EFFECT OF VESICULAR ARBUSCULAR MYCORRHIZAE ON THE GROWTH AND MINERAL NUTRITION OF TEAK (*TECTONA GRANDIS* LINN. F.)

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Introduction

It is a well established fact that root colonization by Vesicular-Arbuscular Mycorrhizal fungi helps in host plant growth and nutrition (Mosse, 1973; Menge *et al.*, 1982; Phillips and Hayman, 1983). Here, an attempt is made to study the effect of VAM fungi on the growth of a commercially important tree, *T. grandis* Linn.f. belonging to family Verbenaceae, in its early stages of establishment. The mineral nutrition of the host plant as influenced by the Mycorrhizal fungi in addition to growth parameters were studied in polybags so as to be in a better position to predict responses in field.

The "dilution-concentration method" (Jarrel and Beverly, 1981), is a useful method in screening of VAM fungi for beneficial nutritional host plant responses. Dilution in concentrations could be due to increased dry matter production, while increased concentrations are due to more accumulation of nutrients or due to a loss of plant dry matter. A set of three symbols - total element accumulation, yield (given by the product of respective fresh weight and concentration) and mineral nutrient concentration were recorded for all the treatments. A series of eleven such potential growth responses were earlier recorded by Jarrel and Beverly.

The growth parameters studied here in relation to plant growth were, girth of the plant, number of leaves, root length of the plant, total fresh weight and total dry weight of the plant, dry weight of shoot/total dry weight of the plant, in all the treatments as evidenced after a period of four months, after subjecting to various treatments.

Materials and Methods

Six month old, healthy, disease-free Teak stumps were obtained from Social Forestry Division, Warangal and were transported in a physiologically good condition to Forest Research Centre, Mulugu (Medak District), A.P. They were planted in polythene bags (4.95 kg soil capacity), containing sterilized soil, which had a composition of red soil: black soil: sand in the ratio 5 : 3 : 2. The soil pH, electrical conductivity and concentrations of various macro and micro nutrients were analysed. The absence of fungi in the soil is well established by culturing the soils on PDA (Potato-Dextrose-Agar) medium. The

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Fig. 1

Fig. 2

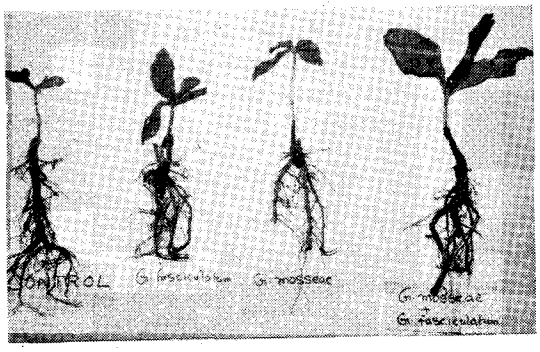
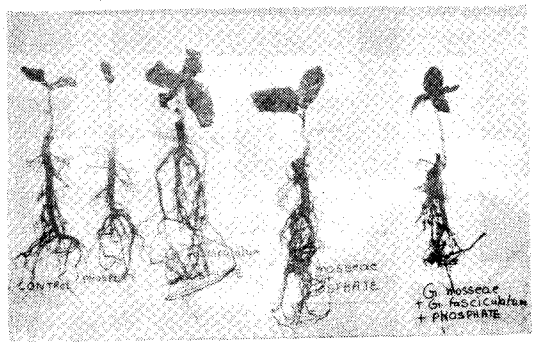


Fig. 3



VAM experiments on *Tectona grandis* at Mulugu

stumps were allowed to grow for a period of 3 months, so as to develop leaves and lateral root growth. Colonization experiments (Phillips and Hayman, 1973) revealed an absence of infection by VAM in Teak plants raised from stumps.

Glomus mosseae and *G. fasciculatum* raised as pure cultures on a genetically pure variety of *Cenchrus ciliaris* var. Molopo in sterilizd soil which had the some composition as given above. The selection of these strains followed the screening of forest soils supporting *T. grandis*. 3.5 kg of inoculum having 80-100 spores/100 gm of soil was thoroughly mixed with 1.45 kg of sterilized soil and filled in polybags of 4.95

kg soil capacity. The Teak plants were then transplanted to these bags.

The treatments consisted of addition of the two VAM fungi *G. mosseae* and *G. fasciculatum* separately and in combination with each other, to the three month old teak plants raised from stumps. In addition, the effects of phosphorus alone, and in combination with all the VAM fungal treatments were also studied (Fig. 1). Low concentrations of phosphorus that is, 100 mg (having 52% PO_4 by mass) of rock phosphate, per polybag were added. The non inoculated plant, with no addition of VAM fungi, and phosphorus served as control. The plants were well watered and all the plants were supplied once with modified Hoagland's solution (minus phosphate), two months after inoculation.

The concentration of macro-nutrients (N, P, K) and micro-nutrients (Cu, Zn, Fe, Mn) were found out in both the roots and shoots of *T. grandis* both initially before inoculation and after a period of three months, in all the treatments by destructive measurement of samples. Cu, Zn, Fe, Mn, were estimated by ICPA (Inductively Coupled Plasma Emission Spectro Photometry Analysis) after initial digestion with tri-acid mixture (Jackson, 1958). Nitrogen was estimated as Kjeldahl Nitrogen and K was estimated on a flame photometer after initial digestion with tri-acid mixture. Ca^{++} in the plant exudates was estimated by titrating them against 0.02 M EDTA, using Muroxide indicator.

Results

The various physical and chemical parameters of the experimental soil are indicated in Table 1. The phosphate content of the soil is quite high, while the soil pH(7.0) is in the same range, as is generally seen in *T. grandis* rhizosphere soils.

It is seen from Table 2 that *G. mosseae* + *G. fasciculatum* shows greater increase in girth, number of leaves, total fresh weight, total dry weight and total fresh weight/total length of the plant while there is a decrease in root length and dry weight of shoot/total dry weight of the plant. These changes are also consistent to a great extent in *G. fasciculatum* + Phosphate, followed by *G. mosseae* + Phosphate and *G. fasciculatum* while *G. mosseae* + *G. fasciculatum* + Phosphate shows a decrease in many growth parameters.

Table 3 shows an increase in the concentrations of all nutrients with the exceptions of N and Fe in all treatments including control, when compared with initial concentrations. In *G. mosseae* + *G. fasciculatum* and G. fasciculatum + Phosphate treatments N, K, Zn concentrations decreased in both roots and shoots, while P concentration increased and Fe concentration decreased in only the shoots.

Table 4 shows the mineral accumulation (respective fresh weight x respective nutrient concentration) in roots and shoots of all treatments.

Table 5 shows the graphical representation in the three parameters - change in nutrient accumulation, change in yield and change in concentration, as effected by the imposed treatments, in the roots and shoots of all plants.

Table 6 shows a general increase in pH, and a decrease in electrical conductivity and Ca concentrations of *G. mosseae* + *G. fasciculatum* + Phosphate and *G.*

Table 1

Physcial and chemical parameters of the experimental soil

pH	E.C in mmhos/cm)	Fe (mg/gm)	Cu (mg/gm)	Zn (mg/gm)	Mn (mg/gm)	P (mg/gm)	K (mg/gm)	N (mg/gm)
7.8	0.395	0.978	0.36	0.451	3.629	9.009	11.219	7.3

Table 2

Growth parameters in T. grandis after a period of four months

	Girth* (cm)	No.of* leaves plant)	Fresh wt* of Root (gm/ plant)	Fresh wt* of Shoot (gm/ plant)	Total* fresh wt. (gm/ plant)	Root* length (cm)	Total* fresh wt. /total length of plant (gm/cm/ plant)	Fresh wt* of Root/ Root length (gm/cm/ plant)	Total* dry wt. (gm/ plant)
Control	1.33	7.00	6.63	0.77	7.39	20.00	0.25	0.33	5.94
G. mosseae	1.50	2.67	8.70	1.05	7.42	27.00	0.18	0.32	13.42
G. fasciculatum	1.83	3.67	7.17	0.80	7.36	22.67	0.27	0.32	6.43
G. mosseae + *G. fasciculatum*	2.00	17.67	7.31	1.41	8.72	21.33	0.31	0.342	13.20
Phosphate	1.00	3.33	8.48	1.09	9.57	24.83	0.29	0.341	8.57
G. mosseae + Phosphate	1.50	4.00	4.80	0.76	5.77	23.33	0.18	0.21	6.92
G. fasciculatum + Phosphate	2.50	6.67	8.02	1.12	9.14	22.33	0.32	0.36	11.87
G. mosseae + *G. fasciculatum* + Phosphate	1.67	15.67	4.89	0.93	5.78	20.33	0.20	0.24	5.89

* Readings are average of three values

fasciculatum as estimated from total plant exudates.

Discussion

Significant increases in dry matter are seen in *G. mosseae* + *G. fasciculatum* + Phosphate treatments (Table 2). Such increases were also found earlier (Antunes and Cardoso, 1991; Eivazi and Weir, 1989). Increases in total fresh weight and total fresh weight/total length of plant are also consistently higher (Table 2). In contrast, root length decreased in *G. mosseae* + *G. fasciculatum* + Phosphate treatments, showing that the phosphate availability effects root geometry.

Uptake of P is observed in *G. mosseae* + *G. fasciculatum* and *G. fasciculatum* + phosphate shoots (Table 3 and 4). Such an uptake of P was also recorded earlier

Table 3

Mineral nutrient concentration in T. grandis treatments after a period of three months

Treatment	Caculated per plant						
	Fe (mg/gm)	Cu (mg/gm)	Mn (mg/gm)	Zn (mg/gm)	P (mg/gm)	K (mg/gm)	N (mg/gm)
Initial (S)	1.2690	0.0081	0.06299	0.02860	1.9148	6.4480	4.6530
Initial(R)	2.8450	0.0081	0.02866	0.02974	0.0844	1.9240	6.0450
Control (S)	1.1120(↓)	0.0118(↑)	0.13830(↑)	0.04310(↑)	2.6190(↑)	10.5860(↑)	12.8850 (↑)
Control (R)	4.0070(↑)	0.0158(↑)	0.04590(↑)	0.05040(↑)	0.9214(↑)	8.1500(↑)	6.8500(↑)
G. mosseae (S)	1.7920(↑)	0.0132(↑)	0.16240(↑)	0.08500(↑)	2.3840(↑)	9.1560(↑)	9.7580(↑)
G. mosseae (R)	6.7400(↑)	0.0146(↑)	0.05500(↑)	0.12370(↑)	0.9100(↑)	4.9780(↑)	6.1440(↑)
G. fasciculatum (S)	0.7740(↓)	0.0167(↑)	0.13500(↑)	0.04450(↑)	2.2400(↑)	11.9610(↑)	9.4830(↑)
G. fasciculatum (R)	3.8240(↑)	0.0137(↑)	0.04000(↑)	0.07530(↑)	0.7280(↑)	6.8160(↑)	5.0760(↓)
G. mosseae + *G. fasciculatum* (S)	0.6070(↓)	0.0167(↑)	0.13550(↑)	0.05980(↑)	3.2970(↑)	9.6850(↑)	9.1380(↑)
G. mosseae + G. *fasciculatum* (R)	4.9620(↑)	0.1580(↑)	0.04560(↑)	0.06670(↑)	0.8492(↑)	8.0880(↑)	5.3900 (↓)
Phosphate (S)	0.0673(↓)	0.0087(↑)	0.19620(↑)	0.04990(↑)	1.8360(↑)	6.4110(↑)	8.1790(↑)
Phosphate (R)	6.0160(↑)	0.0157(↑)	0.05770(↑)	0.06010(↑)	1.0010(↑)	6.4800(↑)	6.9530(↑)
G. mosseae + Phosphate (S)	0.7920(↓)	0.0111(↑)	0.16010(↑)	0.04720(↑)	4.6270(↑)	9.7560(↑)	11.4880(↑)
G. mosseae + Phosphate (R)	6.8620(↑)	0.2150(↑)	0.08840(↑)	0.07630(↑)	0.9654(↑)	6.7720(↑)	7.7250(↑)
G. fasciculatum + Phosphate (S)	0.7720(↓)	0.0102(↑)	0.12380(↑)	0.04760(↑)	2.8820(↑)	10.2270(↑)	11.2050(↑)
G. fasciculatum + Phosphate (R)	6.3440(↑)	0.0935(↑)	0.04180(↑)	0.08900(↑)	0.5802(↑)	7.2720(↑)	5.2080(↓)
G. mosseae + *G. fasciculatum* + Phosphate(S)	0.3040((↓)	0.0146(↑)	0.09620(↑)	0.06630(↑)	2.3240(↑)	8.6760(↑)	9.5060(↑)
G. mosseae + *G. fasciculatum* + Phosphate(R)	6.6350(↑)	0.0157(↑)	0.09980(↑)	0.16850(↑)	1.1350(↑)	6.8700(↑)	5.8170(↓)

(↑) Denotes an increase in mineral concentration, (↓) Denotes a decrease in mineral concentration.

Table 4

Mineral accumulation and fresh weights of roots and shoots of T. grandis

Treatment	Fe (mg/gm)	Cu (mg/gm)	Zn (mg/gm)	Mn (mg/gm)	P (mg/gm)	K (mg/gm)	N (mg/gm)	Fresh wt. (after 3 months (gm)	Fresh wt.* (after 4 months) (gm)
Control(S)	2.1684	0.0230	0.02690	0.08000	5.1070	20.6400	25.1300	1.9500	-
Control(R)	42.7600	0.1690	0.49000	0.54000	9.8300	86.9600	50.1600	10.6700	6.6300
G. mosseae (S)	3.1180(↑)	0.0229(↓)	0.08000(↑)	0.14790(↑)	4.1480(↓)	15.9300(↓)	16.9790(↓)	1.7400(↓)	-
G. mosseae (R)	62.8842(↑)	0.1360(↓)	0.51400(↑)	1.15400(↑)	8.4900(↓)	45.4900(↓)	39.4600(↓)	9.3300(↓)	8.7000(↑)
G. fasciculatum (S)	1.8344(↓)	0.0396(↑)	0.32000(↑)	0.10600(↑)	5.3100(↑)	28.3500(↑)	22.4750(↓)	2.3700(↑)	-
G. fasciculatum (R)	39.5020(↓)	0.1420(↓)	0.41400(↓)	0.77900(↑)	7.5200(↓)	70.3500(↓)	40.4100(↓)	10.3300(↓)	7.1700 (↑)
G. mosseae + *G. fasciculatum* (S)	1.5050(↓)	0.0280(↑)	0.34000(↑)	0.14800(↑)	8.1800(↑)	24.0290(↑)	22.6600(↓)	2.4800(↑)	-
G. mosseae + *G. fasciculatum* (R)	59.5400(↑)	0.1896(↑)	0.54700(↑)	0.80000(↑)	10.1900(↑)	97.0600(↑)	47.0900(↓)	12.0000(↑)	7.3190 (↑)
Phosphate (S)	2.0900(↓)	0.0270(↑)	0.61000(↑)	0.16000(↑)	5.7100(↑)	19.9400(↓)	25.4400(↑)	3.1140(↑)	-
Phosphate(R)	24.3500(↓)	0.3250(↑)	1.19300(↑)	1.24000(↑)	20.6900(↑)	13.9400(↑)	66.0600(↓)	20.6700(↑)	8.4800 (↑)
G. mosseae + Phosphate (S)	1.5500(↓)	0.0220(↓)	0.31400(↑)	0.09250(↑)	9.0690(↑)	19.1200(↓)	22.5200(↓)	1.9600(↑)	-
G. mosseae + Phosphate (R)	96.0700(↑)	0.3000(↑)	1.23800(↑)	1.06800(↑)	13.5160(↑)	94.8100(↑)	44.5700(↓)	14.0000(↑)	4.8000(↓)
G. fasciculatum + Phosphate(S)	1.6400(↓)	0.0127(↓)	0.21640(↓)	0.10000(↑)	6.1390(↑)	21.7840(↑)	23.8700(↓)	2.1300(↑)	-
G. fasciculatum + Phosphate(R)	77.2100(↑)	1.1380(↑)	0.50900(↑)	1.08300(↑)	7.0600(↓)	88.5000(↑)	47.6000(↓)	12.1700(↑)	8.0200(↑)
G. mosseae + *G. fasciculatum* + Phosphate(S)	1.2160(↓)	0.0580(↑)	0.38500(↑)	0.26500(↑)	9.2960(↑)	34.7000(↑)	38.0200(↑)	4.0000(↑)	-
G. mosseae + *G. fasciculatum* + Phosphate(R)	86.2600(↑)	0.2040(↑)	1.29700(↑)	2.19000(↑)	14.7600(↑)	89.3100(↑)	33.6200(↓)	13.0000(↑)	4.8800 (↓)

(↑) Shows an increase in accumulation of nutrients, (↓) shows a decrease in accumulation of nutrients.

* Nitrogen in Teak roots was estimated in the fourth month.

Table 5

Graphical representation of nutrient accumulation yield and mineral concentration in roots and shoots of T. grandis treatments (Jarrel and Beverly method)

Treatment	Fe	Cu	Zn	Mn	P	K	N
G. mosseae (S)	↑↓↑(C)	↓↓↑(C)	↑↓↑(C)	↑↓↑(C)	↓↓↓(A)	↓↓↓(A)	↓↓↓(A)
G. mosseae (R)	↑↓↑(C)	↓↓↓(A)	↑↓↑(C)	↑↓↑(C)	↓↓↓(A)	↓↓↓(A)	↓↓↓(A)
G. fasciculatum (S)	↓↑↓(D)	↑↑↑(S)	↑↑↓(D)	↑↑↑(S)	↑↑↓(D)	↑↑↑(S)	↓↑↓(D)
G. fasciculatum (R)	↓↓↓(A)	↓↓↓(A)	↓↓↓(A)	↑↓↑(C)	↓↓↓(A)	↓↓↓(A)	↓↓↓(A)
G. mosseae + *G. fasciculatum* (S)	↓↑↓(D)	↑↑↓(D)	↑↑↓(D)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↓↑↓(D)
G. mosseae + *G. fasciculatum* (R)	↑↑↑(S)	↑↑↓(D)	↑↑↓(D)	↑↑↑(S)	↑↑↓(D)	↑↑↓(D)	↓↑↓(D)
Phosphate(S)	↓↑↓(D)	↑↑↓(D)	↑↑↑(S)	↑↑↑(S)	↓↑↓(D)	↓↑↓(D)	↑↑↓(D)
Phosphate (R)	↑↑↑(S)	↑↑↓(D)	↑↑↓(D)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)
G. mosseae + Phosphate (S)	↓↑↓(D)	↓↑↑(D)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↓↑↓(D)
G. mosseae + Phosphate (R)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↓↓↑(C)
G. fasciculatum + Phosphate (S)	↓↑↓(D)	↓↑↓(D)	↑↑↓(D)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↓↑↓(D)
G. fasciculatum + Phosphate (R)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↑↑↑(S)	↓↑↓(D)	↑↑↓(D)	↓↑↓(D)
G. mosseae + *G. fasciculatum* + Phosphate(S)	↓↑↓(D)	↑↑↑(S)	↑↑↓(D)	↑↑↑(S)	↑↑↓(D)	↑↑↓(D)	↑↑↓(D)
G. mosseae + *G. fasciculatum* + Phosphate (R)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↑(S)	↑↑↓(D)	↓↓↓(A)

(C) Concentrated (↑↓↑, ↓↓↑)
(S) Synergistic (↑↑↑)
(D) Diluted (↓↑↓, ↑↑↓, ↓↑↑)
(A) Antagonistic (↓↓↓)
* (↓↑↑) A Special case of dilution is seen.

(Eivazi and Weir, 1989). There is and absolute growth depression in *G. mosseae* + *G. fasciculatum* + Phosphate probably due to the high phosphate levels in the rhizosphere. Inhibition of growth due to high P levels is already known.

There is a higher uptake of K as shown by increasing concentration in shoots of *G. mosseae* + *G. fasciculatum* + Phosphate treatments (Table 3 and 4). Such an uptake can be due to mass flow or diffusion depending on soil concentration.

N uptake decreased with phosphate treatments in mycorrhizal plants (Table 4). Such a decrease was also reported earlier (Hamel, *et al.*, 1991). In *G. mosseae* + *G. fasciculatum*, Cu and Zn concentrations were diluted in both roots and shoots (Table 5) and this can be attributed to dry matter dilution effect (Eivazi and Weir, 1989; Hamel *et al.*, 1991). High levels of phosphate are said to depress the rate of Zn uptake (Safaya, 1976; Lambert *et al.*, 1979). Dilution of copper in the shoot tissue concentrations may be due to the inhibition of Zn on Cu (Kausar *et al.*, 1976).

Fe is concentrated in the roots of all the treatments but its transport to shoot system is reduced (Table 3). The mutual inhibitory action of Zn and Fe is well Know (Brar and sekhar, 1976). Increasing concentrations of p and Mn also inhibit Fe translocation (Cumbus *et al.*, 1977), although increased retention in roots in seen.

Mn increased consistently in the shoots and roots of all treatments, and this could be due to its high mobility (Table 4 and 5). The radio-isotope techniques have shown that the rhizosphere may be responsible for solubilization of Mn and Fe (Van Beuchim, 1990).

The interactions between P and other nutrients must be considered if the overall effect on the host plant is to be assessed. Soil P, Mn and Zn are known to have greater predictive values for mycorrhizal dependents (Menge *et al.*, 1982). It is significant that only P and Mn concentrations increased in *G. mosseae* + *G. fasciculatum* and *G. fasciculatum* + Phosphate treatments which also have shown larger growth.

Table 6

pH Electrical conductivity and Calcium contents in the Plant Exudates of T. grandis

Treatment	pH	E.C. (m mhos/cm)	Ca (ppm)
Initial values	7.40	1.250	(Not Estimated)
Control	6.75	1.380	256
G. mosseae	6.65	1.410	352
G. fasciculatum	7.80	1.110	184
G. mosseae + *G. fasciculatum*	7.45	1.310	152
Phosphate	7.85	1.240	264
G. mosseae + Phosphate	7.45	1.340	336
G. fasciculatum + Phosphate	7.85	1.240	264
G. mosseae + *G. fasciculatum* + Phosphate	7.10	1.240	368

The cation Ca^{++}, given out in plant exudates in less in *G. mosseae* + *G. fasciculatum* and *G. fasciculatum* + Phosphate treatments (Table 6). It is a secondary constituent of poly phosphate granules and can stimulate alkaline phosphate activity. Generally lower concentration of Ca are found in mycorrhizal plants (Jarrel and Beverly, 1981). The pH and electrical conductivity of the plant exudates on the other hand, increased in the following order : *G. mosseae* + *G. fascicuilatum* > *G. fasciculatum* + Phosphate > *G. mosseae* + Phosphate > *G. fasciculatum* (Table 6).

Conclusion

Higher growth and accumulation of phosphorus is seen in *G. mosseae* + *G. fasciculatum* and *G. fasciculatum* + Phosphate treatments followed by *G. fasciculatum*. Mn concentration also increased in these treatments, while N, K, Cu and Fe concentrations decreased or diluted. It is possible that Mn is transported along with poly phosphate granules.

Different mycorrhizal fungi respond differently to host species and these differences reflect selection pressures which favour certain host-fungus combinations (Smith *et al.*, 1972). The variation between genotypes can be used in selection of varieties, whose infection is rapid and nutrient uptake is increased from nutrient deficient systems (Smith *et al.*, 1972).

A combination of *G. mosseae* + *G. fasciculutum* inoculation can be the best treatment while inoculation of *G. fasciculatum* with low P concentration can also give good results. Excess phosphate in the rhizosphere can hamper the growth of the plant by mere accumulation in the root of the plant as seen in *G. mosseae* + *G. fasciculatum* + Phosphate treatments. The better growth of *G. fasciculatum* treated plants over that of *G. mosseae* treated plants proves that there is a certain degree of specificity in host-fungus interactions. The higher phoshate content in the soils could have effected the specific interactions between the host and fungi.

SUMMARY

The effect of VAM Fungi (*Glomus fasciculatum* and *Glomus mosseae*) on initial establishment and mineral nurition of Teak was studied. The uptake of various macro-nutrients, (N,P, K) and micro-nutrients (Cu, Zn, Fe, Mn) studied along with various growth parameters. *G. mosseae* + *G. fasciculatum* **treated plants which registered greater growth, also showed an increase in the concentrations of Phosphate, K and Mn, while N, Cu, Zn, Fe concentrations decreased in the shoots. The plants to which** *G. fasciculatum* **in combination with a small amount of rock phosphate was given was the next best treatment followed by** *G. fascicualatum* **alone treated plants.** *G. mosseae* + *G. fasciculatum* **+ Phosphate treatment proved to be deleterious to the growth of the teak plants. The possible role of VAM on the growth of Teak is discussed keeping in view the specificity of host-symbiont relationship.**

सागौन (*टैक्टोना ग्रांडिस* लि० वत्स) की वृद्धि और खनिज पोषण पर आशयक - आर्बुस्कुलर कवकमूलों का प्रभाव

वी०वी०के० दुर्गा व संजय गुप्त

सारांश

सागौन की आरम्भिक स्थापना और खनिज पोषण पर वैम कवकों (*ग्लोमस फैस्सीकुलेटम* और *ग्लोमस मोसी*) के प्रभाव का अध्ययन किया गया । बड़े पोष्याहारों (नाइट्रोजन, फास्फोरस और पाटोशियम) और छोटे पोष्याहारों (तांबा, जस्ता,

लोहा और लोहक) के उद्ग्रहण का अध्ययन कई वृद्धि परिमापों पर किया गया । *ग्लो० मोसी* + *ग्लो० फैस्सीकुलेटम* से उपचारित पौधों में जिनकी वृद्धि तेज रही, उनमें फास्फेट, पोटाशियम और लोहक का जमाव भी अधिक रहा किन्तु उसके प्ररोहों में नाइट्रोजन, तांबा, जस्ता और लोहे का जमाव घटा । जिन पौधों का *ग्लो० फैस्सीकुलेटम* से उपचार थोड़ा सा चट्टानी फास्फेट मिलाकर किया गया वह सबसे अच्छा रहा उसके बाद केवल *ग्लो० फैस्सीकुलेटम* से उपचारित पौधे रहे । *ग्लो० मोसी* + *ग्लो० फैस्सीकुलेटम* + फास्फेट उपचार सागौन पौधों के लिए हानिकर रहा । पोषित-सहजीविता संबन्ध की विशिष्टता को ध्यान में रखते हुए सागौन की वृद्धि पर वैम कवकों की संभावित भूमिका पर विचार किया गया है ।

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