Indian Journal of Ecology (2023) 50(5): 1373-1378
DOI: https://doi.org/10.55362/IJE/2023/4064

Manuscript Number: 4064
NAAS Rating: 5.79

Influence of Biofertilizers on Seedling Growth and Vigour of Indian Redwood [*Soymida febrifuga* Roxb.]-A Lesser Known Tree Species

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Abstract: *Soymida febrifuga* popularly called as Indian Redwood, is one of the lesser known tree species distributed naturally in the deciduous forests. Through the research project, some population of this species are identified in different forests of South Gujarat. Its occurrence is found to be random and less dense with poor natural regeneration. In the present study, influence of biofertilizers on growth and vigour of Indian redwood seedlings were assessed in the nursery. A nursery experiment consisting of twenty-two treatments of six biofertilizers *viz*. Azotobacter, Azospirillum, Acetobacter, PSB, Pseudomonas and VAM in single and combinations including control, which were kept by following completely randomized design. Result shows that single and combination of biofertilizers treatments significantly influenced the seedling growth and vigour parameters in the seedlings of Indian redwood. Among them, seedlings treated with Azospirillum-PSB combination *i.e.,* Azospirillum @ 5ml plant^{-1} + PSB @ 5ml plant^{-1} treatment, recorded the maximum seedling height (16.01 cm), collar diameter (4.90 mm), total leaf area (469.43 cm^2), fresh weight (17.66 g) and dry weight of seedlings (3.78 g) along with seedling quality index (0.75) after the age of six months over control and many other treatments. Therefore, this treatment is suggested for production of good quality seedlings Indian redwood in large quantity in nursery.

Keywords: Biofertilizer, Indian redwood, Nursery growth, Seedling vigour

Soymida febrifuga (Roxb.), popularly known as Indian Redwood, belongs to the family Meliaceae and is confined only to India and Sri Lanka (Hooker 1982). In India, it is distributed in the hilly districts of north, western, central and southern India, which extends to Travencore (Hooker 1982). Occasionally, it is found in mixed deciduous forest on Aravalli hill slopes and its outliers in Rajasthan and its presence is also well documented in deciduous forests of Maharashtra (Singh and Karthikeyan 2000), Uttar Pradesh, Bihar, Odisha, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala (Sharma et al 1993); whereas, in Gujarat, it is rarely seen in the districts of Dangs, Vyara, Rajpipla regions of South Gujarat as well as Chhotaudepur and Panchmahals area of Central Gujarat and some other parts of Saurashtra region (Shah 1978). Due to non scientific and over extraction of bark the population of old trees has been declining and kept in the status of Near Threatened regional basis in Gujarat (Anonymous 2008).

Indian Redwood, is a very slow growing species, approximately 2.5 to 5 cm height of seedlings attains in the first year in its natural habitat (Bhide et al 2016, Sandhya and Birader 2015 and Sukhadiya et al 2019). As a part of research project, some population of this species were identified in different forests of South Gujarat. Its occurrence is random, occasionally clumped having less dense population with poor natural regeneration. Indian Redwood reach up to the height of 30 m with girth of 2.5 to 3.0 m. It has rough bark that exfoliates in scales. Seed germination is found to be less than 30%; however, Prajapati (2021) reported that the germination of this species can improve upto about 52 % than control 35% by varying germination media. Viability of seeds of Indian redwood decreases with the increase of storage period (Ashalatha and Thejaswini 2015).

Considering utilization of this species, the dark brown heartwood is hard and durable, which is used in house building as posts, rafters and beams, for well work, plough shares, furniture, pestles and pounders. It is also well suited for carving and turnery, wooden flooring, for making furniture for frames and stiles and for framing lighter coloured paneling (Sukhadiya et al 2019). Bark is used in tanning and tanned leathers possess good colour, good feel and fullness. Bark is used in ayurvedic medicine and it has the characteristics of acrid, refrigerant, anthelmintic, aphrodisiac, laxative, good for sore throat and it removes "vata" cures "tridosha" fevers, cough, asthma, it also removes blood impurities and good for ulcers, leprosy, dysentery (Kirtikar and Basu 2003). Moreover, the bark is useful as an anticancer remedy, for blood coagulation, wounds, dental diseases, uterine bleeding and hemorrhage (Chiruvella et al 2010).

By looking into the usage of species and its natural occurrence and being lesser known species, the use of this species for large scale plantation in different land-use systems is necessary. Further, this species could be one for the programme of ToF (Trees Outside Forests) for plantation establishment and increasing the green cover. Thus, the present experiment was undertaken to understand the influence of biofertilizers on early growth and vigour of seedlings in Indian redwood (*Soymida febrifuga*).

MATERIAL AND METHODS

The present investigation was conducted during the year 2021-22 in College of Forestry, Navsari Agricultural University (NAU), Navsari, Gujarat, India. Mature fruits of Indian redwood were collected from the middle-aged trees distributed in Amania range of Vyara forest division (South Gujarat). Fruits were dried under shade for seven days to crack down the pericarp. After capsule break open, seeds were collected, processed and stored properly . Seeds were sown in germination trays containing soil and sand (1:1). Germinated seedlings of two leaf stage were transferred into polythene bags of size 6 x 8 inch having common growing media of Soil: Sand: FYM (2:1:1). The transplanted seedlings were arranged in CRD (Completely Randomized Design) consisting of three repetitions and twenty two treatments *viz.,* T_1:Control (No biofertilizer), T_2:Azotobacter @ 10 ml plant^{-1}, T_3:Azospirillum @ 10 ml plant^{-1}, T_4:Acetobacter @ 10 ml plant^{-1},T_5:PSB @ 10 ml plant^{-1}, T_6:Pseudomonas @ 10 ml plant^{-1}, T_7:VAM @10ml plant^{-1}, T_8:Azotobacter @ 5ml plant^{-1} + Azospirillum @ 5ml plant^{-1}, T_9:Azotobacter @ 5ml plant^{-1} + Acetobacter @ 5ml plant^{-1}, T_{10}:Azotobacter @ 5ml plant^{-1} + PSB @ 5ml plant^{-1}, T_{11}:Azotobacter @ 5ml plant^{-1} + Pseudomonas @ 5ml plant^{-1}, T_{12}:Azotobacter @ 5ml plant^{-1}+ VAM @ 5ml plant^{-1} , T_{13}:Azospirillum @ 5ml plant^{-1} + Acetobacter @ 5ml plant^{-1} , T_{14}:Azospirillum @ 5ml plant^{-1} + PSB @ 5ml plant^{-1}, T_{15}:Azospirillum @ 5ml plant^{-1} + Pseudomonas @ 5ml plant^{-1}, T_{16}:Azospirillum @ 5ml plant^{-1} + VAM @ 5ml plant^{-1} , T_{17}:Acetobacter @ 5ml plant^{-1} + PSB @ 5ml plant^{-1}, T_{18}:Acetobacter @ 5ml plant^{-1} + Pseudomonas @ 5ml plant^{-1}, T_{19}:Acetobacter @ 5ml plant^{-1}+ VAM @ 5ml plant^{-1}, T_{20}:PSB @ 5ml plant^{-1}+ Pseudomonas @ 5ml plant^{-1}, T_{21}:PSB @ 5ml plant^{-1}+ VAM @ 5ml plant^{-1} and T_{22}:Pseudomonas @ 5ml plant^{-1}+ VAM @ 5ml plant^{-1}.

The biofertilizers were applied @ 10 ml/seedling after establishment of transplanted seedlings. Various growth parameters such as seedling height, collar diameter, number of leaves per seedling, total leaf area per seedling, root length, fresh and dry weight of plant were recorded after 180 DAT (Days After imposing Treatment). Further, the seedling vigour indices such as root to shoot ratio, sturdiness quotient and seedling quality index (Dickson et al 1960) were calculated. The data obtained from the experiment were processed and fed to the data sheet in MS Excel and subjected to statistical analysis using DOS based software developed by Department of Agricultural Statistics, NAU, Navsari by following CRD (Panse and Sukatme 1985).

RESULTS AND DISCUSSION

There was significant variation among 21 treatments of biofertilizers (single and combination) with control ($P< 0.05$) (Table 1 and Figure 1). The height of seedling varied from 11.57 cm (T_1) to 16.01 cm (T_{14}) with overall mean of 13.07 cm; while seedling collar diameter varied from 2.83 mm (T_1) to 4.90 mm (T_{14}) with overall mean of 3.99 mm (Table 1). Similarly, significant variation was also recorded among various biofertilizer treatments for seedling dry biomass, which ranged from 1.15 g (T_1) to 3.78 g (T_{14}) with mean of 2.07 g.

Among all the biofertilizer treatments, seedlings of *S. febrifuga* treated with Azospirillum @ 5ml plant^{-1}+ PSB @ 5ml plant^{-1} treatment (T_{14}) achieved significantly maximum shoot length (16.01 cm) and collar diameter (4.90 mm). Moreover, this treatment (T_{14}) also enhanced the total leaf area (469.43 cm^2), which was statistically at par with Azotobacter @ 5ml plant^{-1} + Acetobacter @ 5ml plant^{-1} (T_9) at 180 DAT. Further, maximum root length (20.28 cm) was recorded in seedling treated with Azotobacter @ 5 ml plant^{-1}+ Azospirillum @ 5 ml plant^{-1} (T_8), which was followed by T_{21}. In fact, seedlings exposed to T_{14} also showed significantly higher fresh (17.66 g) and dry weight of plant (3.78 g; Table 1).

Most of the growth parameters of *S. febrifuga* seedlings were more effective in combination treatments of biofertilizers as compared to single application and than control (Table 1). The combination biofertilizer treatments enhanced the growth attributes and it may be due to the synergistic effect with each other along with the host plant. The growth of seedlings in early stages in nursery normally depends upon the tree species and its growth characteristics, growing media and its types, nature along with the types of inoculants or biofertilizers applied (Chauhan 2020). Normally, certain biofertilizers enhanced the growth of seedlings due to their symbiotic and positive interaction with the seedlings (Duponnoisa et al 2005 and Wu et al 2010). Moreover, increment in growth attributes of seedlings might be due to increased cell elongation and cell multiplication coupled with enhanced nutrient uptake by plants due to biofertilizer inoculation (Vijayakumari and Janardhanan 2004). Azospirillum in the soil media, helps in enhancing the nutrient and water uptake capacity which are necessary for better growth and assists in maintenance of good physical and chemical properties of the media (Chiranjeevi et al 2018); moreover, the increase of growth may be attributed to high accumulation of chlorophyll and protein in the plant tissue by the application of nitrogen fixing bacteria of the genus *Azospirillum* (Mohan and Rajendran 2017 and Rajendran 2012). Further, phosphate solubilizing bacteria (PSB) can convert the insoluble phosphates into plant available forms and can also promote plant growth via producing hormones, such as cytokinin and indole acetic acid (Wu et al 2010) which helps in increasing the growth and also attributed to the increase in P uptake in shoots of the seedling (Jangandi et al 2017). Therefore, these two combinations are most important in producing quality seedlings in forest tree species. Such influence was also noticed in the present study, where the combination of Azospirillum @ 5ml plant^{-1} + PSB @ 5ml plant^{-1}treatment (T_{14}) resulted in significant increase in seedling growth attributes (Table 1), where combine application of Azospirillum and PSB could made synergistic effect of enhanced seedling growth in *S. febrifuga*. Such inference also reported in other tree species like *Gmelina arborea* (Maharana et al 2018) and *Aegle marmelos* (Mohan and Rajendran 2017).

Apart from growth parameters, various vigour indices like root: shoot ratio, sturdiness quotient and seedling quality index were also worked out for these twenty-two treatments and result showed that single and combination of biofertilizer treatments influenced the seedling vigour in Indian redwood at 180 DAT (Fig. 1). Seedling Quality Index (SQI) is considered as a promising integrated measure of morphological traits and a good indicator of seedling quality as it computes robustness and biomass distribution of seedlings as compared to individual growth parameters like shoot length, collar diameter (Binotto et al 2010). In the present study, among various biofertilizer treatments, T_{14} (combination of Azospirillum @ 5 ml plant^{-1} + PSB @ 5 ml plant^{-1}) resulted in highest seedling quality index of 0.75 than

Table 1. Influence of biofertilizers on the growth parameters of *S. febrifuga* seedlings at 180 DAT

Treatments	Seedling height (cm)	Collar diameter (mm)	No. of leaves plant^{-1}	Total leaf area plant^{-1} (cm^2)	Root length (cm)	Fresh weight of plant (g)	Dry weight of plant(g)
T_1	11.57	2.83	6.38	241.81	18.28	6.97	1.15
T_2	12.94	4.13	7.51	396.72	18.00	13.77	2.70
T_3	12.87	4.20	6.67	391.87	16.83	12.46	2.30
T_4	13.60	4.15	7.47	354.46	18.44	11.02	2.02
T_5	12.27	3.93	6.40	310.92	17.78	9.73	1.52
T_6	13.47	4.10	7.47	375.43	17.13	13.30	2.48
T_7	12.98	4.20	6.08	369.56	18.06	12.00	1.98
T_8	13.80	3.94	6.67	414.71	20.28	11.63	1.95
T_9	14.66	4.38	5.30	462.37	18.09	16.09	3.21
T_{10}	11.93	4.04	6.13	373.50	17.44	11.35	1.76
T_{11}	13.44	4.11	6.33	361.03	18.28	10.16	1.71
T_{12}	13.07	4.33	5.00	272.11	17.17	6.84	1.25
T_{13}	14.16	4.25	6.40	432.89	16.89	13.20	2.33
T_{14}	16.01	4.90	7.00	469.43	19.28	17.66	3.78
T_{15}	12.55	4.15	4.87	233.88	16.41	8.46	1.56
T_{16}	10.64	3.03	4.83	272.03	15.72	9.69	1.75
T_{17}	13.34	3.73	5.59	343.00	15.61	9.44	2.52
T_{18}	13.44	4.17	6.48	340.00	18.39	12.95	2.20
T_{19}	12.27	3.84	4.55	219.97	17.17	8.05	1.72
T_{20}	12.37	4.03	5.95	326.09	16.56	11.37	1.75
T_{21}	13.08	4.07	6.82	332.55	19.95	11.80	2.13
T_{22}	13.09	3.31	6.53	371.50	14.22	10.56	2.10
Mean	13.07	3.99	6.20	348.45	17.54	11.29	2.07
SEm (±)	0.33	0.09	0.21	11.59	0.22	0.23	0.05
CD (p=0.05)	0.95	0.27	0.61	33.03	0.63	0.65	0.14

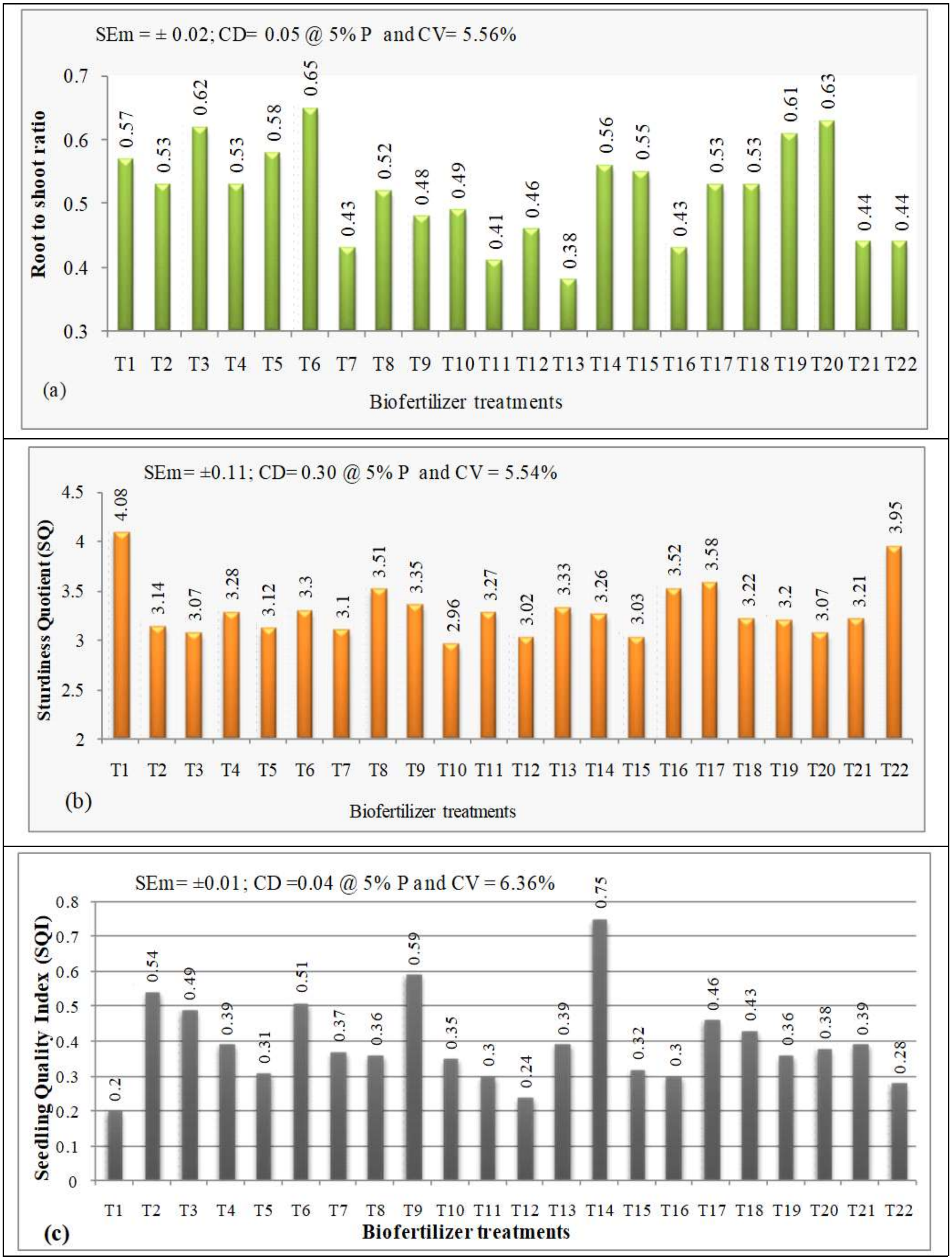

Fig. 1. Influence of biofertilizers on (a) root - shoot ratio; (b) sturdiness quotient(SQ) and (c) Seedling Quality Index (SQI) of *Soymida febrifuga* at 180 DAT

others (Fig. 1). Such synergetic influence of biofertilizer on vigour index was also reported in many forest species like *Santalum album* (Choudhury 2016), *Melia azedarach* (Rajeshkumar et al 2009) and *Azadirachta indica* (Sumana and Bagyaraj 2003). In fact, *Gmelina arborea* seedlings inoculated with AM + PSB + Banana Pseudostem sap resulted in maximum SQI than other treatments including control (Maharana et al 2018). On other hand, the root: shoot ratio is an important measure for seedling survival It relates the water absorbing area of roots to the transpiring area of shoot. A good ratio indicates a healthy plant (Jaenicke 1999). For root: shoot ratio, application of Pseudomonas @ 10 ml plant^{-1} (T_6) resulted in higher ratio of 0.65. It may be due to the fact that nitrogen deficiency in soil media may result in an increased root: shoot ratio (Harris 1992). Such finding was recorded when Pseudomonas inoculated with seedlings of *Swietenia macrophylla* at 90 DAT (Saini 2019) and seedlings of *Anthocephalus cadamba* at 150 DAT (Chauhan 2020).

The lowest sturdiness quotient (2.96), which is a good indicator for sturdiness in the field performance, was achieved by seedlings exposed to combination treatment of Azotobacter @ 5 ml plant^{-1}+ PSB 5 ml plant^{-1} (T_{10}), which was followed by other treatments *viz.,* T_{12}, T_{15}, T_3, T_{20}, T_7, T_5, T_2, T_{19}, T_{21}, T_{18} and T_{14}(Fig. 1). Shreedhar and Mohan (2016) reported that the biofertilizer inoculated seedlings showed better sturdiness quotient value as compared to uninoculated seedlings. Maharana et al (2018) reported the lowest SQ of 11.75 in treatment inoculated with Azospirillum + Novel in *Gmelina arborea* seedlings; whereas, Mishra and Channabasappa (2016) recorded lower sturdiness quotient in teak for treatment of VAM + Azospirillum. The study shows that application of biofertilizer not only influence the seedling growth, but also vigour that help the seedlings to perform better in the field.

CONCLUSION

Study shows that there was an influence of biofertilizers in its single and combination treatments on seedling growth and vigour of Indian Redwood. Among several biofertilizer treatments, seedlings of Indian Redwood treated with Azospirillum @ 5ml plant^{-1}+ PSB @ 5ml/plant was found to be superior with respect to seedling height, collar diameter, leaf area, fresh and dry biomass of plant along with seedling quality index (SQI). Hence, this combination may be used for raising quality seedlings of Indian Redwood in the nursery for timely transplanting or field planting.

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Received 14 April, 2023; Accepted 10 September, 2023