Journal of Forestry Research (2009) 20(1):45–48
DOI 10.1007/s11676-009-0007-1

RESEARCH PAPER

Seedling response of three agroforestry tree species to phosphorous fertilizer application in Bangladesh: growth and nodulation capabilities

Mohammad Belal Uddin[1,2], Sharif Ahmed Mukul[1,*], Mohammed Abu Sayed Arfin Khan[1], Mohammed Kamal Hossain[3]

[1]*Dep. of For and Env Sci., School of Agriculture and Mineral Sciences, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh*
[2]*Department of Biogeography, University of Bayreuth, D-95447 Bayreuth, Germany*
[3]*Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh*

Abstract: Triple Super Phosphate, TSP fertilizer, was applied @ 80 kg·ha^{-1} as the source of phosphorous on six months old polybag seedlings of *Albizia chinensis, Albizia saman* and *Pongamia pinnta* in nursery beds in Bangladesh. The effects of P-fertilizer on seedling growth and nodulation were compared to that of seedlings grown in unfertilized soil or in control at different harvesting intervals. The study revealed that, seedling growth was enhanced significantly with the application of P-fertilizer. The growth was found more pronounced in cases of *A. saman* and *P. pinnata*, whereas it was not noticeable and showed depressed growth in case of *A. chinensis*. The study also suggests that nodulation in terms of nodule number and size was also increased significantly with P-fertilization except in case of *P. pinnata*, where higher harvesting intervals lowered the nodulation performance of that species

Keywords: *Albizia chinensis*; *Albizia saman*; *Pongamia pinnta*; growth parameters; nodulation performance; TSP fertilizer

Introduction

Low soil fertility is one of the greatest biophysical constraints to agroforestry production (Ajayi 2007) and the application of commercial fertilizers undoubtedly accelerates the seedling growth of most agroforestry tree species throughout the globe (Walker et al. 1993; Sanginanga et al. 1989). These also enhanced the nodulation and nitrogen fixing capabilities of many legume species traditionally used as agroforestry tree species (MacDicken 1994). The rapidly increasing global population resulted in higher demand for plant products that have stimulated fertilizer production, especially nitrogen and phosphorous containing fertilizers (Stamford et al. 1997). Phosphorus is probably the most common limiting nutrient in many tropical areas where it plays an essential role in plant nutrition and energy transference (Ackerson 1985). Again, leguminous agroforestry species requires relatively higher amount of phosphorus than that of any other plant, which markedly contributes to their nodulation and nitrogen fixing capabilities.

Albizia chinensis (Osbeck) Merr.; *Albizia saman* (Jacq.) Merr. and *Pongamia pinnata* (L.) Pierre, are three medium to large sized agroforestry tree components of Bangladesh belonging to family Fabaceae (Bisby et al. 2007; Das and Alam 2001). These species are commonly found in the rural farm, homesteads and road side plantation of the country and have been extensively used as a potentially important agroforestry tree species. Nevertheless, in last decades these leguminous tree species have gained wider recognition of rural tree growers because of their promising economic importance particularly in tropical regions (NAS 1979). Although several studies so far have been done to assess the effects of inorganic fertilizer on growth and nodulation capabilities of various agroforestry species (Uddin et al. 2007; Hossain and Khan 2003; Hossain et al. 2001; Bhuiyan et al. 2000; Aryal et al. 2000; Hossain et al. 1996; Fakir et al. 1988; Prasad and Ram 1986), no detailed experiments have been conducted on these three potentially important agroforestry species, particularly in respect to application of P-fertilizer. Our study therefore aimed to understand the effects of P-fertilizer on growth and nodulation capabilities of the seedlings of these three commonly used agroforestry tree species of the country.

Material and methods

Experiment environment

The entire experiment was performed in nursery condition in the polybag of 6″ x 4″ size. The climate of the area is tropical in general with mean monthly maximum temperature of 29.75°C and a monthly minimum of 21.14°C. The highest temperature usually occurs on May as 32.6°C and minimum in January as 14.1°C (Ahmed 1990). The area is subjected to an average annual rainfall of 2500–3000 mm which mostly takes place between June

Received: 2008-05-05; Accepted: 2008-07-07

The online version is available at http://www.springerlink.com
Biography: Mohammad Belal Uddin (1976-), male, Assistant Professor in Department of Forestry and Environmental Science, School of Agriculture and Mineral Sciences, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh (E-mail: romelahmed76@yahoo.com)
[*]Corresponding author: Sharif Ahmed Mukul
Email: sharif_a_mukul@yahoo.com
Responsible editor: Hu Yanbo

and September.

The receptor species

Six-month-old healthy seedlings of selected agroforestry species, i.e., *A. chinensis, A. saman* and *P. pinnata*, were used as receptor species for the experiment. Healthy and disease-free seedlings were collected from a recognized local nursery maintaining their phenotypical uniformity as far as possible.

The control and treatments

TSP fertilizer [$Ca(H_2PO_4)_2$; containing 48% of P_2O_5] was applied as treatment at each polybag (@ 80 kg·ha^{-1}). No TSP fertilizer was used as the controls. Fertilizer was applied immediately after collection and arrangements of the seedlings in case of treatments. Polybags was filled with soil of similar composition containing garden soil and farmyard manure in a 3:1 proportion. The average pH of the soil was 5.5 with texture of loam to sandy clay loam (Aryal et al. 1999). The following control (C) and treatments (T) were used:

C_{20}- Seedlings of unfertilized plants harvested after 20 days
C_{40}- Seedlings of unfertilized plants harvested after 40 days
C_{60}- Seedlings of unfertilized plants harvested after 60 days
C_{80} - Seedlings of unfertilized plants harvested after 80 days
T_{20}- Seedlings of fertilized plants harvested after 20 days
T_{40}- Seedlings of fertilized plants harvested after 40 days
T_{60}- Seedlings of fertilized plants harvested after 60 days
T_{80} - Seedlings of fertilized plants harvested after 80 days

Experiment design and data recording

There were altogether eight treatments (i.e., four controls and four treatments) with three replicates for each species. Twenty-four seedlings of each species were collected. In total there were 72 polybag seedlings arranged in four groups- 4 control and 4 treatments of each three receptor species. Groups of each species were arranged in such a manner so that plants can be harvested at every 20-day intervals up to 80 days with almost the entire root system in-tact. Collar diameter, root length, root diameter, shoot length, leaf number, nodule number and nodule size of corresponding seedlings were recorded at each 20-day interval after every harvesting.

Care, maintenance and precautions

The seedlings were kept under nursery shade to prevent strong sunlight and heavy rainfall. Proper care, maintenance and precaution were followed during the whole study period. During applying fertilizers care was taken thus they were not superficially applied on the top of the polybags. Watering was done everyday morning and weeding was done in every third day.

Results

Shoot length

The shoot lengths of *A. saman* were significantly increased with the increases of harvest interval in both control and treatments, in case of *P. pinnata* where it was significant in control but not in treatment. The highest (57.67 cm) shoot increment was recorded in *A. saman* at T_{80} treatment (Table 1).

Root lengths

Root lengths were found to be significantly affected by harvesting intervals both in treatment and control. *A. chinensis* was significantly increased in both control and treatments with the increases of harvesting intervals, and the lowest root length (13.83 cm) was found at T_{20} treatment. Pronounced increases in root lengths were found in *P. pinnata* in treatments and the largest root length (45.67 cm) was observed at T_{80} treatment (Table 1).

Collar diameter

It was evident that, in most cases, the collar dia. of the species was increased with the increases of harvest interval both in control and treatment and the rate of increment was higher in treatment than in control. The increment in *P. pinnata* was more pronounced in control than that of treatment and the highest observation (8.27 mm) was recorded at C_{80}. The lowest (2.50 mm) increment was found in *A. chinensis* at treatment T_{20}.

Root diameter

In *A. saman* there was no significant variation in root dia. (cm) in control. In *A. auriculiformis* it has showed significant increment both in control and treatment in first two harvesting intervals (i.e., 20 and 40 days) but in last two harvesting intervals (i.e., 60 and 80 days) it has showed decline in root dia. in both control and treatments. In *A. chinensis* it was significantly varied in treatment but not in control. The highest (8.33 cm) root dia. was recorded in *P. pinnata* at treatment T_{40} and the lowest (4.17 cm) in *A. chinensis* at control C_{20} (Table 1).

Number of leaves

The numbers of leaves of the selected agroforestry tree seedlings in nursery conditions were given in Table 2. It was observed in most cases that, the numbers of leaves were increased significantly with the increases of harvest interval in both control and treatment. The highest numbers of leaves (18.00) were counted in *P. pinnata* at treatment T_{40} whereas the lowest (8.00) was in *A. chinensis* at control C_{20}.

Nodule number

It was observed that, nodule numbers were varied significantly with the increases of harvest intervals. In *A. saman* the nodule numbers were increased significantly in treatment but not in control. In *A. chinensis* there was no significant variation in nodules in treatments. In *P. pinnata* the nodule numbers were reduced significantly in both control and treatments with the increases of harvest intervals. The highest numbers (63.33) of nodules were recorded in *A. saman* at treatment T_{80} while the lowest (0.00) was found in *P. pinnata* in treatment T_{80} (Table 2).

Nodule size

It was evident from the data that, in most cases nodule sizes were significantly increased with the increases of harvest interval in both control and treatments. In case of *A. chinensis* nodule sizes were varied significantly in treatment but not in control. In *P.*

pinnata although nodule sizes were increased in control with the increases of harvesting interval but in treatment it has showed depressed growth. The biggest nodules (4.90 mm) were found in *A. saman* at treatment T_{40} while the smallest (0.00 mm) was observed in *P. pinnata* at treatment T_{80}.

Table 1. Shoot length, root length, collar diameter and root diameter of *A. chinensis, A. saman* and *P. pinnata* at different harvest intervals (days) in control and treatments (fertilized soil) under nursery conditions

Species	Shoot length (cm)							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	27.00b	25.67b	47.00a	33.00b	45.33a	55.33a	37.50ab	59.33a
A. saman	34.33a	34.83c	48.67a	45.67bc	53.33a	59.00ab	52.67a	66.33a
P. pinnata	43.67bc	37.67a	50.00ab	39.33a	60.33a	44.33a	65.33a	45.00a
Species	Root length (cm)							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	18.33a	13.83a	22.33a	19.00a	24.33a	23.67a	27.67a	25.00a
A. saman	19.33a	14.50b	20.67a	17.33b	36.00a	40.33a	26.67a	27.67ab
P. pinnata	35.6a	19.00b	30.33a	41.33a	31.33a	40.67a	28.33a	45.67a
Species	Collar diameter (mm)							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	2.52b	2.50b	4.75a	3.45b	4.48a	4.90a	3.60ab	6.08a
A. saman	4.60a	4.53b	5.72a	5.02b	6.12a	7.48a	6.60a	7.92a
P. pinnata	5.93a	6.37a	7.80a	8.05a	7.71ab	7.42a	8.27a	7.53a
Species	Root diameter (cm)							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	4.17a	5.67ab	5.67a	5.83ab	4.33a	4.50b	5.00a	6.67a
A. saman	6.00a	6.83a	5.67a	5.50a	5.67a	6.50a	6.00a	5.50a
P. pinnata	5.83a	6.50b	7.50a	8.33a	7.00a	5.50b	5.83a	5.50b

Notes: *Values in the columns followed by the same letter (s) are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test (DMRT)

Table 2. Number of leaves, nodule number and nodule size (mm) of *A. chinensis, A. saman* and *P. pinnata* at different harvest intervals (days) in control and treatments (fertilized soil) under nursery conditions

Species	Number of leaves							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	8.00a	9.33b	11.33a	10.30ab	10.00a	12.3a	10.60a	11.0ab
A. saman	11.60a	8.67c	11.00a	10.00bc	12.00a	14.0ab	12.60a	15.30a
P. pinnata	10.30a	11.00a	14.00a	18.00a	10.00a	15.30a	11.60a	13.00a
Species	Nodule number							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	26.67ab	27.00a	33.00a	26.00a	13.33b	28.33a	11.67b	28.33a
A. saman	39.33a	27.33b	34.33a	29.33b	36.67a	43.33b	31.67a	63.33a
P. pinnata	16.33a	23.67a	15.33a	4.33b	1.00b	1.00b	6.67ab	0.00b
Species	Nodule size (mm)							
	Harvesting at 20th day		Harvesting at 40th day		Harvesting at 60th day		Harvesting at 80th day	
	C_{20}	T_{20}	C_{40}	T_{40}	C_{60}	T_{60}	C_{80}	T_{80}
A. chinensis	1.47b	2.02a	3.08a	1.90a	1.72b	2.75a	1.77b	3.47a
A. saman	1.92b	4.53ab	4.67a	4.90a	2.95ab	2.10b	3.22ab	3.73ab
P. pinnata	2.47a	3.05a	3.10a	2.57b	1.72a	1.60c	3.00a	0.00d

Notes: *Values in the columns followed by the same letter (s) are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test (DMRT)

Discussion and conclusions

The experiment clearly revealed that, the application of P-fertilizer significantly enhanced the seedling growth of selected agroforestry tree species in nursery condition which varied with different harvesting intervals. During the study overall growth rate of the selected agroforestry tree seedlings was increased in most cases. The growth was found more pronounced in *A. chinensis*, whereas it was not noticeable and showed depressed growth in case of *P. pinnata*. It, therefore can be understood from the study that, with few exception the growth parameters of the selected agroforestry tree seedlings is dependent on the application of P-fertilizer i.e., growth was more as P-fertilizer applied.

The observations of this study is in accordance with the findings of Totey (1992) and Sundralingam (1983), who have also found the significant positive effect of P-fertilizers on *Tectona grandis,* of Bhuyiyan et al. (2000); Sanginga et al. (1989) and Bhatnagar (1978), who have reported the acceleration of growth parameters on the application of P-fertilizer, particularly on *Casuarina* spp. The significant effects of P fertilizers on plant height, collar dia., root length etc are also evident from the study of Uddin et al. (2007) respectively on *Acacia auriculiformis* and *A. procera*, of Verma et al. (1996) on *Dalbergia sissoo* and Sundralingam (1983) on *T. grandis*. Higher doses of P-fertilizers also reduce the seedling growth of *A. chinensis* which may hamper the seedling growth by the initiation of toxic effects. Similar observation was also reported by Uddin et al. (2007) for *A. lebbeck* in response to application of P-fertilizer. Negative effects of commercial fertilizers on seedling growth was also observed by Kadeba (1978), who reported that, the addition of excess fertilizer on *Pinus caribaea* depressed growth and increased mortality of the seedlings. The findings of Van der Driessche (1980) also supported these, who reviewed both the positive and negative effects of nursery fertilizer application on subsequent seedling growth and survival.

Another finding of the study was the positive effect of P-fertilizers on the nodulation of two selected agroforestry tree seedlings except in case of *P. pinnata*. It was found that nodulation was significantly increased in terms of number and size in both levels of P-fertilizations in comparison to the control (without P-fertilizations). Similar findings were reported by Munns (1997); Hicks and Loynachan (1987) and Gates and Wilson (1974), who had also found the increase in nitrogen fixation with the application of P-fertilizer on *A. mangium* seedlings; Sanginga et al. (1989) who reported that, the application of P-fertilizer in *Leucaena leucocephala* improved the seedling biomass and nitrogen fixation. As nitrogen fixing tree (NFT) species are of great importance in traditional agroforestry system, we recommended for a detailed field investigation to ensure the long term growth performance of the selected NFT species in response to P-fertilizer application in natural stands.

References

Ackerson RC. 1985. Osmoregulation in cotton in response to water stress. III. Effects of phosphorous fertility. *Plant Physiology*, **77**: 309–312.

Ahmed GU. 1990. Survival percentage and growth statistics of some plantation species at the Chittagong University Campus. *Chittagong University Studies, Part II: Science*, **14**(1): 45–50.

Ajayi OC. 2007. User acceptability of sustainable soil fertility technologies: lessons from farmers' knowledge, attitude and practice in Southern Africa. *Journal of Sustainable Agriculture*, **30**(3): 21–40.

Aryal UK, Hossain MK, Mridha MAU, Xu HL. 2000. Nodulation status and nitrogenase activity of some legume tree species in Bangladesh. *Journal of Crop Production*, **3**: 325–335.

Bhatnagar HP. 1978. Preliminary studies on nutritional requirements of *Casuarina equisetifolia* and *Dipterocarpus macrocarpus* seedlings. *Indian Journal of Forestry*, **1**(2): 35–41.

Bhuiyan MZA, Hossain MK, Osman KT. 2000. Effect of inorganic fertilizers on the initial growth performance of *Casuarina equisetifolia* seedlings in the nursery. *Indian Journal of Forestry*, **23**(3): 296–300.

Bisby FA, Roskov YR, Ruggiero MA, Orrell TM, Paglinawan LE, Brewer PW, Bailly N, van Hertum J. (eds). 2007. Species 2000 & ITIS Catalogue of Life: 2007 Annual Checklist (CD-ROM). UK: Species 2000 Secretariat, University of Reading.

Das DK, Alam MK. 2001. *Trees of Bangladesh*. Chittagong: Bangladesh Forest Research Institute (BFRI), 342 pp.

Fakir MSA, Munshi AAA, Alam SMM. 1988. Effect of rhizobium inoculant, nitrogen and phosphorous on yield contributing characters of soybean. *Bangladesh J Agric Sci*, **15**(2): 211–215.

Gates CT, Wilson JR. 1974. The interaction of nitrogen and phosphorous on the growth, nutrient status and nodulation of *Stylosanthes humilis* H.B.K. (Townsville stylo). *Plant and Soil*, **41**: 325–333.

Hicks PM, Loynachan TE. 1987. Phosphorous fertilization reduces vesicular-arbuscular mycorrhizal infection and changes nodule occupancy of field grown soyabean. *Agronomy Journal*, **79**: 841–844.

Hossain MK, Islam SA, Islam QN. 1996. Growth and biomass production of the international provenance trial of *Gliricidia sepium* in Bangladesh. *Chittagong University Studies, Part II: Science*, **20**(1): 77–82.

Hossain MK, Khan BM. 2003. Performance of two exotic nitrogen fixing tree species at Chittagong university campus, Bangladesh. *NFT News*, **6**(1): 2–3.

Hossain MS, Hossain MK, Koirala B. 2001. Growth and nodulation status of seven multipurpose tree legumes grown in hill soils under nursery conditions. *J For and Env*, **1**(1): 97–101.

Kadeba O. 1978. Nutrition aspects of afforestation with exotic tree species in the savanna regions of Nigeria. *Common For Rev*, **57**: 191–199.

MacDicken KG. 1994. Selection and management of nitrogen fixing trees. Morrilton: Winrock International Institute for Agricultural Development and Bangkok: FAO- Regional Office for Asia and the Pacific (FAORAP), 27 pp.

Munns DN. 1997. Mineral nutrition and the legume symbiosis. In: Hardy RW and Gibson AH. (eds). *A Treatise on Di-nitrogen Fixatiion.* New York: John Wiley and Sons, 137–153 pp.

NAS. 1979. *Tropical Legume: Resources for the future.* Washington DC: National Academy of Science (NAS), 89 pp.

Prasad J, Ram H. 1986. Effect of zinc and copper and rhizobium inoculation on phosphorus availability and uptake in mung bean. *Journal of Indian Soil Science*, **34**: 62–66.

Sanginga N, Danso SKA, Bowen GD. 1989. Nodulation and growth response of *Allocasuarina* and *Casuarina* species to P fertilization. *Plant and Soil*, **119**: 125–132.

Stamford NP, Ortega AD, Temprano F, Santos DR. 1997. Effects of phosphorous fertilization and inoculation of *Bradyrhizobium* and mycorrohizal fungi on growth of *Mimosa caesalpiniaefolia* in an acid soil. *Soil Biol Biochem*, **29**(5/6): 959–964.

Sundralingam P. 1983. Responses of potted seedlings of *Dryobalanops aromatica* and *Dryobalanops oblongifolia* to commercial fertilizers. *Malaysian Forester*, **46**: 86–92.

Totey NG. 1992. Fertilizer management in forest plantations in non-traditional sectors for fertilizer use (HLS Tandaned.). New Delhi: Fertilizer Development and Consultation Organization, 156 pp.

Uddin MB, Mukul SA, Khan MASA, Hossain MK. 2007. Effects of phosphorous fertilizer on seedlings growth and nodulation capabilities of some popular agroforestry tree species of Bangladesh. *Journal of Forestry Research*, **18**(4): 283–286.

Van den Driessche R. 1980. Effects of nitrogen and phosphorous fertilization on Douglas fir nursery growth and survival after out-planting. *Canadian Journal of Forest Research*, **10**(1): 65–70.

Verma RK, Khatri PK, Bagde M, Pathak HD, Totet NG. 1996. Effect of bio-fertilizer and phosphorous on growth of *Dalbergia sissoo*. *Indian Journal of Forestry*, **19**(3): 244–246.

Walker RB, Chowdappa P, Gessel SP. 1993. Major element deficiencies in *Casuarina equisetifolia. Fertilizer Research*, **34**: 127–133.