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RESEARCH ARTICLE

Effect of Phosphorus Application on Growth and Stump Quality of Teak (*Tectona grandis* Linn f.) Seedlings

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ABSTRACT

A nursery experiment was conducted to study the effect of phosphate fertilizer application on seedling growth and stump quality of teak seedling. The pre-conditioned 8 months-old teak drupes (fruit with seed) were placed for germination in the nursery bed. The experiment consisted of seven treatments replicated four times. The number of seedlings emerged/4m^2 was observed at 28 days after sowing (DAS) and, 2,3,4,5 and 6 months after sowing (MAS). The results revealed that the application of different levels of P_2O_5 did not have any significant effect on number of seedlings/4m^2 of teak up to 4 months after sowing, whereas the significant influences were observed at 5 to 6 months after sowing. Significant differences were also observed in root length, shoot length and stump girth at 6 months after sowing due to P fertilization levels. The correlation relationship of teak growth parameters with post-harvest soil revealed the positive and significant correlation of teak root volume and dry matter with soil available P status was observed. The results suggest that the application of 60 kg P_2O_5/ha in teak nursery bed enhanced the seedling growth and stump quality of 6 months-old teak nursery plants through enhanced P availability.

Keywords: *Teak nursery, phosphorus application, seedling growth, stump quality.*

INTRODUCTION

Globally, teak plantations increased substantially over the years and currently, India has 44 percent of the global teak plantation (4.35 million ha). India has the major share of the total area under teak plantations, followed by Indonesia (Kollert and Walotek, 2015). In India, natural zone of teak distribution is mainly confined to the peninsular region below 24-degree latitude. The distribution is discontinuous throughout the range. The most important teak forests found are Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka and Kerala, besides Uttar Pradesh, Gujarat, Orissa and Rajasthan (Tewari, 1992).

Teak plantations are generally established either through seedling mainly sourced from unknown seed origin and a limited quantity from seed orchards/ seed production areas/tissue culture of selected superior trees (Arun Dev *et al.,* 2020). In the present study, nursery beds were established in red soil field with sandy loam texture. In red soil, there may be restrictions on root penetration, root proliferation, stump filling and shoot growth due to hardening and crusting behavior of soil. Nursery soil needs to be ameliorated with suitable amendments and nutrient carriers for easy penetration of root and produce palatable stump within a short period in the nursery. The use of fertilizers is virtually important for healthy seedlings under nursery conditions. However, the optimal requirement varies for the different fertilizers, depending on the nature of species and prevailing status of soil fertility. Rapid growth of seedlings under nursery conditions enables them for early field establishment. Improved mineral nutrition during the establishment stage may increase the growth rate of the seedlings (Ruaysoongnern *et al*., 1984). Fertilizer use is important in tropical region where the soils lose their fertility at rapid rate, especially after the removal of natural vegetation for nursery establishment (Abod and Siddiqui, 2002). The advantage of nursery fertilization is noticed with the better survival of seedlings under field conditions. In general, fertilized seedlings are larger and sturdier, indicating better survival in the field condition than unfertilized seedlings (Stockeler,1960).To some extent, phosphorus brings about pronounced influence on meristematic activity in the seedlings by way of protein synthesis resulting better seedling growth (Qureshi and Yadav, 1967). Proper fertilization increases the growth potential of teak seedlings under nursery conditions, paving

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more batches of seedlings within a short interval. In Malaysia, the positive effect of phosphorus fertilizer on teak was reported by Sundralingam (1983).

In the present investigation, it was aimed to clarify the stalemate situation of soil conditions for supporting germination, seedling growth and stump quality of teak. The focus was given to explore the possibility of utilizing the phosphorus fertilizer in the form of superphosphate as a component of nursery media at an optimum level.

MATERIAL AND METHODS

The study was conducted in red sandy loam non - calcareous soil at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur ($11^{O}19$'N; $76^{O}56$'E; 300MSL.), Tiruchirappalli, District, Tamil Nadu during December 2019. In this study, the effect of gypsum and different levels of phosphorus application as a component of nursery media on germination, seedling growth in nursery was determined. Based on the recommended fertilizer phosphorus dose of Cassava, different phosphorus levels were fixed for identifying the optimum dose for the growth of teak seedlings. The physical and chemical properties of the nursery soil were analyzed before imposing the treatments and after uprooting the seedling from the nursery (post-harvest soil). The pH of the soil sample (1:2 soil: water ratio) was measured using pH meter with a combined pH electrode. The Electrical Conductivity (EC) was measured in soil (1:2 soil: water ratio) to assess the salt content using a conductivity meter. The organic carbon (OC) in the potting mixture was determined by wet digestion method (Walkley and Black, 1934). Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus was extracted with 0.5 M $NaHCO_3$ and measured in UV-Visible spectrophotometer by ascorbic acid reduction method (Olsen *et al.,* 1954). Available potassium was extracted with neutral normal ammonium acetate and determined in flame photometer (Stanford and English, 1949). Physical constants such as bulk density, particle density, porosity, water holding capacity in air-dried soil was determined by cylinder method (Piper, 1966). Volume expansion was determined by Keen Raczkowski box method (Tables 1 & 2).

In each treatment, the preconditioned (one-day soaking, drying for three days and repeating this cycle for six times: ISTA, 1985) eight-months-old teak drupes (fruit with seed) were placed for field emergence in nursery bed of 30 m^2 size (teak seeds 6.25 kg/ 30m^2). The experiment consisted of seven treatments with different levels of phosphorus viz., T_1-Control, T_2-500 kg Gypsum/ha, T_3– 20 kg P_2O_5/ha, T_4– 40 kg P_2O_5/ha, T_5– 60 kg P_2O_5/ha, T_6– 80 kg P_2O_5/ha and T_7-100 kg P_2O_5/ha. Single super phosphate was used as P fertilizer. In all the treatment plots, 12.5 t FYM /ha and bagasse fly ash 60t/ha (Masilamani *et al.,* 2018) were applied uniformly, including the control plot. Before imposing the treatment, sunhemp was raised up in the field up to the flowering stage and incorporated uniformly into soil. Three days after sowing of teak seeds, the pre-emergence herbicide Atrazine 50%WP was applied as liquid spray (2.5%) on the nursery bed (Masilamani *et al.,* 2018) using a knapsack sprayer fitted with fan type nozzle. The experiment was laid out in a randomized block design with four replications. After sowing, 28 days after sowing and, 2,3,4,5 and 6 months after sowing, observations were made on number of seedlings/4m^2. Thereafter at 2 and 6 months after sowing, observations were made on number of seedlings/m^2, root length(cm), shoot length (cm), number of leaves/ seedlings, stump girth (cm) and stump dry matter production(g/stump). For the estimation of stump dry matter production, stumps were selected at random and kept in a hot air oven maintained at 85^{o}C for 24 hours after measuring their girth. The results were subjected to analysis of variance and tested for significant difference (P=0.05) of means (Panse and Sukhatme, 1995).

RESULTS AND DISCUSSION

The experimental results revealed that the application of phosphorus fertilizer did not have any significant effect on number of seedlings/4m^2 up to 4 months after sowing.

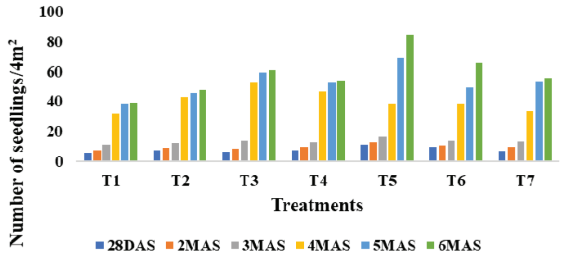
Table1. Physico-chemical properties of nursery soil before treatment

pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Bulk Density (Mg m^{-3})	Pore space (%)	WHC (%)	Available nutrients ($kg\ ha^{-1}$)		
						N	P	K
7.37	0.28	7.3	1.25	44.2	23.75	286	11.20	147

The average number of seedlings/4m^2 were 7.75, 9.46, 13.36 and 40.61 at 28 DAS, and 2, 3, 4 MAS, respectively. However, the significant influence was observed at 5 to 6 months after sowing. Six months after sowing, the maximum number of seedlings/4m^2 was recorded by the application of 60 kg P_2O_5/ha (84.50) followed by 80 kg P_2O_5/ha (65.75). The minimum number of seedlings/m^2 was observed in control (39.25) (Table 3 & Fig.1).

The data on root length and shoot length of

Figure 1. Effect of P fertilization on number of seedlings/4m²



Treatment details

T_1 – Control

T_2 - 500 kg Gypsum /ha

T_3 - 20 kg P_2O_5 /ha

T_4 - 40 kg P_2O_5 /ha

T_5 - 60 kg P_2O_5 /ha

T_6 - 80 kg P_2O_5/ha

T_7 - 100 kg P_2O_5 /ha

the seedlings were significantly influenced by phosphorus application in 2 months after sowing. The longest root of 8.21 cm was recorded by 60 kg P_2O_5/ha followed by 40kg P_2O_5/ha (7.70 cm), while the shortest length of root of 5.91 cm was recorded by control. Similarly, the longest shoot lengths of 9.35 cm was recorded by 60 kg P_2O_5/ha, while the shortest shoot length of 5.52 cm and a smaller number of leaves/seedlings (5.3 cm) were recorded by control. The other parameters viz., stump girth and dry matter production of the stump were not statistically significant (Table 4). Phosphorus is an essential element determining plant growth and productivity. Due to soil fixation of P, its availability in soil is rarely sufficient for optimum growth and development of plants. Phosphorus plays an important role in an array of cellular processes, including maintenance of membrane structure, synthesis of biomolecules and formation of high-energy molecules. It also helps in cell division, cell elongation, enzyme activation/inactivation and carbohydrate metabolism (Assuero *et al*., 2004; Razaq *et al*., 2017).

Table 2. Physico-chemical properties of post-harvest soil of teak nursery

Treatments	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Bulk Density (Mg m^{-3})	Pore space (%)	WHC (%)	Available nutrients (kg ha^{-1})		
							N	P	K
T_1	7.72	0.23	6.0	1.21	46.6	21.75	243	10.67	116
T_2	7.75	0.25	6.5	1.17	52.2	25.58	262	11.33	129
T_3	7.80	0.21	6.1	1.21	47.1	22.23	270	12.33	124
T_4	7.64	0.23	6.3	1.20	49.7	24.57	268	13.62	132
T_5	7.55	0.25	6.6	1.21	51.2	25.45	260	15.48	128
T_6	7.23	0.25	6.1	1.22	49.1	24.24	253	16.75	135
T_7	7.48	0.27	6.0	1.20	46.0	21.41	248	17.93	132
SED	**0.15**	0.01	0.05	0.03	1.04	0.30	4.4	0.30	3.2
CD 5%	0.31	NS	NS	NS	2.24	0.65	9.5	0.63	6.8

In the case of results recorded at 6 months after sowing, the root length, shoot length and stump girth were influenced significantly by the phosphorus application. The longest seedling length was recorded in 60kg P_2O_5/ha (root length 16.50 cm, shoot length 12.10 cm) and the shortest seedlings length was observed in control (root length 12.60 cm, shoot length 10.85 cm).

Table 3. Effect of P fertilization on number of seedlings/4m²

Treatments	28DAS	2MAS	3MAS	4MAS	5MAS	6MAS
T_1-Control	5.75	7.25	10.75	31.75	38.72	39.25
T_2- 500kg Gypsum /ha	7.50	8.75	12.25	42.75	45.25	48.00
T_3- 20 kg P_2O_5 /ha	6.50	8.25	13.75	52.50	59.25	61.00
T_4-40 kg P_2O_5 /ha	7.25	9.50	12.75	46.25	52.75	53.50
T_5-60 kg P_2O_5 /ha	10.75	12.75	16.75	38.75	69.25	84.50
T_6-80 kg P_2O_5/ha	9.50	10.50	13.75	38.75	49.75	65.75
T_7-100 kg P_2O_5 /ha	7.00	9.25	13.50	33.50	53.00	55.75
Mean	7.75	9.46	13.36	40.61	52.57	58.25
SEd	2.94	3.06	3.09	3.31	5.78	7.20
CD(P=0.05)	NS	NS	NS	NS	11.43	14.53

DAS-Days After Sowing MAS-Month After Sowing

Number of leaves/seedlings and stump girth were not statistically significant. Stump girth was maximum in application of 60kg P_2O_5/ha (8.56 cm) followed by application of 80kg P_2O_5/ha (8.08 cm) while the minimum was in control (5.86 cm). The number of leaves/seedlings and dry matter production of stumps were not statistically significant (Table 5).

Table 4. Effect of P fertilization on growth of teak seedlings (2 months after sowing)

Treatments	Root length(cm)	Shoot length(cm)	No. of leaves/ seedling	Stump girth(cm)	DMP (g/stump)
T_1-Control	5.91	5.52	5.32	2.09	1.98
T_2-500kg Gypsum /ha	6.33	8.00	5.68	3.37	1.98
T_3- 20 kg P_2O_5 /ha	7.25	8.85	5.94	2.75	2.30
T_4-40 kg P_2O_5 /ha	7.70	8.20	6.61	2.41	2.13
T_5-60 kg P_2O_5 /ha	8.21	9.35	7.35	3.60	2.73
T_6-80 kg P_2O_5/ha	7.55	8.65	6.75	3.02	2.63
T_7-100 kg P_2O_5 /ha	6.65	6.96	6.33	2.41	2.10
Mean	7.09	7.93	6.24	2.81	2.26
SEd	1.05	0.33	1.07	0.72	0.36
CD(P=0.05)	2.19	0.70	2.35	NS	NS

Phosphorus is an important constituent of energy-rich compounds, including adenosine triphosphate (ATP), cytidine triphosphate (CTP), guanosine triphosphate (GTP), uridine triphosphate (UTP), phosphoenol pyruvate and other phosphorylated intermediate compounds. Hence, it supplies energy to drive various cellular endergonic processes. Being a constituent of nucleic acids (DNA, RNA), it is essential for reproduction and protein synthesis. In order to maintain its role as inorganic phosphate (P-deprived conditions), plants undergo various morphological, physiological and biochemical adaptations. These include alterations in root architecture, formation of cluster roots; shoot development, organic acid exudation and alternative glycolytic and respiratory pathways (Vance *et al*. 2003). In perennial species, roots can be an important storage site for nutrients during low growth periods, and the main source of remobilized P during high growth demand (Cote and Dawson, 1990). Sundaralingam (1983) found that phosphorus fertilizer improves the height and diameter of teak seedlings. Phosphorus supports root growth in plants. Specifically, phosphorus encourages plants to put down a dense collection of new roots and to strengthen existing roots as they develop. The present results are supported by the study by Sonker and Kubhare (1991), who have reported that the effect of fertilizer application and growth of 5-month-old teak seedlings revealed that 100 kg of phosphorus, 150 kg potash and 200 kg nitrogen/ ha had a significant response in terms of increased the root length, shoot length, collar girth, when compared to control treatment.

Table 5. Effect of P fertilization on growth of teak seedlings (6 months after sowing)

Treatments	Root length(cm)	Shoot length(cm)	No. of leaves/ seedling	Stump girth(cm)	DMP (g/ stump)
T_1 – Control	12.60	10.85	6.12	5.86	8.74
T_2 - 500 kg Gypsum /ha	13.20	11.20	6.97	6.33	9.21
T_3 - 20 kg P_2O_5 /ha	13.35	11.40	7.01	6.54	9.30
T_4 - 40 kg P_2O_5 /ha	13.90	11.45	7.15	7.08	9.54
T_5 - 60 kg P_2O_5 /ha	16.50	12.10	7.84	8.56	9.99
T_6 - 80 kg P_2O_5/ha	15.25	11.85	6.93	8.08	9.57
T_7 - 100 kg P_2O_5 /ha	15.05	11.30	7.13	6.62	9.46
Mean	14.26	11.45	6.98	7.01	9.40
SE.d	1.02	0.43	0.75	0.52	1.09
CD(P=5%)	2.17	0.89	NS	1.14	NS

The effect of imposed treatments on post-harvest soil characteristics is presented in Table 2. It was found that the gypsum treatments and P levels influenced the soil physico-chemical properties when compared to control except the soil EC, organic carbon and bulk density. Significant decrease in soil pH with increased P levels was observed and could be ascribed to the acidifying effect of increased teak roots volume. Highest percent pore space and water holding capacity in soil was recorded due to gypsum application and lowest was in 100 kg/ha P level and which showed the amendment effect of gypsum on improving soil properties. In a similar study, application of gypsum has been found to enhance the water infiltration in poorly structural soils. This effect might be due to calcium ions which would have reduced the repulsive forces by compressing the diffuse double layer at the particle surface, thereby enhancing colloidal aggregation (Uusitalo *et al*., 2012). An increase in P application levels increased the available P status of soil and decreased the available N content, which showed the positive effect of P fertilization on increasing the bioavailability of P in soil and corresponding P uptake and increased teak growth. Similar result was reported by Doo (1982) that the N and P fertilization influenced the growth parameters of one-year-old teak seedlings. Husen and Pal (2003) also reported an increased root growth of teak shoot cuttings with the NPK fertilization. The K availability was significant due to P fertilization when compared to control, however not influenced significantly by the levels of P application.

Table 6. Pearson correlation (r) of post harvest soil characteristics with the teak seedling parameters at 6 months after sowing

Parameters	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Bulk Density (Mg m^{-3})	Pore space (%)	WHC (%)	Available nutrients (kg ha^{-1})		
							N	P	K
Root length (cm)	-0.691	0.574	0.351	0.363	0.240	0.335	-0.026	0.709*	0.592
Shoot length (cm)	-0.577	0.227	0.497	0.389	0.450	0.562	0.326	0.511	0.592
No. of leaves/ seedling	-0.229	0.294	0.651	0.006	0.472	0.522	0.502	0.552	0.569
Stump girth (cm)	-0.658	0.285	0.472	0.438	0.447	0.570	0.190	0.498	0.571
DMP (g/stump)	-0.490	0.349	0.547	0.200	0.440	0.537	0.390	0.622	0.693

*Significant at 5 % level

The influence of soil characters on the growth parameters of teak seedlings was assessed through Pearson correlation analysis (Table 6) using the data recorded at 6 months after sowing. It was found that the soil pH had a negative correlation with growth parameters. The root length, shoot length and stump girth of teak seedling was influenced highly by the soil pH. Other soil characteristics showed a positive correlation with the growth parameters of teak seedlings except for the relationship between the available N and root length. Though the soil EC showed positive correlation with growth parameters, it was not significant and root length was highly influenced by the soil EC. Positive correlation was observed between organic carbon and number of teak leaves/seedlings. Soil physical parameters did not show significant correlation though it was positive with growth parameters. The available nutrients viz., nitrogen, phosphorus and potassium, showed positive correlation with growth parameters of teak seedlings. Available P showed a highly significant positive correlation with root length (r=0.709**). Results showed that the optimum P application is vital for maintaining the soil fertility, increasing the root growth and for quality teak seedling production. Similar result of the importance P fertilization for the production of healthy and quality forest *Acer mono* tree seedling was reported by Razaq *et al*. (2017).

CONCLUSION

In the present study, application of super phosphate fertilizer in the nursery bed has resulted in the healthy growth of teak seedling with improvement in root length, shoot length, number of leaves/seedling and stump girth, which can be positively attributed to improvement in the physical properties of the soil type studied. From this study, it could be concluded that the application of 60 kg P_2O_5/ha improved the seedling growth, stump quality of teak nursery and physico-chemical properties of soil.

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