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Effects of Arbuscular Mycorrhiza and Phosphate Fertilizer on Phosphorus Uptake of Vetiver Using Nuclear Technique

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ABSTRACT

This experiment was done in 4×4 factorial treatment combinations with 4 replications in completely randomized design to evaluate the effects of 3 species of arbuscular mycorrhizal fungi : *Acaulospora scrobiculata*, *Glomus aggregatum* and *Glomus* sp. combined with phosphate fertilizer on phosphorus uptake of vetiver (*Vetiveria zizanioides* L. Nash). Four levels of superphosphate 0, 30, 60 and 90 kg P_2O_5 / ha (labels with P-32)were used. Vetiver height was increased when phosphate fertilizer was supplied, whereas the tiller number and biomass did not show any responses when P-fertilizer was applied. Comparing the different types of mycorrhizal treatments, *A. scrobiculata* significantly increased vetiver growth in terms of height and biomass, while the number of tillers per plant were not affected. The highest number of tiller per plant was found in *G. aggregatum* treated plant.

Arbuscular mycorrhizal fungi significantly increased P-concentration, P-uptake, % P derived from fertilizer and P-availability in vetiver. At 60 kg P_2O_5 / ha level of application, the highest percentage of P derived from fertilizer(0.545%), P-availability(0.037%FPU), and total P-uptake(6.25mg/clump) were obtained from *A.scrobiculata* , whereas *G. aggregatum* treatments with no P-supplied gave the greatest P-concentration (0.104%). Increasing phosphate fertilizer up to 90 kg P_2O_5 / ha, resulted in non-significant changes of P-uptake and P-availibility in VA mycorrhizal plants.

Key words: vetiver (*Vetiveria zizanioides* L. Nash), arbuscular mycorrhiza , phosphorus uptake, P-32, *Acaulospora scrobiculata, Glomus aggregatum,Glomus sp.*

INTRODUCTION

It is now widely known that application of arbuscular mycorrhizal fungi could increase the growth of several plant species (Mosse, 1973). The growth improvement has been mainly attributed to the enhanced uptake of phosphorus by the host plant . Phosphorus is an essential element for plant growth development and crop production as well as mycorrhiza fungal growth. Many types of soil in Thailand are defined as having high phosphorus fixation capacity whereby plants growth will be limited due to deficient phosphorus supply to the plant. Mycorrhiza is capable of absorbing and translocating nutrients as well as exploring more soil volume than the non-mycorrhizal roots (Joner and Jacobson,1995), and provide a direct link between soil and roots, thus increase the supply of

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slowly diffusing ions, such as phosphate to the plant. Menge *et al*. (1978) have shown that the control of mycorrhizal colonization is related to phosphorus concentration in the host plant. The growth stimulus by mycorrhizal symbiont is most frequently observed in soil low in phosphate. Addition of high rate phosphate fertilizer to the soil generally decrease the colonization of plant roots by mycorrhizal fungi (Abbott and Robson, 1984). The effect of phosphate supply on mycorrhiza colonization and plant growth may be dependent on the plant species (Valentine *et al*., 2000). However, at extremely low phosphorus available in soil it is expected that the benefit of the symbiosis to the host would be small. Under such condition the development of mycorrhizal symbiosis may not be advantageous to the host plant as compare with the non-mycorrhizal plant, since phosphorus uptake is not facilitated by infection (Hayman, 1983). In most case the addition of more readily available P into the soil eliminates differences in growth and phosphate uptake of the test plant. Many researchers concluded that root colonization of VA mycorrhiza, P- concentration and the host plant are postulated to be the important factors for the determination of mycorrhiza efficacy (Smith and Gianinazzi-Pearson, 1988). Under these circumstances there may be a complex relationships among host performance, mycorrhizal infection and amount of phosphorus in the soil to improve plant growth.

Radioisotope tracer techniques have been used extensively to measure P-uptake in rock phosphate (Fried, 1954). Tracer techniques provided better indexes of availability than the non-tracer method and highly correlation with chemical extraction measurements (Kucey and Bole, 1984). The objective of this study was to evaluate the effects of 3 species of arbuscular mycorrhizal fungi : *Acaulospora scrobiculata*, *Glomus* sp., *Glomus aggregatum* in combinations with phosphate fertilizer on phosphorus uptake of vetiver grass using nuclear technique.

MATERIALS AND METHODS

Soil

Pakchong series soil, Reddish Brown Lateritic Group were collected from the National Corn and Sorghum Research Center, Nakhon Ratchasima Province. The soil contained 1.31% organic matter, 12 ppm available P, 62 ppm extractable K, 0.173 mmhos EC at 25°C, and the pH of 7.3,

Arbuscular mycorrhiza fungi

The arbuscular mycorrhiza fungal species used in this study were obtained from rhizosphere of natural vetiver grass which have been isolated and selected for the highly effective species to improve vetiver growth in the previous experiment (Techapinyawat *et al*., 2001). Spores of arbuscular mycorrhiza fungi were produced using *Zea may* as host plant in pot culture containing sterile soil and were extracted by wet sieving and decanting (Gerdemann and Nicolson,1963). These arbuscular mycorrhiza spores were used as inoculum.

Host plant

Vetiver grass (*Vetiveria zizanoide*s L. nash) plantlets from tissue culture were propagated in 3 inches diameter plastic bag using sterile soil for one month and then transplanted into 6 inches diameter pot containing 1.5 kg fumigated Pakchong soil per pot. Approximately 200 arbuscular mycorrhizal spores were added to each pot prior to transplanting. After growing for one month the plants were uniformly thinned into 3 clumps / plant and the shoots were cut to the height of 20 cm. Then phosphate fertilizer were applied at this stage of growth.

The experimental design

This experiment was performed at Botany Department, Kasetsart University, Bangkok, Thailand. The experiment was laid out in 4×4 factorial treatment combination with 4 replications in completely randomized design. The inoculation treatments consisted of 4 inocular types : *Glomus* sp., *Glomus aggregatum*, *Acaulospora scrobiculata*, and a control. The fertilizer treatments consisted of 4 phosphorus levels : 0, 30, 60 and 90 kg P_2O_5 / ha (0, 4.8, 9.6 and 14.4 kg / rai). Superphosphate used as phosphorus source was applied into the soil. About 0.048 gm Urea (46%) and 0.038 gm of K_2O_5 were also incorporated into each pot as basal fertilizer. Two hundred microliter of P-32 solution with the activity of 4.38 μCi per pot was mixed with 10 gm sterilized sand and used in each treatment except those without phosphate fertilizer application. The plants were grown in the greenhouse and water was given regularly to maintain the field capacity of the soil. Harvest was done at 2 weeks after fertilizer application.

Plant height and the number of tiller were measured at 1 and 2 weeks after phosphate fertilizer application. At harvest time (2 weeks after fertilizer application), the total dry weight of vetiver was determined after drying the plant samples at 70°C for 3 days in a hot air oven .

The whole dry ground plant was ashed at 500°C for 5 hours . The ash was dissolved in 20 ml of 2 N HCl. Ten ml of this ashing solution was pipetted into grass scintillation vials and P-32 activity was measured by Cerenkov technique using liquid scintillation counter.

The percentage of P-31 concentration in the filtrate was determined using Vanadomolybdate method (Tassanee *et al*., 1989). The percentage of P in the plant derived from the fertilizers (% P dff) and P-uptake by the plant were calculated by the isotopic dilution concept as described by Hardarson (1990).

All datas were subjected to analysis of variance and the mean values were compared using Duncan’s new multiple range test at 95% confidence.

RESULTS AND DISCUSSION

Plant growth

Vetiver height as affected by arbuscular mycorrhizal (AM) inoculation combined with phosphate fertilizer were significantly (P< 0.05) different at 1 and 2 weeks after fertilizer applications. Similarly, the effects of AM inoculations on plant height for both stages of growth were significantly (P< 0.05) different (Table1). *Acaulospora scrobiculata* treated plant was found to reach the maximum height. However, the average height of the plants inoculated with *Glomus* sp. and G. *aggregatum* were not differed from the control (Table 2 and 3). Phosphate fertiliizer gave highly significant (P< 0.01) effect on plant height (Table 1). Applications of phosphate fertilizer the average plant height were increased. The effect of *A. scrobiculata* combined with 30 kg P_2O_5 /ha on plant height was clearly shown in both stages of growth. However, the tallest plant at harvesting stage was observed in *A. scrobiculata* treated plant (21.13 inch.) combined with 60 kg P_2O_5 / ha, while the height of the control plant was only 18.63 inch. Without phosphate fertilizer application, non-significant responses of AM inoculation on plant height at 1 week stage were attained. However, at 2 weeks the height of *A. scrobiculata* treated plant tend to be taller than other treatments (Table 2 and 3). Since the soil used in this experiment contained low available P (12 ppm), this phenomenon may due to the depletion of nutrient (phosphorus) by plant uptake.

Hayman (1983) indicated that at extremely low phosphorus availability, the benefit of arbuscular mycorrhiza symbiosis would be small, despite the host being limited by the supply of phosphorus. Under such condition, the development of the mycorrhiza symbiosis may represent no advantage to the host plant over the non-mycorrhizal state. Increasing phosphate fertilizer up to 90 kg P_2O_5 / ha, the height of mycorrhiza treated plant and the control were not significantly different at both stages of growth (Table 2 and 3).

Phosphorus had non-significant ($P< 0.05$) effects on the number of vetiver tiller whereas AM inoculations resulted in significant ($P<0.05$) effects on the averge tiller number at 1 week and at harvesting stage (Table 1). *G. aggregatum* inoculum gave the maximum tiller number (Table 4 and 5). Since mycorrhizal fungi can synthesize extracellular hormones such as cytokinin and auxin required by the host plant (Mayer, 1974), the ratio of cytokinin and auxin in the plant also affects plant height and the number of tillers. Cytokinin is known to stimulate shoot growth or tiller in plant. The result indicated

Table 1 Mean square value from ANOVA of plant height, the number of tillers per clump and biomass of vetiver grass (*Vetiveria Zizaniodes* L. Nash), Surat Thani ecotype inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 1 and 2 weeks after fertilizer application.

SV	DF	Height		Number of tiller		Biomass
		1 week	2 week	1 week	2 week	2 week
Treatment	15	6.86*	6.23*	6.77**	7.63 ns	0.503 ns
Mycorrhiza (V)	3	9.78*	6.55*	14.64**	20.52*	0.645 ns
Phosphate (P)	3	13.34**	14.43**	2.93 ns	3.14 ns	0.546 ns
V × P	9	3.89 ns	3.39 ns	5.42 *	3.84ns	0.441 ns
Error	48	2.852	2.662	2.359	8.380	0.406
C.V. (%)		11.0	8.4	23.1	34.6	12.4

Note : ** Significant at P = 0.01, * Significant at P = 0.05

Table 2 Plant height of vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 1 week after phosphate fertilizers were applied.

Treatments	Height (inch) /1 Phosphate fertilizer levels (P_2O_5 kg/ha)				Mean
	0	30	60	90	
Non AM	14.38 a /2	14.25 b	15.13 ab	17.13 a	15.22 b
Glomus sp.	13.88 a	15.38 ab	15.38 ab	14.75 a	14.84 b
G. aggregatum	14.75 a	12.88 b	14.25 b	16.88 a	14.69 b
A. scrobiculata	16.00 a	16.88 a	17.00 a	16.88 a	16.69 a
Mean	14.75 b /3	14.84 b	15.44 ab	16.41a	15.36

C.V. (%) = 11.0 LSD .05 V-means = 1.20, P-means = 1.20, V*P means = 3.20

Note : /1 means value from 4 replications

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that plant height was stimulated by *A. scrobiculata* whereas the maximum tiller number was obtained from *G. aggregatum* inoculated plant. This may due to the ability of some arbuscular mycorrhiza such as *G. aggregatum* in inducing the production of cytokinin in vetiver and altering the ratio of cytokinin and auxin in plant. Therefore, the protrusion of vetiver tiller in *G. aggregatum* inoculum was increased. The control plant at 1 week and at harvesting stage had 5.5 and 7.5 tillers/ clump respectively.

The maximum tiller number at 1 week stage

Table 3 Plant height of vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Height (inch) /1 Phosphate fertilizer levels (P_2O_5 kg/ha) 0	30	60	90	Mean
Non AM	18.63 ab /2	18.50 bc	19.00 a	19.75 a	18.97 b
Glomus sp.	17.50 b	19.75 ab	20.50 a	18.88 a	19.16 b
G. aggregatum	18.63 ab	16.75 cd	19.13 a	20.13 a	18.66 b
A. scrobiculata	20.13 a	20.88 a	21.13 a	21.00 a	20.78 a
Mean	18.72 b /3	18.97 ab	19.94 a	19.94 a	19.39

C.V. (%) =8.4 LSD .05 V-means = 1.16, P-means = 1.16, V*P means = 2.32

Note : /1 means value from 4 replications

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Table 4 Number of tiller per clump of vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 1 week after phosphate fertilizers were applied.

Treatments	Number of tiller per clump /1 Phosphate fertilizer levels (P_2O_5 kg/hectare) 0	30	60	90	Mean
Non AM	5.50 ab /2	7.25 a	5.75 b	5.75 b	6.06 bc
Glomus sp.	6.75 ab	6.00 a	7.00 b	8.25 a	7.00 ab
G. aggregatum	7.75 a	7.00 a	10.25 a	6.25 ab	7.81 a
A. scrobiculata (big)	5.25 b	5.25 a	6.00 b	6.25 ab	5.69 c
Mean	6.31 a /3	6.38 a	7.25 a	6.63 a	6.64

C.V. (%) = 23.1 $LSD_{.05}$ V-means = 1.09, P-means = 1.09, V*P means = 2.18

Note : /1 means value from 4 replications

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was found in *G. aggregatum* treated plant (10.25 tillers/clump) when vetiver grass was fertilized with 60 kg P_2O_5 / ha (Table 4). On the other hand, at 2 weeks stage, there was no significant (P< 0.05) difference affected by AM inocculation combined with phosphate fertilizer application (Table 1 and 5).

The enhancement of AM inoculum and phosphate fertilizer on total biomass or vetiver dry weight at harvesting stage were not significantly (P< 0.05) different (Table 1). When no phosphate was applied , those inoculated with AM in the plant receiving *A. scrobiculata* (5.48 g/clump), the highest dry matter was obtained which was not significantly different from the dry matter of *Glomus* sp., and *G. aggregatum* treatments (4.95 and 4.78 g/clmp, respectively) . The dry matter of the control plant tended to be the lowest (4.32 g/clump), however it also shown non significant different from *Glomus* sp. and *G aggregatum* treated plants (Table 6). Generally, the yield and growth of plants enhanced by mycorrhiza were higher than those in non-inoculated plants as reported by Ortus *et al.* (1996). However, the growth of host plant in this experiment in terms of tiller number and dry weight in some AM inoculums were not differed from the control. This may due to the limited time of growth since the plants were still small. On the other hand, if the growth period is extended, one might perceive the degradation of P-32 activity used in the experiment. Heijne *et al.* (1996) also reported that dry matter of herbs was higher in the control than in the AM inoculated plant. Plant fertilized with phosphate usually results in the increasing of plant dry matter yield. However, the yield of vetiver fertilized with various phosphate levels did not show significant (P< 0.05) difference among various treatments. Furlan and Berrier-Cardou (1989) reported that the presence of VA mycorrhiza inoculum has a stronger effect on the yield in the absence of phosphate than when phosphate was present.

Phosphorus in plant

The effects of AM inoculations and phosphate fertilizer on phosphorus (P) concentration and P-uptake of the plants were presented in Table 7 and 8, respectively. The phosphorus concentration and P-uptake of the control plant were 0.059% and 2.78 mg / clump, respectively. AM inoculation

Table 5 Number of tiller per clump of vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Number of tiller per clump /1 Phosphate fertilizer levels (P_2O_5 kg/hectare) 0	30	60	90	Mean
Non AM	7.50 a /2	8.50 a	7.75 a	6.25 a	7.50 b
Glomus sp.	7.75 a	9.25 a	8.50 a	9.75 a	8.81 ab
G. aggregatum	10.00 a	10.50 a	11.00 a	7.50 a	9.75 a
A. scrobiculata (big)	7.50 a	6.50 a	7.75 a	7.75 a	7.38 b
Mean	8.19 a /3	8.69 a	8.75 a	7.81 a	8.36

C.V. (%) = 34.6 LSD $_{.05}$ V-means = 2.06, P-means = 2.06, V*P means = 4.12

Note : /1 means value from 4 replications

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gave highly significant (P< 0.01) increased P-concentration of the vetiver shoot .Likewise, the uptake of P in the shoot of AM inoculated plant was also highly significant (P< 0.01) increased (Table 7). Among the 3 types of mycorrhizal treatments ,*A. scrobiculata* was the best inoculum to increase P-uptake (4.97 mg/clump) of vetiver On the other hand, the average concentration of P in *A. scrobiculata* plant (0.91%) was not differed from the other AM inocculations. However, when no P-fertilizer was applied, *G.aggregatum* inoculum tend to be the most superior in enhancing P concentration (0.104%) in the vetiver shoot. At 60 kg P_2O_5 / ha level of application, the highest P-uptake (6.25 g/ clump) was obtained in *A. scrobiculata* treated plant. Increasing the phosphate fertilizer up to 90 kg

Table 6 Plant biomass of vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Plant biomass (gm./clump) /1 Phosphate fertilizer levels (P_2O_5 kg/hectare) 0	30	60	90	Mean
Non AM	4.32 b /2	5.25 a	5.10 a	4.83 a	4.88 a
Glomus sp.	4.95 ab	5.45 a	5.33 a	5.35 a	5.27 a
G. aggregatum	4.78 ab	5.05 a	5.48 a	5.20 a	5.13 a
A. scrobiculata	5.48 a	5.30 a	4.77 a	5.75 a	5.32 a
Mean	4.88 a /3	5.26 a	5.17 a	5.28 a	5.15

C.V. (%) = 12.4 LSD $_{.05}$ V-means = 0.91, P-means = 0.91, V*P means = 0.91

Note : /1 means value from 4 replications

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Table 7 Mean square value from ANOVA of percentage of phosphorus (%P), total phosphorus (TP), percentage of phosphorus derived from fertilizer (% Pdff) and Fertilizer P Utilization (%FPU) in vetiver grass (*Vetiveria Zizaniodes* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after fertilizer application

SV	DF	% P	TP	% Pdff	% FPU
Treatment	15	0.000878**	3.915**	0.1119**	0.00164**
Mycorrhiza (V)	3	0.002984**	12.490**	0.2969**	0.00368**
Phosphate (P)	3	0.000585*	3.114*	0.0043 ns	0.00140**
V x P	9	0.000274 ns	1.323 ns	0.0552**	0.00070**
Error	48	0.000261	0.740	0.0094	0.00011
C.V. (%)		20.7	21.1	45.5	55.0

Note : ** Significant at P = 0.01, * Significant at P = 0.05

P_2O_5 / ha no significant effects of AM inocculums were observed (Table 8 and 9).

The percentage of P-32 derived from fertilizer and the P-availability in vetiver inoculated with various mycorrhizal species and AM inocculations combined with phosphate fertilizer showed significant ($P< 0.05$) difference among treatments (Table 7). Similarly phosphate fertilizer significantly increased P availability but did not significantly ($P< 0.05$) enhance the percentage of P derived from fertilizer . AM inoculation resulted in the increased percentage of P-32 derived from

Table 8 Percentage of phosphorus in vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Phosphorus (%) /1 Phosphate fertilizer levels (P_2O_5 kg/hectare)				Mean
	0	30	60	90	
Non AM	0.059 c /2	0.055 b	0.058 b	0.064 b	0.059 c
Glomus sp.	0.083 ab	0.066 ab	0.090 a	0.072 ab	0.078 ab
G. aggregatum	0.104 a	0.081 a	0.080 ab	0.075 ab	0.085 ab
A. scrobiculata	0.091 a	0.082 a	0.099 a	0.090 a	0.091 a
Mean	0.084 a /3	0.071 b	0.082 ab	0.075 ab	0.078

C.V. (%) = 20.7 LSD $_{.05}$ V-means = 0.012, P-means = 0.012, V*P means = 0.023

Note : /1 means value from 4 replications

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Table 9 Total phosphorus uptake (mg./clump) in vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Total Phosphorus uptake (mg./clump) /1 Phosphate fertilizer levels (P_2O_5 kg/hectare)				Mean
	0	30	60	90	
Non AM	2.78 b /2	2.96 b	2.64 c	3.06 a	2.86 c
Glomus sp.	4.06 a	3.56 ab	5.50 ab	3.81 a	4.23 b
G. aggregatum	4.83 a	4.03 ab	4.33 b	3.86 a	4.26 b
A. scrobiculata	4.92 a	4.34 a	6.25 a	4.38 a	4.97 a
Mean	4.15 ab /3	3.72 b	4.68 a	3.78 b	4.08

C.V. (%) = 21.1 LSD $_{.05}$ V-means = 0.61, P-means = 0.61, V*P means = 1.22

Note : /1 means value from 4 replications

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fertilizer and P availability. *A. scrobiculata* was the best inoculum to increase the percentage of P-32 derive from fertilizer (0.429% Pdff) , P availability (0.044% FPU*), and the effect of this mycorrhiza was clearly shown when low amount of P-fertilizer was applied to the soil (table 10 and 11).

Generally, mycorrhizal plant has greater P-content than non-mycorrhizal plant. The increased uptake of P may result from the increased absorbing area contributed by hyphae (Pearson and Tinker,

Table 10 Percentage of phosphorus derived from fertilizer (% P dff) in vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Phosphorus derived from fertilizer (% P dff *) /1 Phosphate fertilizer levels (P_2O_5 kg/hectare) 30	60	90	Mean
Non AM	0.074 b /2	0.051b	0.105 b	0.077 c
Glomus sp.	0.097 b	0.144 b	0.114 b	0.118 c
G. aggregatum	0.128 b	0.173 b	0.382 a	0.228 b
A. scrobiculata	0.483 a	0.545 a	0.257 a	0.429 a
Mean	0.196 a /3	0.228 a	0.214 a	0.213

C.V. (%) = 45.5 LSD $_{.05}$ V-means = 0.080, P-means = 0.069, V*P means = 0.139

Note : /1 means value from 4 replications

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Table 11 Fertilizer P- utilization (% FPU or A-value) in vetiver grass (*Vetiveria zizanioides* L. Nash, Surat Thani ecotype) inoculated with different types of mycorrhiza and different levels of phosphate fertilizer at 2 weeks after phosphate fertilizers were applied.

Treatments	Fertilizer P Utilization (% FPU *) /1 Phosphate fertilizer levels (P_2O_5 kg/hectare) 30	60	90	Mean
Non AM	0.006 c /2	0.002 b	0.004 a	0.004 c
Glomus sp.	0.012 bc	0.012 b	0.005 a	0.010 bc
G. aggregatum	0.023 b	0.013 b	0.016 a	0.017 b
A. scrobiculata	0.075 a	0.037 a	0.019 a	0.044 a
Mean	0.029 a /3	0.016 b	0.011 b	0.019

C.V. (%) = 55.0 LSD $_{.05}$ V-means = 0.008, P-means = 0.007, V*P means = 0.0147

Note : /1 means value from 4 replications

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* = This data derived from P-32 analysis.

1975) and root growth with greater affinity of site transporting phosphate (Cress *et al*., 1979). An enhanced P-sink was caused by higher photosynthetic rate accompanying mycorrhizal infection, and increased phosphate activity (Allen *et al*., 1981). Gianinazzi and Gianinazzi (1986) reported that in P-deficient soil, mycorrhizal was shown to enable exploitation of non-labile organic phosphate to inorganic available from the soil by excretion of phosphatase enzyme, therefore plant growth was improved.

Increasing phosphate fertilizer upto 90 kg P_2O_5 / ha resulted in non-significant ($P< 0.05$) effects of AM inoculum on P-uptake and P-availability. It was clear that at high P-level, the effect of mycorrhiza on plant growth was not observed. This was due to the reduction of the effectiveness of mycorrhizal fungi by phosphate (Smith, 1980), and may change from mutualism to parasitism to endophyte-host relationship as phosphorus availability increased (Crush, 1976). Under such condition mycorrhizal may not contribute to the plant growth. The result showed that radioisotope tracer technique provides better indexes of phosphorus availability and P- uptake of the vetiver plant and also is a good method for selecting effective mycorrhiza species to improve the growth and P- uptake of the vetiver.

CONCLUSION

From the results of this study :

1. Arbuscular mycorrhizal inoculum significantly affects height, tiller number, and vetiver Biomass. *A. scrobiculata* inoculum gave the greatest height and vetiver biomass whereas the maximum tiller number was obtained from *G. aggregatum* treated plant.

2. Plant biomass was not significantly effected by AM inoculation, phosphate fertilizer and AM inocculation combined with P-fertilizer supplied. Howerver, when no P-fertilizer was applied *A. scrobiculata* tended to give greater plant dry matter than other treatments.

3. AM inocculation significantly increased P-concentration, P-uptake,% P derived from fertilizer and P- availability of vetiver. At 60 kg P_2O_5/ha level of application, the highest P-uptake,% P derived from fertilizer and P- availability were obtained from *A. scrobiculata* treated plant ,while the highest P-concentration of vetiver was obtained from *G. aggregatum* treatment with no P-fertilizer supplied.

4. Increasing P- fertilizer upto 90kg/ha, non significant effects of AM inocculation on P-concentration, P-uptake,% P derived from fertilizer and P- availability of vetiver were observed.

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