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Effect of Disturbance on Seed Germination and Seedling Growth of *Cassia fistula* (L.), *Albizia lebbeck* (L.) Benth. and *Dalbergia sissoo* Roxb. of Similipal Biosphere Reserve, Odisha, India

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Abstract

With the aim of restoring the disturbed sites on one of the premier tiger reserve of the country or the only biosphere reserve of the state, the study was planned to investigate the effect of disturbance on seed germination, early seedling growth and adaptation potential of *Cassia fistula* (L.), *Albizia lebbeck* (L.) and *Dalbergia sissoo* Roxb. in Similipal Biosphere Reserve (SBR), Odisha. The study sites of the biosphere reserve was categorised into disturbed, moderately disturbed and undisturbed stands on the basis of disturbance index. They differ from each other in forest floor light intensities along with other biophysical characters. High light intensity in the forest floor of Disturbed Stand (DS) than Undisturbed Stand (UDS) and Moderately Disturbed Stand (MDS) of the reserve was found suitable towards significantly higher rate of seed germination and seedling growth of the three investigated tree (over storey) species for all growth characteristics measured except S/R ratio. High soil nutrient content and low light intensity in the forest floor of undisturbed stand than disturbed and moderately disturbed stands of the reserve was not suitable for better seed germination and early stage of seedling growth. Moderate light intensity in the forest floor of moderately disturbed stand produced seed germination and seedling growth to come in the second order. All growth characteristic parameters of *Albizia lebbeck* seedlings had almost the highest values among species in all the forest stands of the reserve. Though *Cassia fistula* seedlings had lower growth characteristics than others, but its low S/R ratio in all the forest stands evidenced its higher adaptation potential.

Keywords: Disturbance, Forest stands, Similipal, Seedling growth, Seed germination, Light intensity, Forest floor

Introduction

The forest covers of Similipal Biosphere Reserve (SBR) in Mayurbhanj district of Odisha have faced serious problems over the years in extraction of over storey plants (trees) for timber, fuel wood and other energy requirements [1,2]. Identification of trees extracted for such practices and their rehabilitation within the depleting forest stands are urgently needed. Studies on ecological adaptation and growth characteristics of such species are therefore important for conservation, management and restoration of disturbed forest stands of SBR.

Plant growth and development is controlled by various environmental conditions [3-5] of which light is one of the most important factor [6]. In this regard studies stated that light availability on the forest floor is the primary limiting factor for seedling growth [7,8]. The major part of the forest floor receives only 1-2% photosynthetically active radiation [9]. Spatial variation in light availability in different stands of forest covers leads to variation in phytosociological characters of plants and physico-chemical parameters of soil [10,11]. Thus for successful seedling establishment it is crucial to study the seedling growth with respect to different growth parameters of seedlings. In addition species-specific responses to availability of light on the forest floor are important towards initial growth of seedlings [12,13]. The need for light during early stage of seedling growth is essential because seeds with smaller nutrient content are not able to sustain development for long periods in the shade [14].

In tropical forests it appears that seedling establishment and seedling growth face a more heterogeneous situation as compared to other forests. To study some of the mechanisms of seedling establishment and resource capture in tropical seasonal forests, it is helpful to investigate the growth responses of seedlings to different forest stands along with forest floor light content. Comparative quantitative information on seedling growth in terms of seedling height, shoot biomass, root biomass, total biomass and S/R ratio may also help to explain species co-existence and their adaptability to different forest stands [4,5,15]. Many authors confirmed the importance of light intensity on seedling growth and survival. Mayer and Mayber [16] and Osunkoya et al. [17] found that many trees at the seedling stage reduced their growth (e.g. root size and weight) with reduced light intensity. Moreover, Buylla and Ramous [18] indicated that reduced light was one of the factors that led to mortality of young plants. Similarly, Rao [19] studied the effect of forest floor light availability on the seedling growth of five important tree species in Tarai region of Uttaranchal and found that growth of all species was strongly affected by canopy gap position and availability of light on the forest floor.

Dalbergia sissoo, *Albizia lebbeck* and *Cassia fistula* belongs to the family, Fabaceae, Mimosaceae and Caesalpiniaceae, respectively are some of the timber yielding and ethno-medicinal tree species of Similipal that propagate by seeds. Different parts of *Cassia fistula* and *Albizia*

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lebbeck have medicinal values and were used by the tribal inhabited inside SBR to cure from different diseases [20,21]. Their woods were used for furniture, decorations, fine carving, etc. [2,22]. The woods of *Dalbergia sissoo* is economically very important and used in making high quality furniture, cabinet wood and general utility requirements [22]. Study on phytosociological analysis of woody perennials of SBR indicated that density of these species in comparison to others is too low [1]. Considering the ethno-medicinal values, use of woods of these species for various purposes and low density of these species inside the reserve, their introduction in afforestation programmes and planting trials is essential, which needs knowledge concerning about the optimum conditions for their germination and growth in different forest stands. Thus in the present study seed germination and seedling growth of these three indigenous tree species of Similipal was examined in different forest stands and light intensities on the forest floor.

Materials and Methods

Study site description

The study was carried out in Similipal Biosphere Reserve (SBR) located in Mayurbhanj district of Odisha (21°28′- 22° 08′ N latitude and 86°04′ - 86°37′ E longitude). The climate of the reserve is influenced by a monsoon pattern of rainfall. Maximum rainfall was occurred from mid-June to October and accounting for 75-80% of annual rainfall. Summer and winter were relatively dry generally with <15cm monthly rainfall (Figure 1). Summer was not unbearable, as the maximum temperature never exceeds 40°C. Winter was severe and the temperature comes down to 30°C with frosts in valleys. Spring was very pleasant. Because of luxuriant vegetation cover and a network of perennial streams, Similipal is relatively moist throughout the year. Minimum humidity of Similipal at 0600 hrs ranged from 40 to 70% and maximum at 1800 hrs ranged from 73 to 90% (Figure 1). The whole forest cover of Similipal was divided into three forest stands i.e. disturbed, undisturbed and moderately disturbed on the basis of disturbance regime.

Experimental design

Mature seeds of *Dalbergia sissoo* Roxb., *Albizia lebbeck* (L.) and *Cassia fistula* (L.) were collected from mother plants within the study area during end parts of winter and early parts of summer i.e. from February to March, 2013 and their germination potential was studied under three forest stands of SBR. For germination trial under each forest stand, 5 replicates of 100 seeds each were placed on the forest floor after removing all naturally fallen seeds from the ground in an area measuring 2 m × 2 m (3 forest stands × 3 species × 5 replicates of 100 seeds each). The seed plots were roofed with fine nylon net to avoid natural seed deposition until the seeds germinated. After emergence of seedlings nylon net was replaced with PVC pipes just to demarcate the seed plots for subsequent observations.

Seed germination and measurement of seedling growth

Observation on seed germination was made at an interval of 10 days for a total period of three months. Seed germination was recorded at each forest stand when epicotyls were visible above ground. After germination seedlings of each species were allowed to grow for one year. Species specific growth response (shoot length, root length and S/R ratio) and biomass (Shoot dry weight, root dry weight and total dry weight) of one year old seedlings of each species were measured in three different forest stands of SBR.

For extension growth five seedlings of each species from seed plots of three forest stands were randomly selected and shoot length was measured using centimeter scale. Means with standard deviation were calculated for each data set. Statistical test such as Least Significant Difference (LSD) was calculated at $p \leq 0.05$ level of significance to determine the overall influence of the forest stands on germination, seedling survival, and extension growth (shoot length, root length, shoot dry weight, root dry weight, total dry weight and S/R ratio) of *Dalbergia sissoo*, *Albizia lebbeck* and *Cassia fistula*. One way ANOVA (Analysis of Variance) was calculated to determine the degree of variation of growth parameters within the species among forest stands and the level of significance was also determined.

Measurement of bio-physical parameters

Each of the forest stands of SBR was sampled using square quadrats. A total of 120 quadrats of 20 m × 20 m for tree (≥ 30 cm cbh) species, 480 quadrats of 5 m × 5 m for shrubs and 600 quadrats of 1 m × 1 m for herbs were placed randomly. Plant species were collected, brought to the laboratory and identified with the help of Flora of Orissa [23]. Canopy area of tree species of each forest stand was calculated following Larson and Zaman [24]. Tree, shrub and herb density of each forest stand were calculated following Misra [25] and disturbance index was measured following Mohanty et al. [26].

Five number of soil samples were collected from each forest stand during February to April, 2013 at a depth of 0-15 cm. The moisture percentage was determined as per Misra [25] and the soil pH was measured using a digital pH meter (Systronics, 802) in a 1:5 soil water suspension. Soil organic carbon [27], available phosphorus [28] and nitrate nitrogen [29] was measured spectrophotometrically. The available potassium was measured by flame photometer method and the total nitrogen content by Kjeldahl digestion method [30]. Light intensity on the forest floor in each of the forest stand was measured by using Quantum Sensor (Hansatech, QSRED, UK).

Results

Biophysical condition of study sites

The three forest stands of SBR differ considerably in soil characters, tree density, canopy area (%) and light intensity (μmol/m²/Sec.) on the forest floor (Table 1). Tree density (Plants/ha) and canopy area (%) in undisturbed forest stand was comparatively higher than the disturbed and moderately disturbed forest stands of the reserve. However, a reverse trend was marked in case of shrub and herb density. Light intensity on the forest floor is one of the most important factor

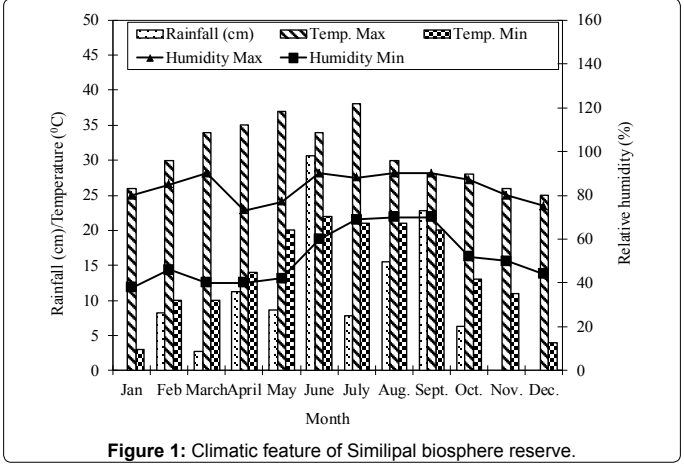

Figure 1: Climatic feature of Similipal biosphere reserve.

Character	DS	MDS	UDS
Disturbance Index (%)	>30	15-30	<10
Soil moisture (%)	11.74 ± 1.62	24.53 ± 2.81	34.16 ± 4.56
pH	6.26 ± 0.14	5.83 ± 0.33	5.69 ± 0.18
Organic Carbon (%)	0.96 ± 0.04	1.09 ± 0.07	1.25 ± 0.06
NO_3^- -N (kg ha^{-1})	14.26 ± 3.27	17.26 ± 3.39	22.68 ± 5.56
Total Nitrogen (%)	0.16 ± 0.014	0.25 ± 0.02	0.38 ± 0.037
Available -P (kg ha^{-1})	19.03 ± 4.72	18.86 ± 3.29	18.51 ± 3.76
Available -K (kg ha^{-1})	205.33 ± 31.55	197.61 ± 31.27	171.65 ± 19.84
Tree density (Plants ha^{-1})	655 ± 23.53	750 ± 21.56	920 ± 31.41
Shrub density (individuals ha^{-1})	1680 ± 96.77	1560 ± 77.31	1040 ± 40.66
Herb density (individuals m^{-2})	28 ± 4.71	16 ± 3.12	5.0 ± 1.08
Tree crown area (%)	23.16 ± 5.79	31.42 ± 5.96	45.42 ± 4.87
Light intensity (µmol/m^2/Sec.)	344.91 ± 33.74	158.16 ± 22.84	59.36 ± 9.13

Table 1: Comparison of biophysical characters at disturbed (DS), moderately disturbed (MDS) and undisturbed (UDS) forest stands of Similipal Biosphere Reserve (SBR).

towards seedling growth differ among the forest stands. Maximum and minimum light intensity on the forest floor was measured at disturbed and undisturbed forest stands of the reserve, respectively (Table 1). Soil moisture in the studied forest stands varied between 11.74 ± 1.62% and 34.16 ± 4.56%. In all the forest stands the soil was slightly acidic (pH value ranging between 5.69 ± 0.18 and 6.26 ± 0.14) in nature. Average soil organic carbon ranged from 0.96 ± 0.04% to 1.25 ± 0.06% with a maximum at undisturbed forest stand and minimum at disturbed forest stand of the reserve. The same trend was marked in NO_3^- -N and total nitrogen content, while the trend in case of available phosphorus and available potassium was reverse (Table1).

Seed germination

The seed germination percentage of three indigenous tree species viz. *Albizia lebbeck, Cassia fistula* and *Dalbergia sissoo* were tested in three different forest stands of Similipal. Irrespective of forest stands maximum percentage of seed germination was exhibited by *Albizia lebbeck* followed by *Dalbergia sissoo* and *Cassia fistula*. The percentage of seed germination among the species was significantly differed from each other (Figure 2). Irrespective of species maximum percentage of seed germination was marked in the disturbed forest stand than undisturbed and moderately disturbed forest stands of the reserve and the variation was significant (Figure 3). Comparative analysis of seed germination of individual species among forest stands showed significant variation which may be due to variation in light intensity on the forest floor (Figure 4). As evidenced from the soil chemical parameters, high soil nutrient content in undisturbed and moderately disturbed forest stands of the reserve than disturbed forest stand may not be suitable for maximum seed germination of these tree species. But, high light intensity on the forest floor of disturbed forest stand than undisturbed and moderately disturbed forest stand may be the cause towards high seed germination.

Seedling growth

Statistical analysis of the obtained data on stem height, root length, shoot dry weight, root dry weight, total dry weight and S/R ratio revealed that there was significant difference in seedling growth among the tree species (Table 2). Irrespective of forest stands *Albizia lebbeck* seedlings had the highest values for stem height (15.1 ± 2.735 cm), root length (8.6 ± 1.831 cm), shoot dry weight (1.553 ± 0.231 g), root dry weight (0.635 ± 0.185 g), total dry weight (2.189 ± 0.395 g) and S/R ratio (1.793 ± 0.197) among the species and varied significantly than *Cassia fistula* and *Dalbergia sissoo* (Table 2).

Across forest stands seedlings of the investigated species had showed maximum growth in terms of shoot height, root length, shoot dry weight, root dry weight and total dry weight at the disturbed forest stand than undisturbed and moderately disturbed forest stands of the reserve. However, the shoot to root ratio was inverse i.e. maximum S/R ratio was observed at undisturbed forest stand and minimum at disturbed forest stand. The variation of each growth parameter of seedlings among the forest stands was significantly different (Table 3).

Seedling growth of each tree species was different with respect to

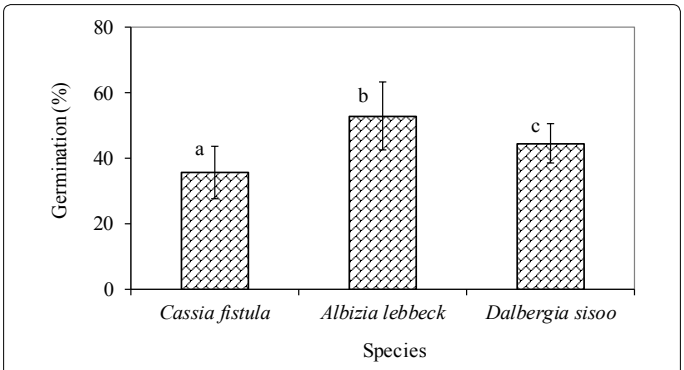

Figure 2: Seed germination percentage of three selected over-storey tree species of Similipal biosphere reserve. Bars represent SD of means. Different small letter above bars signify they significantly differ from each other at p ≤ 0.05

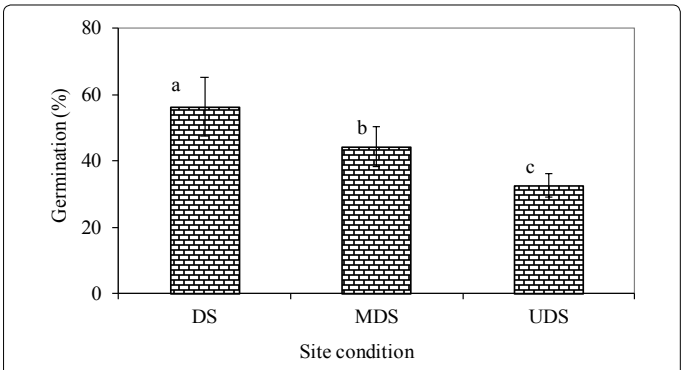

Figure 3: Effect of forest stand condition on seed germination percentage of three selected over-storey (tree) species of Similipal biosphere reserve. Bars represent SD of means. Different small letter above bars signify they significantly differ from each other at p ≤ 0.001.

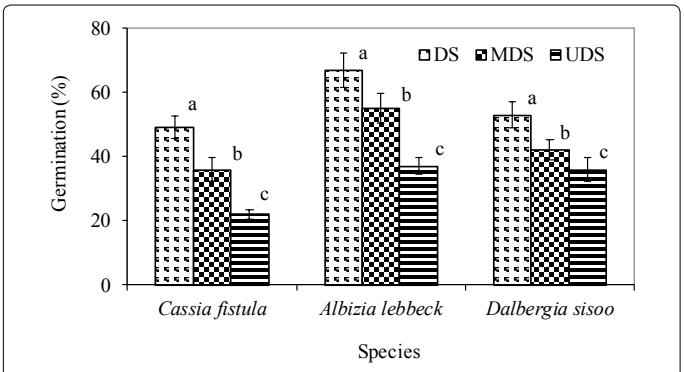

Figure 4: Comparative account of variation in seed germination percentage of individual tree species in different forest stands (disturbed, moderately disturbed and undisturbed) of Similipal biosphere reserve. Bars represent SD of means. Different small letter above bars signify they significantly differ from each other at p ≤ 0.05.

Character	*Cassia fistula*	*Albizia lebbeck*	*Dalbergia sisoo*	L.S.D.*
Stem height(cm)	8.4 ± 1.321	15.1 ± 2.735	10.7 ± 1.497	at 0.05=0.316 at 0.01=0.422 at 0.001=0.553
Root length (cm)	6.3 ± 1.29	8.6 ± 1.831	7.3 ± 1.582	at 0.05=1.833 at 0.01=2.448 at 0.001=3.203
Shoot dry weight (g)	0.393 ± 0.062	1.553 ± 0.231	0.464 ± 0.069	at 0.05=0.135 at 0.01=0.180 at 0.001=0.236
Root dry weight (g)	0.19 ± 0.025	0.635 ± 0.185	0.26 ± 0.053	at 0.05=0.143 at 0.01=0.191 at 0.001=0.25
Total dry weight (g)	0.583 ± 0.062	2.189 ± 0.395	0.724 ± 0.056	at 0.05=0.445 at 0.01=0.594 at 0.001=0.792
S/R ratio	1.355 ± 0.168	1.793 ± 0.197	1.537 ± 0.282	at 0.05=0.163 at 0.01=0.218 at 0.001=0.285

*L.S.D.: Least Significant Difference

Table 2: Mean values (mean ± SD) of stem height, root length, shoot dry weight, root dry weight , total dry weight and S/R ratio of *Cassia fistula, Albizia lebbeck* and *Dalbergia sissoo* seedlings of SBR.

Character	DS	MDS	UDS	L.S.D.*
Stem height(cm)	14.407 ± 2.396	11.6 ± 2.281	8.233 ± 1.217	0.05=2.594 0.01=3.317 0.001=4.34
Root length(cm)	10.333 ± 2.145	7.0 ± 0.829	4.933 ± 0.533	0.05=1.001 0.01=1.339 0.001=1.753
Shoot dry weight (g)	1.263 ± 0.384	0.737 ± 0.151	0.41 ± 0.031	0.05=0.438 0.01=0.586 0.001=0.766
Root dry weight (g)	0.562 ± 0.065	0.31 ± 0.043	0.213 ± 0.023	0.05=0.166 0.01=0.222 0.001=0.291
Total dry weight (g)	1.825 ± 0.346	1.047 ± 0.471	0.623 ± 0.129	0.05=0.598 0.01=0.8 0.001=1.047
S/R ratio	1.365 ± 0.228	1.643 ± 0.269	1.679 ± 0.253	0.05=0.184 0.01=0.246 0.001=0.322

*L.S.D.: Least Significant Difference

Table 3: Effect of forest stands (DS, MDS and UDS) on seedling growth characteristics (mean ± SD) of three selected tree species of Similipal.

different forest stand conditions. Comparison of growth parameters (stem height, root length, shoot dry weight, root dry weight, total dry weight and S/R ratio) among species and forest stands were in the order *Albizia lebbeck* > *Dalbergia sissoo* > *Cassia fistula* and DS > MDS > UDS, respectively. Low light intensity on the forest floor of undisturbed and moderately disturbed forest stands than disturbed forest stand may be the cause towards reduced growth (Table 1).

Species wise comparative analysis of each growth parameter between forest stands showed gradual decrease in shoot length, root length, shoot dry weight, root dry weight and total dry weight from disturbed forest stand to undisturbed forest stand through moderately disturbed forest stand (Table 4). However, a different trend was observed for S/R ratio i.e. S/R ratio was increased from disturbed forest stand to undisturbed forest stand through moderately disturbed forest stand in case of *Cassia fistula* and *Albizia lebbeck*. But no specific trend was marked in case of *Dalbergia sissoo* (Table 4). The difference in each growth parameter within species between forest stands was statistically significant.

Discussion

Light is one of the most important environmental variables responsible for synchronization of germination with conditions suitable for seedling establishment [8,31]. In the present study significant differences in seed germination and seedling growth of the three indigenous tree species is the outcome of the difference in bio-physical condition of the forest stands of the reserve (Table 1). The work fulfilled its primary aim by getting different results of seed germination and seedling growth at different forest stands. As reported by Hartmann and Kester [32] and Sacande and Some [33] seeds usually germinate at low light intensities. However, the present work supported Bahuguna and Pyare [34], Montgomery and Chazdon [35] and Makana and Thomas [11] indicated the importance of high light intensity for tropical over-story species during early stage of growth, since it enhances germination. High and moderate light intensity on the forest floor of disturbed and moderately disturbed forest stands of the reserve resulted enhanced seedling growth of the three investigated species. This result concur with that of Osunkoya et al. [17] who noticed that twelve forest trees under experiment showed reduced growth with decreasing light intensity. Montgomery and Chazdon [35] also reported the best growth of seedlings of *Dipteryx panamensis* and *Brosimum alicastrum* under high light intensity, compared to low light intensity. Similar results were obtained for different forest species like *Terminalia superba* and *Entandrophragma utile* [36]. The present work

Character	*Cassia fistula*				*Albizia lebbeck*				*Dalbergia sissoo*			
	DS	MDS	UDS	F-value	DS	MDS	UDS	F-value	DS	MDS	UDS	F-value
Height (cm)	9.5 ± 1.471	8.2 ± 1.316	7.5 ± 1.254	46.22***	20.9 ± 1.601	14.7 ± 1.316	9.8 ±0.608	65.89***	12.8 ± 0.671	11.9 ± 1.155	7.4 ± 1.380	46.47***
Root length(cm)	7.8 ± 1.504	6.3±1.255	4.5 ± 0.674	66.95***	12.7 ± 1.632	7.9 ± 1.474	5.3 ± 0.847	89.34***	10.5 ± 1.632	6.8 ± 0.867	4.6 ± 0.619	34.64***
Shoot dry weight (g)	0.63 ± 0.081	0.37 ± 0.051	0.18 ± 0.047	71.40***	2.41 ± 0.086	1.43 ± 0.088	0.82 ± 0.063	45.41***	0.75 ± 0.061	0.41 ± 0.055	0.23 ± 0.061	48.7***
Root dry weight (g)	0.28 ± 0.032	0.17 ± 0.041	0.12 ± 0.025	33.57***	0.96 ± 0.12	0.53 ± 0.061	0.38 ± 0.048	68.21***	0.41 ± 0.061	0.23 ± 0.041	0.14 ± 0.032	61.5***
Total dry weight (g)	0.91 ± 0.084	0.54 ± 0.051	0.30 ± 0.041	52.34***	3.37 ± 0.826	1.96 ± 0.473	1.2 ± 0.41	87.9***	1.16 ± 0.591	0.64 ± 0.066	0.37 ± 0.054	31.7***
S/R ratio	1.218 ± 0.041	1.304 ± 0.089	1.541 ± 0.144	16.25**	1.651 ± 0.096	1.866 ±0.119	1.867 ± 0.271	8.75*	1.226 ± 0.138	1.757 ± 0.099	1.629 ± 0.241	15.88**

***Significant at P ≤ 0.001; **Significant at P ≤ 0.01; *Significant at P ≤ 0.05

Table 4: Comparative mean values of growth characteristics of *Cassia fistula, Albizia lebbeck* and *Dalbergia sissoo* under different forest stands of Similipal.

also supported that of Rincon and Huante [37], concerning the effect on root length and root dry weight, and Ashton [38] concerning the effect on total biomass.

Seedling growth in terms of stem height (cm), root length (cm), shoot dry weight (g), root dry weight (g) and total dry weight (g) of the species studied was greater in disturbed and moderately disturbed forest stands than undisturbed forest stand of the reserve [8,39]. It was evident from the study that significantly declined seedling growth in undisturbed forest stand may be due to direct consequence of low light intensity and high percentage of canopy area. High percentage of canopy area and increased shading might increase seedling mortality indirectly by exacerbating fungal attack through increased humidity or by providing concealment for rodents, mollusks and land crabs that predate on seedlings [40].

Study on S/R ratio of the investigated species with respect to different forest stands of Similipal indicated that allocation of more photosynthate to shoot than root as evidenced S/R ratio was >1 for each species (Table 2) in each forest stand (Table 3). Allocation of more photosynthate to shoot resulting into more biomass to shoot is common in stable forests [41,42]. The high S/R ratio of seedlings (in all the tested species) during the initial stage of establishment in undisturbed forest stand than disturbed and moderately disturbed forest stand of the reserve could be at high priority to capture light rather than minerals. Higher root length and root mass of all the studied species in disturbed and moderately disturbed forest stand than undisturbed forest stand indicating the adaptation of these species to drier or disturbed forest stands of the reserve [42].

Conclusion

This study was focused on the germination and seedling growth of three indigenous species viz. *Albizia lebbeck*, *Cassia fistula* and *Dalbergia sissoo* in different forest stands of Similipal Biosphere Reserve (SBR). The results of the study have an important implication for the restoration of degraded forest stands inside the reserve. Seeds of the studied species germinate well and the growth characteristics of seedlings in terms of shoot length, root length, shoot dry weight, root dry weight and total dry weight were more in disturbed and moderately disturbed forest stands of the reserve than the undisturbed forest stand. Individual species followed their own adaptation in different forest stands depending upon the biophysical conditions. Test for S/R ratio indicated that all the three studied species showed more adaptability in the disturbed and moderately disturbed forest stands than undisturbed forest stand. This suggests that these species could potentially serve as frame work species for restoration of degraded forest stands of Similipal. Out of the three studied species, *Dalbergia sissoo* produces high quality timber having economic value. In addition to maintaining the forest structure, this species also provides economic returns to the Forest Managers, if the forest stands of SBR managed properly.

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