests in the southern Western Ghats. Approximately more than half of the natural habitat from NWG has now been cleared (http://www.wwfindia.org/wwf_publications/cdp_india/). As a result, highly fragmented and scattered natural populations of species such as *Dysoxylum binectariferum* (Roxb.) Hook.f. ex Bedd., *Embelia ribes* Burm.f., *Nothapodytes nimmoniana* Grah. Mabb. and *Oroxylum indicum* (L.) Vent. exist in remnant forest patches or

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