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Impact of fertigation on soil nutrient distribution in *Dalbergia sissoo* tree plantations

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Abstract

Fertigation is the application of water-soluble solids/ liquid fertilizers through drip irrigation. Standardizing nutrient management with a micro-irrigation system would require consideration to be contributed to soil nutrient dynamics. The present study was conducted to standardize water and nutrient requirement for raising this tree species in high density plantation and to study the distribution of nutrients in soil sub-surface using SURFER software. The results revealed that the available N content decreased as the distance from the plant increased and was found to be the lowest at 90 cm lateral distance and 30-60 cm vertical depth in subsurface soil. In this investigation, available P content was the highest at 30 cm distance laterally and vertically. The distribution of K was decreased with increasing depth. Nutrient distribution study revealed that irrigation level at 125% PE and fertigation @ 100% RDF (150:100:100 kg N, P and K ha^{-1}) recorded the highest soil N, P and K status at 30 cm lateral distance and horizontal depth of 0-30 cm.

Keywords: *Dalbergia sissoo*, Fertigation, High-density plantation, Nutrient movement

Introduction

Fertigation allows the controlled placement of nutrients reducing fertilizer losses through leaching and minimize groundwater pollution. In fertigation, nutrient use efficiency (NUE) could be as high as 90% compared to 40-60% in the conventional method of fertilizer application. Standardizing nutrient management with a micro-irrigation system would require consideration to be contributed to soil nutrient dynamics. Drip fertigation synchronizes the application of water and nutrients with crop requirements and maintains the proper concentration and distribution of nutrients and water in the soil (Zhang *et al.*, 2015).

Increased precision in the application of both water and nutrients can potentially be achieved by simultaneous application via fertigation (Bar-Josef, 1999; Haynes, 1985; Neilsen *et al.*, 1999). This has the advantage of synchronizing nutrient supply with plant demand (Millard, 1996; Neilsen *et al.*, 2001; Weinbaum *et al.*, 1992), thus enabling a reduction in the amount of nutrients applied and reducing environmental impact (Neilsen and Neilsen, 2002; Tagliavini *et al.*, 1997). Plant availability of soil nutrients is determined by a number of factors including inherent fertility, soil chemistry, and in irrigated production systems, by water supply and movement. The behavior of nutrients in irrigated production systems is thus highly affected by their solubility and mobility. For highly mobile nutrients such as N, water management practices can be used to retard movement through the root zone (Neilsen *et al.*, 1998; Neilsen and Neilsen, 2002). Similarly, fertigation and water management can improve the movement of less mobile nutrients such as K into the root zone (Neilsen *et al.*, 2004a; Uriu *et al.*, 1980) and even allow immobile nutrients such as P to be introduced into the root zone (Neilsen *et al.*, 1999).

Fertigation, in conjunction with drip irrigation, elicits localized plant, and soil responses. The placement of nutrients, as modified by water management techniques, may determine root system development, as roots tend to grow in nutrient-rich environments (Jackson *et al.*, 1990). For example, drip irrigation systems concentrated root development in the wetted zone (Bravdo and Proebsting, 1993; Neilsen *et al.*, 2000). The combination of localized nutrient availability and trees with dwarfing rootstocks can result in restricted root systems, which are highly dependent on external nutrient sources (Levin *et al.*, 1979) and thus are susceptible to nutrient and water deficits. Under drip irrigation, the localized application of fertigated NH4 based fertilizers reduced soil pH (Haynes and Swift, 1986).

Fertigation is the application of water-soluble solids/ liquid fertilizers through drip irrigation. It is the most effective and convenient means of maintaining optimum fertility level and water supply according to the specific requirement. Fertilizers and pesticides applied through a drip irrigation system can improve efficiency, save labour, and increase flexibility in scheduling applications to fit crop needs. *Dalbergia sissoo* is one of the indigenous multipurpose tree species with short rotation, and even the leaves are used as fodder source for livestock (Datt *et al.,* 2008; Paul, 2018). The present study was conducted to standardize water and nutrient requirement for raising this tree species in high-density plantation and to study the distribution of nutrients in soil sub-surface using SURFER software.

Materials and Methods

Study site and experimental design: A field trial was conducted in Forest College and Research Institute, Mettupalayam during the year 2016. The soil of the experimental field was Illupanatham soil series. The soil was loamy sand in texture, well-drained, slightly alkaline in reaction (pH 7.87) and non-saline (EC 0.20 dSm^{-1}). The initial soil fertility was low in available N (154 kg ha^{-1}), medium in available P (5.50 kg ha^{-1}), and high in available K (223 kg ha^{-1}). The surface soil was low in organic carbon content (4.50 g kg^{-1}). The experiment was laid out in split-plot design comprised of main plot with irrigation treatment and subplot with fertilizer levels. Three months old tree saplings were planted at a spacing of 3 m x 2 m. Total number of saplings per hectare was 1667 numbers. The water requirement of the tree plantation was calculated using the pan evaporation (PE) data as under;

Water requirement (litre $tree^{-1}day^{-1}$) = $Pe \times Kp \times Kc \times A \times Wp - Re$

where, Pe - Pan evaporation rate (mm day^{-1}); Kp - Pan coefficient (0.70); Kc - Crop coefficient (1.00); Wp - Wetted percentage (0.50); Re - Effective rainfall (mm)

Pan evaporation (PE) data were used to compute water requirement (Table 1), while duration of irrigation was computed based on water requirement per plant, discharge rate of driper (litre hr^{-1}) as well as numbers of drippers per plant. Fertigation schedule consisted of humic acid (62.5 litre ha^{-1}; F_1), inorganic fertilizer @ 150:100:100 kg N, P and K ha^{-1} (100% of recommended dose; F_2), applied in the form of urea, single super phosphate and muriate of potash, and humic acid (62.5 litre ha^{-1}) + 75:50:50 kg N, P and K ha^{-1} (50% of recommended dose; F_3).

Observations and analysis: The soil samples were collected at a radial distance of 30, 60 cm and 90 cm and a depth of 0-30 and 30-60 cm on 4 and 7 months after planting (MAP). Soil nutrient dynamics were estimated by analyzing available nitrogen, phosphorus, and potassium content of soil. SURFER 7 (Golden Software) packages were used to show the contour and three-dimensional view of nutrient distribution vertically and horizontally from the plant.

Table 1. Water requirement and irrigation schedule of plantations

PE (mm day^{-1})	Water requirement (litre $tree^{-1}day^{-1}$)	Irrigation duration (minutes)
4 .0 (100 % PE; I_1)	1.40	21
5.0 (125 % PE; I_2)	1.75	26
6.0 (150 % PE; I_3)	2.10	32

Results and Discussion

The mobility of nutrients in soil depends on the quantity and kinds of fertilizers applied, form of nutrient ions, moisture content of the soil and other reacting ions present in soil solution. Distribution of macro nutrients in vertical and horizontal directions was assessed.

Nitrogen dynamics: The available N decreased steadily with an increase in distance from the tree horizontally at 30, 60 and 90 cm and vertically at 0-30 and 30-60 cm on 4 and 7 months after planting (MAP). At a vertical depth of 0-30 cm the highest available N was registered on 4 and 7 MAP (168 kg ha^{-1} and 188 kg ha^{-1}). The available N content decreased as the distance from the plant increased and was found to be the lowest at 90 cm lateral distance and at 30-60 cm vertical depth in subsurface soil (Table 2;). A similar pattern of the result was reported earlier by Anitta *et al.* (2013). Urea is relatively mobile in the soil and it is not strongly adsorbed by soil colloids and tends to distribute down the soil profile. The maximum amount of available N was confined below the emitter near the plant and moved laterally up to 30 cm and vertically up to 0-30 cm and after that declined (Fig 1). The more availability of N in the soil near the emitter was the result of adequate quantum of water available just beneath the drippers, which increased the nitrogen availability. These results were in accordance with the results of Bangar and Chaudhari (2004), Gokila (2012) and Pawar et al. (2013).

Table 2. Nitrogen dynamics under the drip fertigated *Dalbergia sissoo* plantation

Irrigation/ Fertigation regimes	Available nitrogen (kg ha^{-1})				
	Lateral distance			Vertical distance	
	30 cm	60 cm	90 cm	0-30 cm	30-60 cm
I_1	154	141	130	132	128
I_2	182	164	157	156	141
I_3	172	160	148	138	146
CD (P=0.05)	11.0**	NS	18.5*	11.4**	19.2
F_1	166	150	142	132	127
F_2	179	165	154	157	153
F_3	165	152	141	138	135
CD (P=0.05)	10.0*	7.4*	9.2*	13.6**	12.7**

Table 3. Phosphorus dynamics under the drip fertigated *Dalbergia sissoo* plantation

Irrigation/ Fertigation regimes	Available phosphorus (kg ha^{-1})				
	Lateral distance			Vertical distance	
	30 cm	60 cm	90 cm	0-30 cm	30-60 cm
I_1	13.04	12.28	8.86	8.39	7.77
I_2	13.97	11.34	8.72	8.51	8.10
I_3	13.17	11.21	8.57	7.48	6.73
CD (P=0.05)	NS	NS	NS	1.63	2.35
F_1	9.73	9.37	6.87	6.42	5.54
F_2	20.14	16.60	12.08	10.12	10.12
F_3	10.32	8.86	7.20	7.83	6.95
CD (P=0.05)	4.35**	2.49**	1.37**	2.54*	2.62*

Table 4. Potassium dynamics under the drip fertigated *Dalbergia sissoo* plantation

Irrigation/ Fertigation regimes	Available potassium (kg ha^{-1})				
	Lateral distance			Vertical distance	
	30 cm	60 cm	90 cm	0-30 cm	30-60 cm
I_1	302	276	286	306	289
I_2	307	293	274	315	312
I_3	276	264	244	282	271
CD (P=0.05)	12.7**	12.0**	69.8**	12.4**	13.0**
F_1	285	261	241	288	267
F_2	316	304	290	326	322
F_3	283	267	272	290	284
CD (P=0.05)	9.2**	8.7**	55.1**	8.6**	9.1**

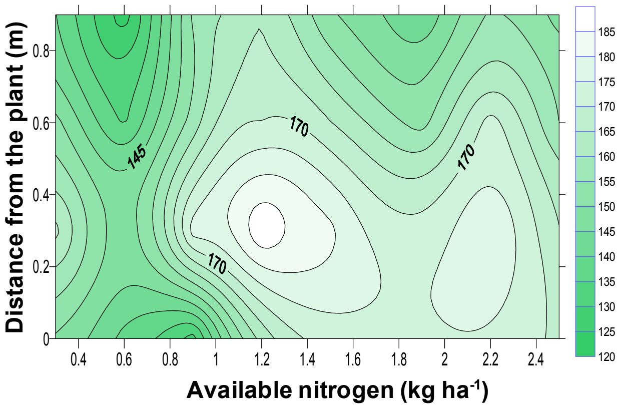

Fig 1. Contour map of nitrogen dynamics (kg ha^{-1})

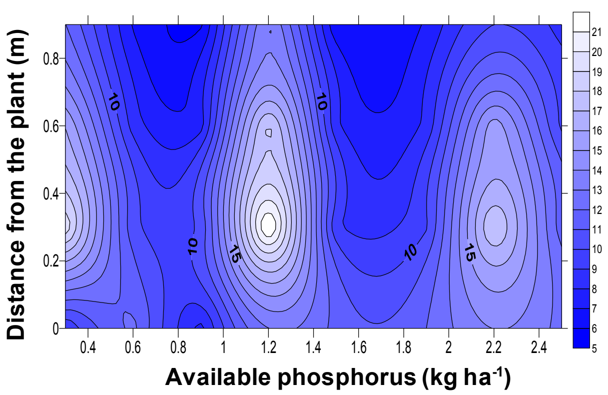

Fig 2. Contour map of phosphorus dynamics (kg ha^{-1})

Phosphorus dynamics: The Olsen-P was decreased with an increase in distance from the tree horizontally at 30, 60 and 90 cm and vertically at 0-30 and 30-60 cm (Table 3). The highest available P content was recorded at a horizontal distance of 30 cm (22.44 kg ha^{-1} and 19.20 kg ha^{-1}) on 4 and 7 MAP. At vertical depth in subsurface soil of 0-30 cm, the Olsen-P contents were 10.87 and 12.80 kg ha^{-1} on 4 and 7 MAP, respectively. These results were in concordance with the findings of Bar-Yosef (1999) who reported that P_2O_5 fertigation might increase yield by stimulating higher P uptake by the roots because roots developed in response to soil water distribution as applied by irrigation. Again fertigation might concentrate nutrients where they are most optimally absorbed by roots. In this investigation, available P content was the highest at 30 cm distance laterally and vertically (Fig 2). This could be due to the restricted mobility of P (Harijinder *et al*., 2004).

Potassium dynamics: Available K was the highest at a horizontal distance of 30 cm (339 kg ha^{-1} and 346 kg ha^{-1}) on 4 and 7 MAP. In subsurface soil at a depth of 0-30 cm, available K content was the highest (351 kg ha^{-1} and 362 kg ha^{-1}) on 4 and 7 MAP. The distribution of K was decreased with increasing depth (Table 4; Fig 3). This could be due to the adsorption of K on the exchange clay complex and were not readily leached away (Jata *et al*., 2013). Suganya *et al.* (2007) inferred that the available K content was higher in the surface layer due to the entrance of K ions in the soil exchange complex resulting in a very small movement to the depth layer. Gokila (2012) and Pawar *et al.* (2013) reported the maximum K availability at 125 percent fertigation and K availability decreased with decreasing level of fertigation. They also reported the availability of more K near the upper surface than the deeper soil layer. Kumar *et al.* (2017) reported that potassium content was higher at the depth of 0-15 cm from the emitter.

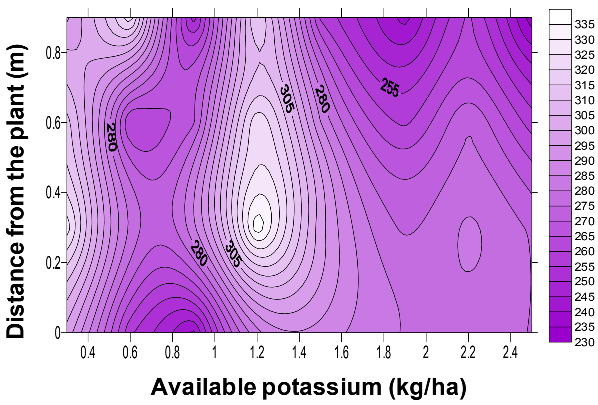

Fig 3. Contour map of potassium dynamics (kg ha^{-1})

Conclusion

Nutrient distribution study revealed that irrigation level at 125% PE and fertigation @ 100% RDF (150:100:100 kg N, P and K ha^{-1}) recorded the highest soil N, P and K status at 30 cm lateral distance and horizontal depth of 0-30 cm. Significant increase in N, P and K in the soil was noticed due to the application of drip fertigation with the recommended fertilizer dose of 150:100:100 kg N, P_2O_5, K_2O ha^{-1} and irrigation level @ 125% PE over the fertigation with humic acid 62.5 lit ha^{-1} and irrigation level @ 100% PE. The SURFER database showed that the nutrient distributions were higher at 30 cm lateral and 0-30 cm vertical distance from the plant.

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