Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 2089-2093
Received: 15-05-2018
Accepted: 20-06-2018

Naresh Kumar
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

Anil Kumar
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

Ashok Shukla
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

AR Uthappa
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

Sudhir Kumar
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

Correspondence
Anil Kumar
ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India

Effect of arbuscular mycorrhizal inoculations on growth and seedling quality of four *Leucaena* species

Naresh Kumar, Anil Kumar, Ashok Shukla, AR Uthappa and Sudhir Kumar

Abstract
An experiment was conducted to study the suitability of arbuscular mycorrhizal (AM) fungi for inoculation of four *Leucaena* species, namely *L. collinsii*, *L. shannoni*, *L. diversifolia* and *L. leucocephala* for assessing their effect on growth and seedling quality index (SQI) at nursery stage. Study consisted of three mycorrhizal treatments (*Acaulospora scrobiculata*, *Rhizophagus irregularis* and *A. scrobiculata* + *R. irregularis*) and a control. Inoculation of *A. scrobiculata* significantly increased only root length, while inoculation of *R. irregularis* increased almost all studied parameters. Among tested *Leucaena* species, *L. collinsii* and *L. leucocephala* showed better response towards inoculated fungi. Plants inoculated with *R. irregularis* showed higher mycorrhizal dependency (20.75%) than other inoculants. *L. leucocephala* recorded maximum mycorrhizal dependency (MD) followed by *L. collinsii*. *R. irregularis* increased SQI significantly, irrespective of tested *Leucaena* species. Thus, the results suggested that the seeds of two *Leucaena* species viz., *L. leucocephala* and *L. collinsii* may be inoculated with *R. irregularis* to obtain more vigorous seedlings.

Keywords: arbuscular mycorrhizal inoculation, *L. collinsii*, *L. shannoni*, *L. diversifolia* and *L. leucocephala*

Introduction
Arbuscular mycorrhizal (AM) fungi are obligate symbiont, occurring in nearly all natural and agricultural soils and colonize roots of most of the plant species (Smith and Read, 1997; Oseni *et al.*, 2010) [30, 23]. The primary effect of AM fungi on the host plant is an increase in nutrients uptake and plant growth (Kumar *et al.*, 2017) [17]. Plants with mycorrhiza are potentially more effective in nutrient and water uptake (Shukla *et al.*, 2010) [29] and less susceptible to diseases (Shukla *et al.*, 2014) [27]. They can increase uptake of nutrients especially which are relatively immobile in the soil such as phosphorus (P) and consequently increase the plant biomass and growth (Ryan and Angus, 2003; Jha *et al.*, 2014) [26, 24].

Genus *Leucaena*, member of family Leguminosae, consists of 22 identified species (Brewbaker, 2016) [3]. Botanical literature claims a sum of 55 species. The only valid ones appear to be *L. collinsii, L. diversifolia, L. esculenta, L. lanceolata, L. leucocephala, L. macrophylla, L. pulverulenta, L. retusa, L. shannoni* and *L. trichodes.* All these species have value for the tropics but only *L. leucocephala* (Lam.) de Wit has been exploited extensively so far (National Research Council, 1984) [21]. At ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi, 25 germplasms of *Leucaena* species (*L. collinsii*, *L. diversifolia*, *L. leucocephala* and *L. shannoni*) have been maintained (Uthappa *et al*., 2015) [33]. Positive effect of AM inoculation on growth of *L. leucocephala* has been reported by various researchers under different conditions (Manjunath *et al.*, 1989; Dixon *et al.*, 1993; Habte *et al.*, 2011; Zhan *et al.*, 2016) [19, 9, 10, 34]. Ramadhani *et al.* (2015) [25] suggested that the effectiveness of AM inoculations can be different among species or even among varieties (cultivars) of a species. According to Chakravarty *et al*. (2018) [5], different species of a genus can exhibit variable response in terms of mycorrhizal dependency (MD) i.e. the dependency of plant species on AM inoculation for dry matter production. Differences in the MD values of species of any genus could be due to the ability of plant roots to acquire P from soil (Tawaraya, 2003) [31]. Thus, selection of optimal relationship between AM inoculants and host plants could result in better growth of the plant. Hence, a study was carried out to test the response of four different *Leucaena* species to AM inoculation.

Materials and Methods

Separate experiments on effect of AM inoculations on growth and seedling quality of four species of *Leucaena*, namely *L. collinsii*, *L. shannoni*, *L. diversifolia* and *L. leucocephala* were conducted at ICAR-CAFRI, Jhansi (78°17′E, 24°11′N) under net-house conditions. The study consisted of four treatments viz., inoculations with *Acaulospora scrobiculata, Rhizophagus irregularis, A. scrobiculata* + *R. irregularis* and a control. Seven replicates were maintained for each treatment in completely randomized design. Red soil (alfisol; pH- 6.5, EC- 134 μScm^{-1}, OC- 0.27%, Olsen P- 2.5 ppm) was used as substrate, which was filled in plastic pots (4-5 kg capacity) and AM inoculum (50 g) was applied 4-5 cm below the seed as per treatments. The pots were transferred to net-house and watered as per need. Thinning of the plants was carried out 15 days after sowing, leaving one plant per pot. The seedlings were harvested after three months and observations on plant height (cm), root length (cm), collar diameter (mm), dry shoot biomass (g) plant^{-1} and dry root biomass (g) plant^{-1} were recorded. MD and SQI were calculated by using the formulae given by Plenchette *et al*. (1983) [34] and Dickson (1960) [7], respectively.

$$\textbf{Mycorrhizal dependency (\%)} = \frac{\text{M} - \text{NM}}{\text{M}} \times 100$$

$$\textbf{Seedling quality index} = \frac{\text{Total dry weight of plant (g)}}{\dfrac{\text{Plant height (cm)}}{\text{Collar diameter (mm)}} + \dfrac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}}$$

The data were analyzed statistically by using a general linear model for analysis of variance in a completely randomized design. Least significant difference ($LSD_{0.05}$) was used to compare treatment differences.

Results and Discussion

Effect of AM inoculations on growth

Among treatments, maximum plant height was recorded in *R. irregularis*, which was significantly higher than other treatments. Remaining two treatments (*A. scrobiculata* and *A. scrobiculata* + *R. irregularis*) were at par with control. Among tested *Leucaena* species, maximum plant height was recorded in *L. collinsii*, followed by *L. shannoni*, *L. diversifolia* and *L. leucocephala*. Two-way interaction between the treatments and tested species was found significant. *R. irregularis* and *A. scrobiculata* + *R. irregularis* in *L. collinsii*, and all the treatments in *L. leucocephala* significantly increased the plant height (Table 1).

Among different treatments, single inoculations of *A. scrobiculata* and *R. irregularis* significantly increased root length. Remaining treatment (*A. scrobiculata* + *R. irregularis*) was found at par with control. On the other hand, maximum root length was recorded in *L. shannoni*, followed by *L. collinsii*, *L. leucocephala* and *L. diversifolia*. Single inoculations of *A. scrobiculata* and *R. irregularis* significantly increased root length of *L. leucocephala* (Table 1).

Differences in collar diameter in different AM treatments were found non-significant. However, results showed that AM inoculations increased the diameter when compared with control. Among tested species, maximum collar diameter was recorded in *L. shannoni*, followed by *L. collinsii*, *L. diversifolia* and *L. leucocephala*. Two-way interaction was found non-significant; hence comparison could not be made (Table 1).

Effect of AM inoculations on dry biomass

Maximum shoot dry biomass was recorded in *R. irregularis*, which was significantly higher than other treatments. Remaining treatments (*A. scrobiculata* + *R. irregularis* and *A. scrobiculata*) were found statistically at par with control. Among tested species, maximum shoot dry biomass was recorded in *L. diversifolia* which was at par with *L. shannoni* and *L. collinsii*. In *L. collinsii*, two treatments (*R. irregularis* and *A. scrobiculata* + *R. irregularis*) and in *L. leucocephala*, all treatments significantly increased the dry biomass (Table 2). More or less similar result was recorded in case of root dry biomass. Single inoculation of *R. irregularis* significantly increased root biomass. Maximum root biomass was recorded in *L. shannoni*, followed by *L. collinsii* and *L. diversifolia*. Two-way interaction was statistically non-significant (Table 2). Total dry biomass was significantly increased by *R. irregularis*. Among tested species, maximum biomass was recorded in *L. shannoni*, followed by *L. collinsii*, *L. diversifolia* and *L. leucocephala*. In *L. shannoni*, *R. irregularis*; in *L. collinsii*, *R. irregularis* and *A. scrobiculata* + *R. irregularis*; and in *L. leucocephala*, all AM treatments significantly increased total biomass (Table 2).

Mycorrhizal dependency (MD) of various AM treatments ranged from 4.65 to 20.75%. Among AM fungi, maximum MD value was recorded for *R. irregularis* (20.75%), which was significantly higher than *A. scrobiculata* + *R. irregularis* (8.11%) and *A. scrobiculata* (4.65%). Among tested species, *L. leucocephala* showed maximum dependency on AM inoculation for dry matter production followed by *L. collinsii* (Table 3).

Thus, the results showed that various AM treatments significantly increased the studied parameters. Plant height was increased by 4.4 to 17.1%, root length by -6.3 to 12.0%, collar diameter by 0.8 to 7.0%, shoot biomass by 4.4 to 27.8%, root biomass by 9.1 to 28.2% and total biomass by 6.9 to 28.1%, over control. The increase in above mentioned parameters can be attributed to the increase in soil volume explored for nutrients/ water uptake by mycorrhizal plants as compared to non-mycorrhizal ones (Shukla *et al.*, 2012) [28]. Results also showed that different tested AM fungi showed variable effects. Single inoculation of *A. scrobiculata* significantly increased only one parameter (root length) while single inoculation of *R. irregularis* increased most of the studied parameters (plant height, root length, shoot and root dry biomass). Such variable effects of the fungi could be due to differences in the uptake of P and other nutrients in AM inoculated plants (Shukla *et al.*, 2012) [28]. These differences might be attributed to (1) differences among AM fungi for hyphal spread and density away from roots (Bürkert and Robson, 1994) [4], (2) ability of AM fungi to increase nutrient availability in soil through enhanced phosphatase/phytase activity (Dinkelaker and Marschner, 1992; Khalil *et al.*, 1994) [8, 15] and/or excretion of solubilizing materials such as ethylene (Ishii *et al.*, 1996) [13], flavonoides (Ishii *et al.*, 1997) [12] and growth regulating compounds (Danneberg *et al.*, 1992; Thiagarajan and Ahmad, 1994) [6, 32], and (3) ability of AM fungi to change rhizosphere soil pH (Li *et al.*, 1991) [18]. Beneficial effects of AM inoculations on growth of *L. leucocephala* have been reported by various workers (Bhagyaraj *et al.*, 1989; Manjunath *et al.*, 1989; Dixon *et al.*, 1993; Habte *et al.*, 2011; Zhan *et al.*, 2016) [2, 19, 9, 10, 34]. The seedling quality index, computed on the basis of the recorded parameters also showed that all AM treatments significantly improved the quality of the seedlings (Table 3). Maximum index value was recorded in *R. irregularis*-inoculated plants, which was found statistically at par with *A. scrobiculata* + *R. irreguaris*.

Results also showed that among tested *Leucaena* species, *L. collinsii* and *L. leucocephala* gave better response towards inoculated fungi than other two species. This could be due to different genetic make-up of tested *Leucaena* species. Variation in terms of response of cultivars and genotypes towards inoculated AM fungi has been reported in many plants (Nemec, 1978; Ibijbijen *et al*., 1996; Khalil *et al*., 1999) [22, 11, 16]. Similar results in tree species are meager. Monzon and Azcon (2001) [20] reported variation in response of three *Alnus* species (*A. cordata*, *A. glutinosa* and *A. incana*) towards AM inoculation. The MD value of *A. glutinosa* was ten times as large as that of the other two species. Adjoud *et al.* (1996) [1] also reported variation in MD values of four *Eucalyptus* species (*E. bosistoana*, *E. delegantensis*, *E. dumosa* and *E. macarthurii*). The MD values in these four species varied from 14-27%.

Thus, based on the results obtained in present study it can be concluded that the seeds of two *Leucaena* species viz., *L. leucocephala* and *L. collinsii* may be inoculated with *R. irregularis* to obtain more vigorous seedlings.

Table 1: Effect of arbuscular mycorrhizal inoculations on growth of *Leucaena* species

Treatments	*L. diversifolia*	*L. shannoni*	*L. collinsii*	*L. leucocephala*	Mean
Plant height (cm)					
A. scrobiculata (As)	67.0	77.2	77.0	58.0	69.8
R. irregularis (Ri)	80.3	83.3	84.0	59.2	76.7
As+Ri	61.7	73.7	83.0	55.2	68.4
Control	72.0	80.5	71.0	38.7	65.5
Mean	70.3	78.7	78.8	52.8	
Root length (cm)					
A. scrobiculata	33.8	42.0	32.3	33.8	35.5
R. irregularis	28.3	41.2	37.2	33.7	35.1
As+Ri	25.3	30.7	34.2	28.5	29.7
Control	29.3	36.7	35.3	25.5	31.7
Mean	29.2	37.6	34.8	30.4	
Collar diameter (mm)					
A. scrobiculata	6.65	8.93	7.31	7.42	7.58
R. irregularis	7.91	8.59	8.23	7.28	8.00
As+Ri	7.18	8.04	8.00	6.94	7.54
Control	7.76	8.23	7.51	6.41	7.48
Mean	7.37	8.45	7.76	7.01	
		LSD $_{(0.05)}$			
	Shoot length	Root length	Collar diameter		
Treatment	5.5	2.7	NS		
Species	5.5	2.7	0.54		
Interaction	11.0	5.5	NS		

Table 2: Effect of arbuscular mycorrhizal inoculations on dry biomass of *Leucaena* species

Treatments	*L. diversifolia*	*L. shannoni*	*L. collinsii*	*L. leucocephala*	Mean
Shoot dry biomass (g)					
A. scrobiculata (As)	9.95	9.69	8.64	8.01	9.07
R. irregularis (Ri)	11.89	12.43	12.40	7.73	11.11
As+Ri	9.76	9.52	11.67	7.49	9.61
Control	10.80	10.33	8.90	4.73	8.69
Mean	10.60	10.49	10.40	6.99	
Root dry biomass (g)					
A. scrobiculata	5.23	5.96	4.84	4.65	5.17
R. irregularis	5.66	6.58	6.34	5.21	5.95
As+Ri	4.55	5.49	5.51	4.69	5.06
Control	5.34	5.35	4.95	2.90	4.64
Mean	5.20	5.85	5.41	4.36	
Total dry biomass (g)/plant					
A. scrobiculata	15.18	15.65	13.47	12.66	14.24
R. irregularis	17.55	19.01	18.73	12.94	17.06
As+Ri	14.31	15.01	17.18	12.18	14.67
Control	16.14	15.68	13.85	7.63	13.32
Mean	15.79	16.34	15.81	11.35	
		LSD $_{(0.05)}$			
	Shoot dry biomass	Root dry biomass	Total dry biomass		
Treatment	1.14	0.61	1.45		
Species	1.14	0.61	1.45		
Interaction	2.28	NS	2.89		

Table 3: Effect of arbuscular mycorrhizal inoculations on seedling quality index (SQI) and mycorrhizal dependency (MD) of *Leucaena* species

Treatments	***L. diversifolia***	***L. shannoni***	***L. collinsii***	***L. leucocephala***	**Mean**
			SQI		
A. scrobiculata (As)	1.279	1.516	1.093	1.346	1.309
R. irregularis (Ri)	1.405	1.642	1.536	1.357	1.485
As+Ri	1.331	1.384	1.385	1.251	1.338
Control	1.417	1.371	1.225	1.015	1.257
Mean	1.358	1.478	1.310	1.242	
			MD (%)		
A. scrobiculata	-11.98	-2.70	-5.24	38.51	4.65
R. irregularis	1.69	16.18	25.25	39.87	20.75
As+Ri	-14.63	-7.93	18.49	36.50	8.11
Mean	-8.31	1.85	12.84	38.29	
	LSD $_{(0.05)}$				
	SQI	MD			
Treatment	0.145	10.01			
Species	0.145	10.01			
Interaction	NS	NS			

References

1. Adjoud D, Plenchette C, Hallihargas R, Lapeyrie F. Response of 11 *Eucalyptus* species to inoculation with three arbuscular mycorrhizal fungi. Mycorrhiza. 1996; 6:129-135.
2. Bhagyaraj DJ, Byra Reddy MS, Nalini PA. Selection of an efficient inoculant VA mycorrhizal fungus for *Leucaena.* Forest Ecology and Management. 1989; 27: 81-85.
3. Brewbaker JL. Breeding *Leucaena*: Tropical multipurpose tree. Plant Breeding Review. 2016; 40:43-121.
4. Bürkert B, Robson A. Zn uptake in subterranean clover (*Trifolium subterraneum* L.) by three vesicular – arbuscular mycorrhizal fungi in a root free sandy soil. Soil Biology and Biochemistry. 1994; 26:1117-1124.
5. Chakravarty N, Shukla A, Kumar A, Kumar S. Response of three popular varieties of wheat to arbuscular mycorrhizae grown in two common soil types of central India. Indian Journal of Agroforestry. 2018; 20(1):85-90.
6. Danneberg G, Latus C, Zimmer W, Hundeshagen B, Schneider–Poetsch HJ, Bothe H. Influence of vesicular – arbuscular mycorrhiza on phytohormone balances in maize (*Zea mays* L.). Journal of Plant Physiology. 1992; 141:33-39.
7. Dickson A, Leaf AL, Hosner JF. Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle. 1960; 36:10-13.
8. Dinkelaker B, Marschner H. *In vivo* demonstration of acid phosphatase activity in the rhizosphere of soil-grown plants. Plant and Soil. 1992; 144:199-205.
9. Dixon RK, Rao MV, Garg VK. Water relations and gas exchange of mycorrhizal *Leucaena leucocephala* seedlings. Journal of Tropical Forest Science. 1993; 6(4):542-552.
10. Habte M, Diarra G, Scowcroft PG. Post-transplant reactions of mycorrhizal and mycorrhiza-free seedlings of *Leucaena leucocephala* to pH changes in an Oxisol and Ultisol of Hawaii. Botany. 2011; 89:275-283.
11. Ibijbijen J, Urquiaga A, Ismaili M, Alves BJR, Boddey RM. Effect of arbuscular mycorrhizal fungi on growth, mineral nutrition and nitrogen fixation of three varieties of common beans (*Phaseolus vulgaris*). New Phytologist. 1996; 134(2):353-360.
12. Ishii T, Narutaki A, Sawada K, Aikawa J, Matsumoto I, Kadoya K. Growth stimulatory substances for vesicular – arbuscular mycorrhizal fungi in Bahia grass (*Paspalum notatum* Flügge) roots. In: Plant nutrition for sustainable food production and environment. (eds. T Ando, K Fujita, T, Mae, H Matsumoto, S Mori and J Sekiya). Kluwer, Dordrecht, The Netherlands, 1997, 733-736.
13. Ishii T, Shrestha Y, Matsumoto I, Kadoya K. Effects of ethylene on growth of vesicular – arbuscular mycorrhizal fungi and on the mycorrhizal formation of trifoliate orange roots. Journal of the Japanese Society of Horticultural Science. 1996; 65:525-529.
14. Jha A, Kamalvanshi M, Kumar A, Chakravarty N, Shukla A, Dhyani SK. The effects of arbuscular mycorrhizal inoculations and cotyledon removal on early seedling growth of *Pongamia pinnata*. Turkish Journal of Botany. 2014; 38:526-535.
15. Khalil S, Loynachan TE, Tabatabai MA. Mycorrhizal dependency and nutrient uptake by improved and unimproved corn and soybean cultivars. Agronomy Journal. 1994; 86:949-958.
16. Khalil S, Loynachan TE, Tabatabai MA. Plant determinants of mycorrhizal dependency in soybean. Agronomy Journal. 1999; 91(1):135-141.
17. Kumar N, Kumar A, Shukla A, Kumar S, Uthappa AR, Chaturvedi OP. Effect of arbuscular mycorrhiza fungi (AMF) on early seedling growth of some multipurpose tree species. International Journal of Current Microbiology and Applied Science. 2017; 6:3885-3892.
18. Li XL, Marschner H, George E. Phosphorus depletion and pH decrease at the root-soil and hyphae soil interfaces of VA mycorrhizal while clover fertilized with ammonium. New Phytologist; 1991; 119:397-404.
19. Manjunath A, Hue NV, Habte M. Response of *Leucaena leucocephala* to vesicular-arbuscular mycorrhizal colonization and rock phosphate fertilization in an Oxisol. Plant and Soil. 1989; 114:127-133.
20. Monzon A, Azcon R. Growth responses and N and P use efficiency of three *Alnus* species as affected by arbuscular-mycorrhizal colonization. Plant Growth Regulation. 2001; 35:97-104.
21. National Research Council. *Leucaena*: Promising Forage and Tree Crop for the Tropics (2nd Edition). National Academy Press, Washington, D.C, 1984.
22. Nemec S. Response of six citrus rootstocks to three species of *Glomus*, a mycorrhizal fungus. Proceedings of the Florida State Horticultural Society. 1978; 91:10-14.
23. Oseni TO, Shongwe NS, Masarirambi MT. Effect of arbuscular mycorrhiza (AM) inoculation on the performance of tomato nursery seedlings in vermiculite.

International Journal of Agriculture & Biology. 2010; 12:789-79.
24. Plenchette C, Fortin JA, Furlan V. Growth responses of several plant species to mycorrhizae in a soil of moderate P fertility. I. Mycorrhizal dependency under field conditions. Plant and Soil. 1983; 70:199-209.
25. Ramadhani R, Damanhuri, Basuki N. A study of mycorrhizal inoculation on some genotypes of wheat (*Triticum aestivum* L.). IOSR Journal of Agriculture and Veterinary Science. 2015; 8:42-49.
26. Ryan MH, Angus JF. Arbuscular mycorrhizae in wheat and field pea crops on a low P soil: increased Zn-uptake but no increase in P uptake or yield. Plant and Soil. 2003; 250:225-239.
27. Shukla A, Dehariya K, Vyas D, Jha A. Interactions between arbuscular mycorrhizae and *Fusarium oxysporum* f. sp. *ciceris*: Effects on fungal development, seedling growth and wilt disease suppression in *Cicer arietinum* L. Archives of Phytopathology and Plant Protection. 2014; 48:240-252.
28. Shukla A, Kumar A, Jha A, Ajit, Rao DVKN. Phosphorus threshold for arbuscular mycorrhizal colonization of crops and tree seedlings. Biology and Fertility of Soils. 2012; 48:109-116.
29. Shukla A, Kumar A, Jha A, Tripathi VD. Effect of soil moisture on growth and arbuscular mycorrhizal colonization of crops and tree seedlings in alfisol. Indian Phytopathology. 2010; 63:411-417.
30. Smith SE, Read DJ. Vesicular-Arbuscular Mycorrhizas. In: Mycorrhizae (eds. SE Smith and DJ Read). Academic Press, London, 1997.
31. Tawaraya K. Arbuscular mycorrhizal dependency of different plant species and cultivars. Soil Science and Plant Nutrition. 2003; 49(5):655-666.
32. Thiagarajan TR, Ahmad MH. Phosphatase activity and cytokinin content in cowpeas (*Vigna unguiculata*) inoculated with a vesicular arbuscular mycorrhizal fungus. Biology and Fertility of Soils. 1994; 17:51-56.
33. Uthappa AR, Chavan SB, Gupta VK, Dhyani SK, Handa AK, Vimala Devi S *et al*. Genetic evaluation of *Leucaena* genotypes in Bundelkhand region of Central India. Extended abstract in 23rd International Grassland Congress held at New Delhi during 20-24th November, 2015, 00-00.
34. Zhan F, He Y, Yue X, Li Q, Xia Y. Effect of mycorrhizal inoculation on plant growth, nutrients and heavy metals uptake by *Leucaena leucocephala*. Fresenius Environmental Bulletin. 2016; 2:1760-1767.