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Studies on root distribution pattern and nodulation of some important nitrogen fixing tree species

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ABSTRACT

An investigation was carried out to study the root distribution pattern and nodulation of a one year old established plantation consisting of five important nitrogen fixing tree species (*Acacia mangium, Albizia lebbek, Leucaena diversifolia, Leucaena leucocephala* and *Gliricidia sepium*) at Khurda (Orissa) under the Sloping Agricultural Land Technology (SALT) Project. Five plants of each tree species were taken as a unit for investigation following Randomized Block Design (RBD) with five replications. Among all the tree species studied, *Gliricidia sepium* seedlings excelled in root growth and nodule development indicating its suitability for wasteland management programme. However, *Leucaena leucocephala* proved its merit for agroforestry system because of its relatively more vertical root penetration and least horizontal root spread. Taking both the root architecture and nodulation pattern into account the tree species studied in respect of their suitability for crop based farming system could be placed in the following order : *Leucaena leucocephala, Gliricidia sepium, Albizia lebbek, Leucaena diversifolia* and *Acacia mangium.*

Key Words : Nitrogen fixing tree species, root architecture, nodulation

Soil, being one of the important natural resources, is facing over exploitation due to high cropping intensity, introduction of high yielding crop varieties and indiscriminate and imbalanced use of chemical fertilizers and other agricultural chemicals. This in fact has become a subject of great concern and, therefore, needs management and conservation.

Nitrogen fixing tree species have been in the picture over the years due to their ability to fix atmospheric nitrogen through their root nodules. Nodulation is the dominating mechanism of biological nitrogen fixation which utilizes the renewable source of elemental nitrogen without disturbing the fossil fuel, checks contamination of ground water, nitrogen loss through leaching and denitrification (Hiechel, 1987) and serves as a fixed source of nitrogen for both plant and soil (Vance, 1991). Role of nodulating plants in improving soil fertility has been documented by various researchers (Cruz and Valdes, 1990; Galciana, *et al*, 1996). Since the feeder roots of most of the agricultural crops including that of vegetables and flowers are mostly confined to the surface layer of soil (within 30 cm.), it is necessary that the nitrogen fixing tree species, to be suitably fitted into crop based farming systems, should have relatively deeper root systems. Whereas, for waste land management and soil conservation the nitrogen fixing tree species should have massive root system. Hence, it is very much necessary to have a precise idea on their root architecture when nitrogen fixing tree species are employed either for the management of wasteland or in the crop based farming systems. It is preferred to have species with relatively deeper root systems which will be able to pump nutrients from deeper soil layers to which lateral roots scavenge horizontally (Garrity, 1995) and agricultural crops (surface feeders) will utilize. Further, the extensive network of roots with its high surface area, root hair density and mucigel secretions also influence the structure, porosity and moisture retention capacity of soil (Nair, 1990) and bind it against erosion. Thus, study of tree root systems is equally vital for the purposes of wasteland management; afforestation of degraded forests, soil conservation, establishment of shelterbelts, energy plantations, etc.

However, there is little information available on root architecture and nodulation of nitrogen fixing tree species. Keeping the aforesaid requirements in view, the present study was undertaken to generate specific information on the root architecture and nodulation of five important nitrogen fixing tree species of coastal Orissa.

MATERIALS AND METHODS

The investigation was carried out on a small hill at Khurda (Orissa) under the Sloping Agricultural Land Technlogy (SALT) Project involving an one year old established plantation consisting of five important nitrogen fixing tree species (*Acacia mangium*, *Albizia lebbek*, *Gliricidia sepium*, *Leucaena diversifolia* and *Leucaena leucocephala*). The plants were spaced at 1.0 m both way from line to line and plant to plant. The site ($19^0$30'N latitude, 86^0 E longitude and 35 m above mean sea level) chosen for investigation was having slope ranging between 35 and 40 per cent and soil with 83% lateritic pebble content and pH 6.1. The atmospheric temperature of the place during the period of investigation was ranged between 13^0C and to 38^0C and rainfall received during the period under reference was 1450 mm.

The root systems of sample plants were carefully excavated by auger method ensuring minimum breakage. Further, these were washed thoroughly and completely exposed. However, their dimensional structure as well as finer roots and nodules present on them kept undisturbed. Each root system, so obtained after washing, was spread on a blotting paper to get its original morphology. Root and shoot were separated, their fresh biomass were recorded. All observations related to root architecture, shoot growth and nodulation were recorded on five of the randomly selected plants from each treatment / replication and thus, the mean value for each trait was obtained taking into the average of five replications.

Dry biomass of both root and shoot were obtained after drying the plant (root and shoot separately) samples in hot air oven at 65 ± 5^0C to constant weight. Ratio of root and shoot were calculated based on length, lateral spread and dry biomass for each species. In order to establish comparative root architectural pattern, root system of one healthy representative plant was arranged on a big graph paper. Then, border line was drawn for each rootlet accordingly complete rough out line was developed. This was photocopied on an A4 sheet and traced further on a transparent paper and fed into computer through digital camera.

The nodules present on primary, secondary and tertiary roots were counted separately and named as number of nodules on primary, secondary and tertiary roots, respectively. The nodule biomass per seedling was presented on dry weight basis.

RESULTS AND DISCUSSION

Root growth and development

The results revealed that among the five species studied, the vertical penetration of roots (rooting depth) was relatively more in case of *Gliricidia sepium* (33.5 cm.) and minimum in case of *Albizia lebbek* (18.1cm). The latter however recorded the maximum lateral root spread (11.2 cm) which was relatively much less in case of *Leucaena leucocephala* (7.3 cm). *Gliricidia sepium* recorded maximum length of primary roots (41.9 cm.) and minimum length of both, secondary (15.5 cm.) and tertiary roots (5.7 cm). The distribution of root system might have been influenced by genetic character (Huck, 1983) and localized soil conditions. Further, the root architecture of a given tree species also could have been influenced by the availability of water and nutrients (Taylor, *et al*., 1972).

The angle between primary and secondary roots was found to be relatively more under *Leucaena diversifolia* (86^0) and *Acacia mangium* (86^0) and minimum under *Gliricidia sepium* (61.7^0). However, the angle between secondary and tertiary roots was maximum in case of *Gliricidia sepium* (79.0^0C) minimum in case of *Leucaena leucocephala* (47.2^0C). Root branch angles are the key components of root system architecture; lateral roots diverge from parent roots at wider angle, which influence chances of their entry to unexploited horizons (Fitter, 1991). In general, the primary roots tend to be positively geotropic, secondary diageotropics and further branches to be ageotropic (Fitter, 1987). The variation in root angles observed in the present study may be attributed to genetic factors and internal anatomy (Charlton, 1983).

Maximum number of secondary roots was recorded in *Albizia lebbek* (88.6) and tertiary roots was recorded in *Acacia mangium* (130.0). *Gliricidia sepium*, however, recorded minimum number of secondary (18.6) and tertiary roots (32.0). This may be due to various functional attributes and genetic behaviour (Kostler *et al*., 1968) or physical conditions of soil (Pomerleau and Lotie, 1962).

Shoot growth and development

Relatively higher values in respect of plant height (79.50 cm), shoot dry biomass (13.79g) and also root dry biomass (9.91g) were recorded in *Gliricidia sepium.* The minimum values in plant height (43.68 cm) was recorded in *Albizia lebbek,* whereas, that of shoot dry biomass (3.47g) and root dry biomass (2.41g) were recorded in *Leucaena leucocephala.* Higher nodulation in *Gliricidia sepium* might have contributed to better shoot growth in this species (Schwintzer and Lancelle, 1983). The plant spread was found to be relatively more in case of *Leucaena diversifolia* (15.4 cm) and minimum in *Acacia mangium* (10.98 cm).

The ratio between root depth and plant height was maximum in *Albizia lebbek* (0.48) and minimum in *Acacia mamgium* (0.29). The values relating to ratio between root and shoot spread and root and shoot dry biomass were highest in case of *Albizia lebbek* (0.86 and 1.15, respectively).

Nodulation pattern

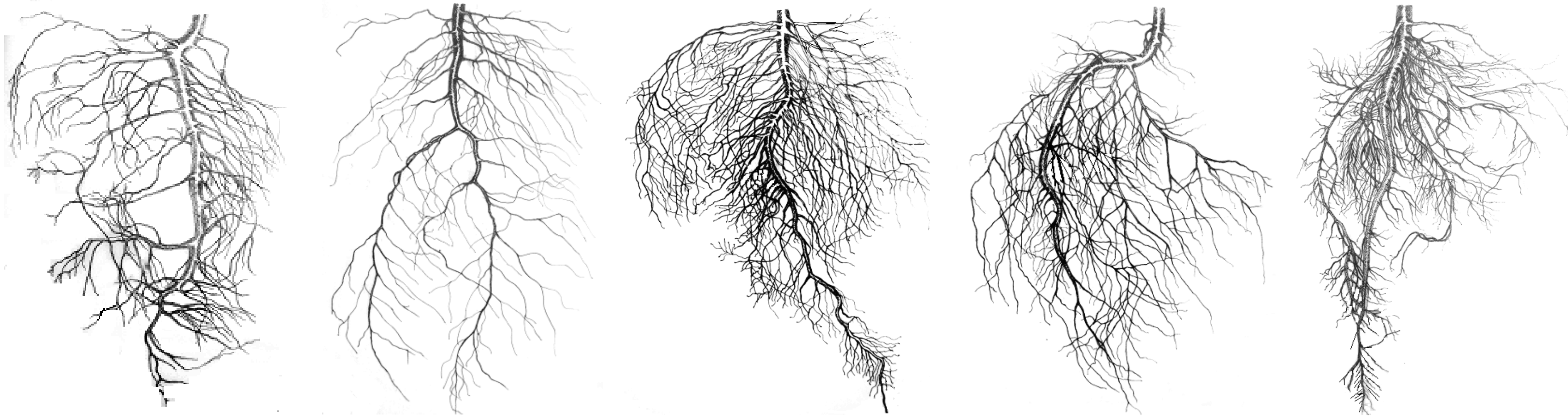
Relatively more number of nodules on primary root was observed in *Albizia lebbek* (10.6) and minimum in *Acacia mangium* (3.4). *Gliricidia sepium* exhibited maximum number of nodules on both the secondary roots (44.6) and tertiary roots

Table 1 : Growth, nodulation and root distribution pattern of five nitrogen fixing tree species

Nitrogen fixing tree species	Rooting depth (cm)	Lateral root spread (cm)	Length of primary root (cm)	Length of secondary roots (cm)	Length of tertiary roots (cm)	Angle between primary and secondary roots (degree)	Angle between secondary and tertiary roots (degree)	Number of secondary roots	Number of tertiary roots	Plant height (cm)	Plant spread (cm)
Acacia mangium	***22.0***	***8.4***	***29.7***	***19.2***	6.78	***86.0***	68.6	***27.0***	***130.0***	***77.26***	***10.98***
Albizia lebbek	18.1	11.2	20.2	16.3	10.20	76.6	78.4	88.6	94.0	43.68	12.80
Gliricidia sepium	33.5	10.8	41.9	15.5	5.66	61.7	79.0	18.6	32.0	79.50	13.94
L. diversifolia	29.0	10.9	40.4	18.3	9.08	86.0	78.5	48.0	100.0	60.22	15.40
L. leucocephala	27.7	7.3	33.0	17.2	6.26	79.4	47.2	34.0	102.0	60.32	11.52
C.D.$_{(0.05)}$	**1.09**	**1.14**	**0.65**	**0.42**	**0.18**	**10.18**	**1.55**	**1.79**	**2.29**	**1.84**	**0.44**

Nitrogen fixing tree species	Root dry biomass (gm)	Shoot dry biomass (gm)	Root depth plant height ratio	Root spread shoot spread ratio	Root shoot biomass ratio on dry weight basis	Number of nodules on primary root	Number of nodules on secondary roots	Number of nodules on tertiary roots	Total number of nodules per plant	Biomass of nodules per plant on dry wt. basis (g.)
Acacia mangium	6.61	8.60	0.29	0.76	0.82	3.4	12.8	20.6	36.8	0.30
Albizia lebbek	8.17	7.49	0.42	0.86	1.15	10.6	41.4	34.6	86.6	0.36
Gliricidia sepium	9.91	13.79	0.42	0.81	0.81	4.0	44.6	69.0	117.6	0.15
L. diversifolia	2.56	4.47	0.48	0.70	0.66	6.0	33.6	42.2	81.8	0.05
L. leucocephala	2.41	3.47	0.37	0.63	0.68	3.8	32.0	48.0	83.6	0.03
C.D.$_{(0.05)}$	**0.47**	**0.09**	**0.01**	**0.02**	**0.03**	**0.5**	**1.62**	**1.55**	**2.19**	**0.01**

Fig. 1 : Root architectural pattern of five nitrogen fixing tree species



Albizia lebbek **Leucaena leucocephala** **Acacia mangium** **Leucaena diversifolia** **Gliricidia sepium**

Fig. 2 : Nodulation pattern of five nitrogen fixing tree species

Albizia lebbek **Leucaena leucocephala** **Acacia mangium** **Leucaena diversifolia** **Gliricidia sepium**

Fig 3 : Nodule development in the nitrogen fixing tree species under study

Albizia Lebbek | **Acacia mangium** | **Leucaena diversifolia** | **Leucaena leucocephala** | **Gliricidia sepium**

(69.0) and also on the total root system (117.6). The corresponding minimum values were recorded in *Acacia mangium* (Table 1). Biomass of nodules on dry weight basis per plant also varied significantly among the species studied. Relatively higher value was observed in *Albizia lebbek* (0.36 g) and lowest in *Leucaena leucocephala* (0.03 g). Variation in nodulation pattern observed among the species may be attributed to conjoint contribution of genetic behaviour and environment (Pokhriyal *et al*., 1996).

Nodulation per rootlet found maximum in the primary followed by lateral roots. Similar result was observed by Kar (1999) in *Acacia catechu, Albizia chinensis* and *Alnus nitida*. Lesser nodulation per rootlet than its parent root might be due to its less surface area, infection sites and enzymatic activities. Nevertheless, the greater rate of turn over of finer root than coarse one may also explain the present findings (Fahey *et al*., 1988).

Among the five nitrogen fixing tree species studied, *Gliricidia sepium* seedlings excelled in root growth and nodule development indicating its suitability for wasteland management programme. However, *Leucaena leucocephala* proved its merit for agroforestry system for its relatively better vertical root penetration and least horizontal root spread. Taking both root architecture and nodulation pattern into account, the tree species studied in respect of their suitability for crop based farming system could be placed in the following order: *Leucaena leucocephala*, *Gliricidia sepium*, *Albizia lebbek*, *Leucaena diversifolia* and *Acacia mangium*.

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