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Observations on re-sprouting as regeneration strategy in *Pterocarpus santalinus* (Red sanders) – an endemic tree in dry deciduous forests of Sri Lankamalleswara wild life sanctuary, southern Eastern Ghats

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Abstract: Re-sprouting from roots and cut stumps as multiple sprouts after disturbance as an important regeneration mode is studied in *Pterocarpus santalinus,* an endemic tree of kadapa hill ranges of southern Eastern Ghats. The study was carried out in dry deciduous forests of Sri Lankamalleswara wildlife sanctuary. The inventory of different regeneration life stages – seedling, sapling, regenerating trees was undertaken in two sites namely site 1 and site 2 of one hectare each by laying transects of 10 × 100 size. The inventory has yielded a range of 198–240 seedlings ha^{-1}, 45–58 saplings ha^{-1} and 38–74 regenerating plants ha^{-1}. Among them 47% of seedlings, 71% of saplings and 7% of regenerating trees comprised of multiple shoots. It reveals that the re-sprouting of stems after a disturbance helps the plant to progress from seedling to sapling and then successfully to a regenerating tree stage. Re-sprouting was observed in both the transects affected by fire and animal browsing, but a higher level of deaths occurred due to the later disturbance. Thus, animal browsing seems to be major factor than fire that affects the seedling survival. A negative relationship between the cut-stump size class and proportion of stumps with sprouts was observed. The 51–70 cm gbh class of cut stumps has registered higher percentage of cut stumps with sprouts as well as mean sprouts per stump. Majority of fruits comprised of two locules with only one seed, the abort of one seed may be helpful to have a better dispersal advantage.

Key words: Coppice, dry deciduous forests, fire, pod, regeneration, sprouts.

Tropical timber tree species are threatened due to selective logging and forest degradation in their natural habitats (Sagar *et al*. 2003). *Pterocarpus santalinus* (Red sanders) is one such highly valued timber yielding endemic tree that occurs restrictively on the dry hill slopes of kadapa and sheshachalam hill ranges (Raju & Nagaraju 1999). Red sanders timber is extensively used for making luxury furniture and a rare wavy grained variant heart wood is in high demand in Japan for making musical instrument 'shamisen'. To meet the huge demand, illicit felling is being carried out in its natural habitat and the population is under threat and this situation has led to its inclusion in endangered category (Reddy & Srivasuki 1990). Against these odds also, Red sanders occurred as the pre-dominant tree species in dry deciduous forests of kadapa hill ranges albeit in lower girth classes (Mastan *et al*. 2016).

The success or dominance of a species in dry forests depends on the modes of regeneration such as sprouts, seedling banks, seed dispersal and ability to re-sprout after disturbance (Teketay 2005). In dry forests, adventitious sprouting from roots and stems can be an important regeneration mode as there lays a low probability of successful regeneration by seeds (Kammesheidt 1999). In addition, in those dry forests exposed to fire, re-sprouting ability of tree seedlings which can produce above ground parts immediately after the fire episode (Wilson & Witkowski 2003) and coppice growth after tree cutting disturbance can form an important means of survival (Levesque *et al*. 2011). Further, regeneration of tree species in dry tropical

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Table 1. The number of different plant life-forms ha^{-1} and the percentage of them comprising multiple sprouts of Red sanders.

	Frequency	
Plant life-form (ha^{-1})	Site 1	Site 2
Seedlings	198 (41%)	240 (54%)
Saplings	45 (73%)	58 (70%)
Regenerating trees	38 (11%)	74 (4%)

forests depend upon their seed size and seed dispersal ability (Khurana *et al*. 2006). Thus understanding the recruitment features of Red sanders at seedling and sapling stages in its natural habitat affected by fire and animal browsing may be useful for its conservation in the natural habitat.

The field study was undertaken in Sri Lankamalleswara wildlife sanctuary (14°28–14°44N and 78°54–78° 59E) that covers an area of 462 km^2 in southern Eastern Ghats. These hill ranges comprise of dry deciduous forests exposed to grazing and forest fires (Rawat 1997). A total of two hectares with ten quadrats of 10 × 100 m size (one hectare) in each site namely Site 1 and Site 2 were laid randomly. Regeneration stages were classified as plants up to 30 cm height as seedlings, plants > 30 cm height but not attained 10 cm girth at 1.37 m height (gbh) as saplings and plants that occur in 10–30 cm gbh as regenerating plants. The multiple sprouts in each category are noted down in the field. In site 1, all the seedlings in five transects of 10 × 100 m size are sequentially tagged and among them two transects are exposed to fire and for comparison another two sites affected by animal grazing were selected and in these transects the tags were re-inventoried after 90 days of fire episode. Fruits (pods) were collected during the field survey for their seed count and morphological study and cut stumps along with their gbh at 25 cm above the ground and presence/absence of sprouts was noted.

The field inventory results of different Red sanders plant life forms under regeneration categories were provided in Table 1. Seedlings were found to be the prominent life form with 198 and 240 seedlings ha^{-1} in site 1 and site 2 and among them 41% and 53.7% of seedlings were recorded with multiple shoots in site 1 and 2, respectively. In the saplings life form category 45 and 58 plants ha^{-1} with a share of 73% and 70.1% of plants with multiple stems in site 1 and site 2, respectively, were recorded. In the regenerating plants category 38 plants in site 1 and 74 plants in site 2 with 10.5% and 4% of plants having multiple stems were recorded, respectively (Table 1). The results indicate that the presence of multiple stems is prevalent in seedling stage became prominent at sapling stage and became less significant at regenerating stage.

Among the 78 sequentially tagged seedlings in the fire affected transects 14 (18%) seedlings were found to be dead (Table 2). In comparison to the recorded baseline data on the number of sprouts, a total of 29 seedlings (26.5%) have produced more sprouts in the range of 1–5 and 25 seedlings have registered reduction of multiple sprouts in the range of 1–3. Further ten seedlings did not record any change in the multiple sprouts frequency. In the tagged 89 seedlings of the browsing affected transects, 32 (36%) seedlings were found dead, 21 seedlings have recorded an increase in the sprouts

Table 2. Number of dead seedlings, increment and decrement of frequency of sprouts among the seedlings in fire and browsing affected transects that were re-sampled after 90 days of fire episode.

	Dead seedlings	Increase in 1 sprout	Increase in 2 sprouts	Increase in ≥3 sprouts	Decrease in 1 sprout	Decrease in 2 sprouts	Decrease in ≥3 sprouts	Seedlings with no change in sprouts
Fire affected site	14 (18%)	21 (27%)	6 (7.7%)	2 (2.6%)	23 (9.5%)	1 (1.3%)	1 (1.3%)	10 (12.8%)
Browsing affected site	32 (36%)	12 (3.5%)	6 (6.7%)	3 (3.4%)	13 (14.6%)	4 (4.5%)	2 (2.3%)	17 (19.1%)

Table 3. Number of cut stumps, their percentage with sprouts and mean sprouts/stump in different size classes.

Gbh class	No of cut stumps	No of cut stumps with sprouts	Mean number of sprouts/stump
30–50	76	34 (45%)	4.4
51–70	52	28 (54%)	5.3
71–90	21	6 (29%)	3.8
91–110	13	2 (15%)	2.4

frequency, 19 seedlings have got registered reduction in their sprouts frequency and 17 seedlings have remained static with respect to the sprouts frequency (Table 2).

Among the 162 cut stems scouted and recorded in the forest area, 70 stumps (43%) have produced sprouts with a range of 1–7 sprouts per stump. The results in Table 3, indicates that stumps in the 30–50 cm gbh class have registered 45% of stumps with sprouts with a mean of 4.4 sprouts per stump. The 51–70 cm gbh class has produced higher mean sprouts/stump (5.3) as well as stumps with higher percentage (54%) of sprouts. The higher gbh classes 71–90 and 91–110 have not only had low mean sprouts/stump (3.8 and 2.4) and lower percentage of stumps with sprouts (29% and 15%), respectively.

The screening of 1000 Red sanders pods for the presence of number of seeds and locules revealed that 684 (68.4%) pods comprise of two locules filled with only one seed followed by pods with 2 locules filled with one seed in each locule (16.3%). The presence of three lobules is also observed (5.6%). The mean weight of two seeded pod is 1.906 ± 0.32 g and the mean weight of pod containing one seed is 1.369 ± 0.35 g. Independent t-test revealed a significant difference between pods containing two seeds and one seed [$t = 3.54$, $df = 38$, $P < 0.05$].

The high percentage of seedlings with multiple sprouts indicates that Red sanders has the potential to resprout at seedling stage (juvenile stage). The multiple sprouts strategy can be thought of a mechanism to produce above ground shoots after a disturbance like fire and browsing as also observed in *Burkea africana* tree of Miobi dry forests (Wilson & Wittowski 2003). But the observed death rates among seedlings indicate that browsing effects more negatively than fire as fire may only destroy the upper shoot while hoofs of animals may rupture whole root collar. The low rate of progression from seedlings to saplings indicates that seedling stage is the bottleneck in the regeneration progression for the Red sanders as also observed among tree species in dry forests (Pare *et al.* 2009). The inventory after fire episode has resulted more dynamism of either increase or decrease of sprouts frequency among seedlings and did not yield any dead sapling suggesting that the deep root system provides greater survivor ability than seedlings. The lower percentage of multiple sprouts at the regenerating plant stage suggests that one among the several multiple sprouts of saplings will manage to grow rapidly and be successful against the disturbances. This kind of suffrutex type regeneration was observed in *Pterocarpus angolensis* a dominant tree in the African dry forests (Banda *et al*. 2006)

The presence of 43% of Red sanders cut stumps with resprouts reveal that Red sanders has the potential to produce re-sprouts at adult stage also. The data has to be read with caution as the cut stumps would be of the past disturbance that have got root decayed also. On the other hand the considerable percentage (36%–45%) of trees > 30 cm gbh featuring multiple stems reflects the coppicing ability of the Red sanders. This kind of producing multiple stems naturally as well as after logging is in line with the observations made by Dunphy *et al*. (2000) in Puerto Rico dry forests. While Vieira *et al*. (2006) observed that trees of hard wood and shade intolerant species produce sprouts and Red sanders is one of the tree species that possess high wood density (1.1 g cm^{-3}). The feature indicate that with increase in stump diameter the stump frequency as well as the percentage of stumps with sprouts (sprouting ability) got decreased as also observed in Bolivian dry forest tree species (Levesque *et al*. 2011). Along with dominant tree Red sanders other dominant tree species like Anogeissus latifolia and Chloroxylon swietenia have also showed resprouting ability. But this ability may vary with respect to the prevailing disturbance intensity (Kennard *et al*. 2002). Thus, a long term study is needed to evaluate the coppicing ability of the red sanders after tree cutting. The present data suggests that Red sanders has more resprouting ability at juvenile stage as well as at the adult stage. Fire affected site showed high dynamism of

either increase or decrease of sprouts and featured low seedling death rate than browsing affected site. The higher the gbh of cut stump they produce lesser the re-sprouts. The presence of 2/3rd pods with only one seed reveals that Red sanders aborts one seed in order to have better dispersal efficiency.

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