THE RELATIONSHIP BETWEEN SOIL MICRO-ORGANISMS AND NUTRIENT ELEMENTS OF *VETIVERIA ZIZANIOIDES* AND *VETIVERIA NEMORALIS* IN SOME PROBLEM SOILS OF THAILAND

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Abstract

The relationship between soil micro-organisms and nutrient contents in soils cultivated with Vetiveria zizanioides *and* Vetiveria nemoralis *was studied. The study was carried out in the context of different types of vetiver grass and different problem soils in Thailand, namely the acid-sulphate soil area in Nakhon Nayok Province, the shallow soil area in Ratchaburi Province and the saline soil area of Kalasin Province. The results were compared to areas that were not planted with vetiver grass. The results showed that the populations of effective micro-organisms in both the* Vetiveria zizanioides *and* Vetiveria nemoralis *rhizospheres in the three planted sites increased. Cellulolytic bacteria, cellulolytic fungi and cellulolytic actinomycetes increased from 5.58-6.70, 2.59-3.16 and 5.41-5.70 log no./g in soil without vetiver grass to 6.00-8.89, 3.18-4.98 and 5.60-8.64 log no./g in soil with vetiver grass respectively. Free-living N-fixing microbes increased from 1.00-2.56 to 2.60-4.36 log no./g in the soil. Phosphate solubilizing micro-organisms changed from 1.04-2.39 to 2.17-3.87 log no./g; endomycorrhizal fungi ranged from 26-143 cell/5 mm length of root in five pieces of vetiver root. The chemical properties of the soil, organic matter, macronutrients, micronutrients and moisture content changed after one year of planting vetiver grass; organic matter and N increased from 0.31-2.34 and 0.008-0.140% to 0.49-2.62 and 0.016-0.239%. Phosphorus and K content increased from 1.75-5.03 and 32-163 ppm to 3.27-6.96 and 51-247 ppm respectively in comparison with the non-planted area. The correlation coefficient indicated that the micro-organism responsible for changing nutrient elements in* Vetiveria zizanioides *soil was arbuscular mycorrhizal fungi; this related significantly to prediction of P increment by multiple linear regression (R^2 = 0.698). Furthermore, organic matter showed a positive correlation with plant nutrient elements and was highly influential in the changing of N, P and Mg (R^2 = 0.933, 0.899 and 0.944 respectively). In* Vetiveria nemoralis *phosphate-solubilizing bacteria significantly correlated with increasing nutrient elements in the soil especially the positive effect of releasing available P; P change could be predicted (R^2 = 0.868). Additionally, the total amount of organic matter had close positive correlation to N, P and moisture content (R^2 = 0.899, 0.788 and 0.951 respectively).*

Introduction

The main agricultural constraints in Thailand are infertile and degraded soil generated by inappropriate utilization of soil resources and soil erosion from deforestation; this has resulted in decreasing crop yields and poverty among farmers. Vetiver grass is regarded as a "miracle" plant; it has a deep and dense root system which can penetrate vertically in a wall-like form into the soil. It is also tolerant to adverse conditions such as infertile lateritic soil or flooding. The Sri Lanka ecotype in particular, grows well in saline and acid sulphate soils (Yoon 1991; Sunantapongsuk 2001; Pongwichian 1999). The potential value of vetiver grass for soil and water conservation is its extensive root systems that penetrate and bind soil

Keywords: *micro-organisms*, Vetiveria zizanioides, Vetiveria nemoralis, *vetiver grass, rhizospheres*

particles tightly; this prevents soil erosion and maintains soil moisture content. For this reason, the King of Thailand has stimulated government agencies to study and research the benefits of vetiver grass especially for soil and water conservation, reclamation of infertile soil and environmental protection. Soil micro-organisms and their activities have important roles in the transformation of plant nutrients to available forms; and also have many metabolic qualities that are related to soil-fertility improvement. Microbial populations and activities are higher in the rhizosphere of vetiver grass than outside the rhizosphere. Changes in chemical, physical and biological soil properties are being studied and microbial activities in the rhizosphere are being promoted to increase soil fertility. Several types of micro-organism in the rhizosphere decompose organic matter and release several plant nutrients; they accelerate P absorption and biological control of some plant pathogens. The objectives of this research focused on the changes and relationships between biological and chemical soil properties in the rhizosphere of vetiver grass under various problematic soil conditions.

Materials and methods

Experimental site: *Vetiveria zizanioides* such as South India, Fiji, Prarachathan, Monto, Sri Lanka, Surathani and Songkhra ecotypes and *Vetiveria nemoralis* such as Prachuabkhiri Khan, Khampangphet, Rachaburi and Nakhonsawan ecotypes were planted in problem soils of Thailand.

Three locations were selected, namely acid sulphate soil in the central plain in Nakhon Nayok Province (Ongkharak soil series), shallow soil in the lower part of the central plain in Ratchaburi Province (Tha Yang soil series) and saline soil in the northeastern part of Kalasin Province (Roi-Et saline variant soil series) as shown in Figure 1.

Experimental design: Randomized complete block design with spacing between plants and rows of vetiver of 50 x 50 cm. The plots without vetiver grass were treated as control.

Data collection: Soil samples were taken in April, August and December from the experimental plots with and without vetiver grass after one year of planting at 0-30 cm soil depth for biological and chemical soil property analyses.

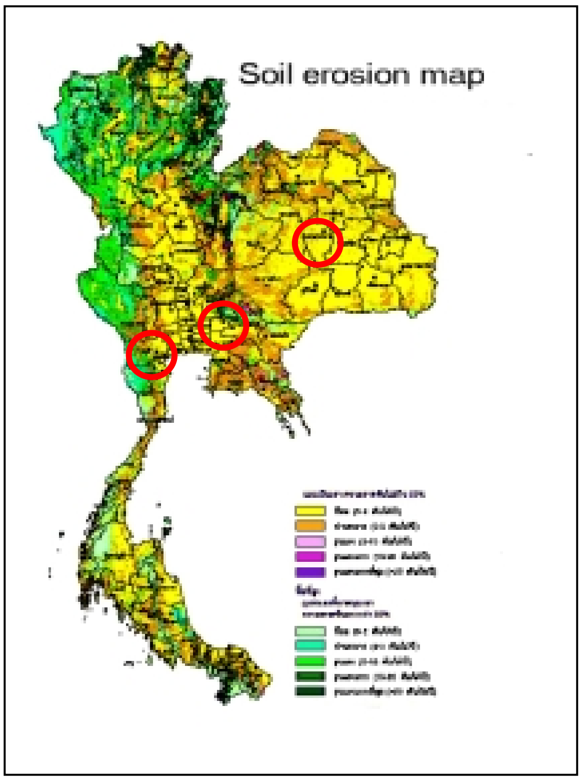


Figure 1. Soil erosion map of Thailand and location of the three experimental sites

Results and discussion

Soil characteristics

Soil characteristics of the three soil series were determined. The chemical properties are shown in Table 1. The acid sulphate soil (Ongkharak soil series) occurs in the central plain and the pH is very low; it is used for rice cultivation and the organic matter content is high at 1.8%. The shallow soil (Tha Yang soil series) is found in the lower part of the central plain; it is used for pineapple and upland crops. The pH is around 5.0 and organic matter content is slightly low at 0.52%. The saline soil (Roi-Et soil series saline variant) occurs in the northeastern part of the country, which has infertile and sandy soil. It is used for rice cultivation in the lowlands and maize, cassava or other crops in the uplands; organic matter and major plant nutrient contents in this soil are very low.

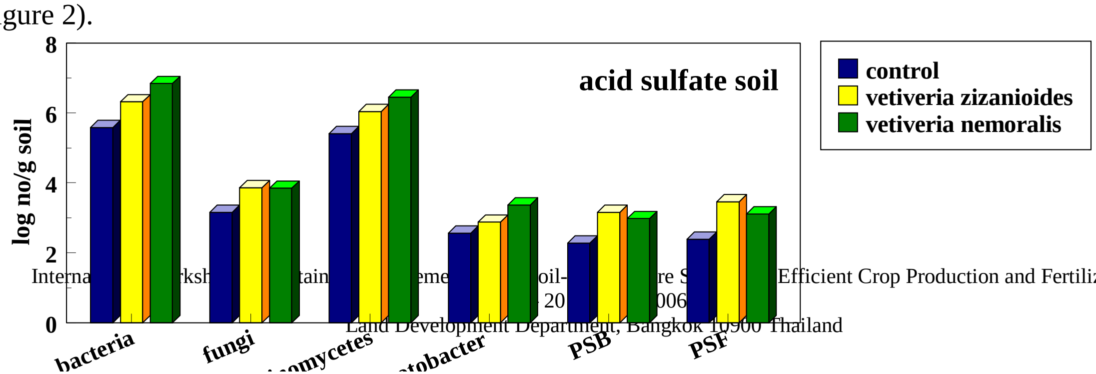
Table 1. Soil characteristics of the Ongkharak, Tha Yang and Roi-Et (saline variant) soil series

Soil series	Soil family	pH	OM (%)	P_2O_5 (ppm)	K_2O (ppm)	ECe (ds/m)
Ongkharak	Sulfic Tropaquepts, very fine, mixed, acid	4.0	1.80	4.5	148	1.1
Tha Yang	Oxic Haplustults, clayey-skeletal, kaolinitic	5.0	0.52	2.2	98	0.9
Roi-Et saline variant	Aeric Halaquept, fine-loamy, mixed	5.5	0.26	1.6	3.0	14.5

Change in soil biological properties

The soil of the three vetiver grass plots showed higher microbial populations than the control. This is attributed to exudates from vetiver fibrous roots secreting into the rhizosphere which contains organic substances such as soluble carbohydrates, organic acids, amino acids and growth hormones. These exudates serve as nutrient and energy sources for the growth of micro-organisms in the rhizosphere (Russell 1982; Lynch 1990). However, the populations of bacteria and actinomycetes were usually higher than fungi in the three soil types as shown in Figure 2. With regard to specific micro-organisms, cellulolytic micro-organisms, especially bacteria and non-symbiotic N-fixing bacteria in the rhizospheres of both *Vetiveria zizanioides* and *Vetiveria nemoralis* increased when compared to unplanted vetiver grass. From 5.58 to 6.32 and 6.84 and from 2.56 to 2.88 and 3.37 log no./gm of soil in acid sulphate soil respectively. In shallow soil they increased from 5.74 to 8.31 and 7.32 and 1.00 to 3.90 and 3.49 log no./gm of soil respectively. In saline soil they increased from 6.7 to 7.67 and 1.51 to 3.31 log no./gm of soil respectively as shown in Figure 2.

The population of phosphate-solubilizing micro-organisms (PSM) in the rhizosphere rose in comparison with the control plot; the PSM population in the acid sulphate soil increased from 2.28-2.39 to 2.98-3.46 log no./gm of soil, in the shallow soil from 1.04-1.60 to 2.24-3.55 log no./gm of soil and in the saline soil from 1.51-1.68 to 3.01-3.06 log no./gm of soil. Moreover the population of chlamydospores of endomycorrhizae in the acid sulphate soil was increased from 2 to 6-7 spores/100 gm of soil, in the shallow soil from 1 to 5-8 spores/100 gm of soil and in the saline soil from 3 to 29 spores/100gm soil (Figure 2).



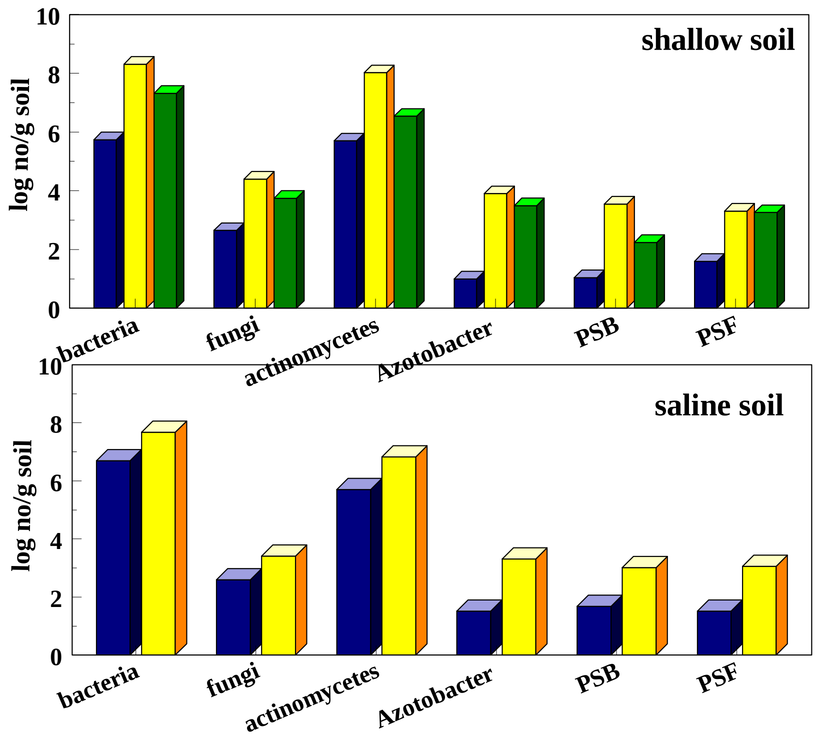


Figure 2. Change in micro-organism populations in the vetiver rhizosphere of some problem soils

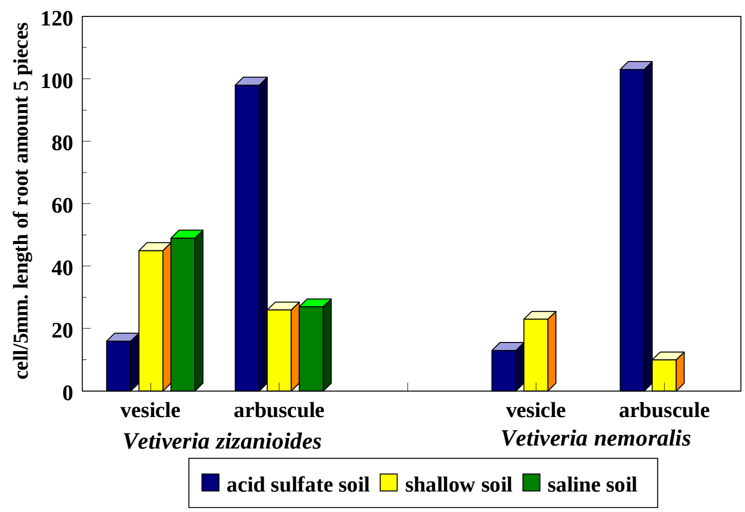


Figure 3. Change of VAM population in the vetiver roots of some problem soils

Vesicular-arbuscular mycorrhizal fungi (VAM) ranged between 13-16 and 113-117 cells in the acid sulphate soil, 23-45 and 10-26 cells in the shallow soil 27-49 cells in the saline soil as shown in Figure 3. These parameters were derived from a 5-mm length of vetiver root (in five different pieces) and were attributable to hyphae germinating from the spore and then penetrating the root cells which formed numerous VAM. This was the structure for the accumulation of nutrient sources, especially P (Ogawa 1994)

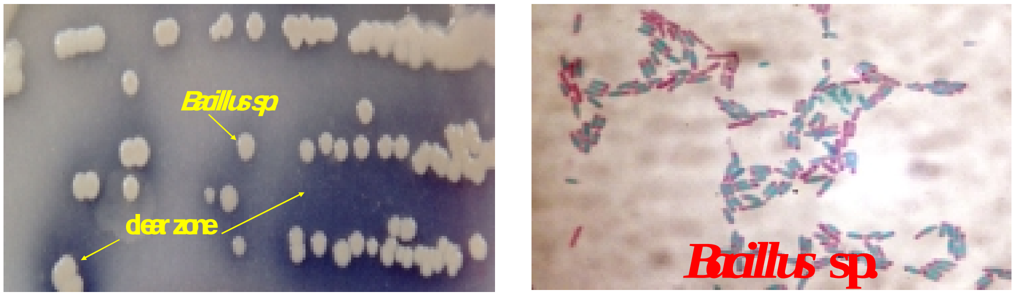


Figure 4. Clear zone by secreting organic acid to solubilize insoluble phosphorus of phosphate solubilizing bacteria (PSB) and morphology under a microscope

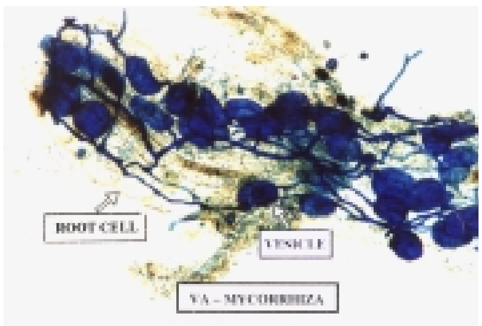


Figure 5. Morphology of VAM within the vetiver root

Change in soil chemical properties

The average content of soil organic matter in the acid sulphate soil was 2.34%; this increased to 2.49% in soil planted with *Vetiveria zizanioides;* the average content of organic matter increased to 2.47% in the soil planted with *Vetiveria nemoralis.* In the shallow soil average organic matter content was 0.58% and this increased to 1.00% and 0.97% in soil planted with *Vetiveria zizanioides* and *Vetiveria nemorali*, respectively.

The average content of N, P, K in the soil planted with two species of vetiver grass was not different but was higher than the control plot; in the acid sulphate soil N content increased from 0.14 to 0.19-0.21%, P content from 5.03 to 6.24-6.36 ppm and K content from 163 to 188-214 ppm. In the shallow soil, N content increased from 0.01 to 0.02 %, P from 2.07 to 4.59-4.82 ppm and K from 103 to 154 ppm. Moreover, in the saline soil, N content ranged from 0.01 to 0.02%, P from 1.75 to 3.28 ppm and K from 32 to 52 ppm (Table 2).

Table 2. Change of organic matter and macronutrient content in the vetiver rhizosphere

Soil type	Without vetiver grass				*Vetiveria zizanioides*				*Vetiveria nemoralis*			
	OM (%)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	OM (%)	N (%)	P_2O_5 (ppm)	K_2O (ppm)	OM (%)	N (%)	P_2O_5 (ppm)	K_2O (ppm)
Acid sulfate	2.34	0.14	5.03	163	2.49	0.21	6.36	214	2.47	0.19	6.24	188
Shallow	0.58	0.01	2.07	103	1.00	0.02	4.82	154	0.97	0.02	4.59	154
Saline	0.49	0.01	1.75	32	0.44	0.02	3.28	52	--	--	--	--

Most micronutrient contents at the three sites were increased, whereas S content in the acid sulphate soil decreased; Ca content increased from 782 to 887-951 ppm, Mg content from 1,121 to 1,134-1,460 ppm, while S content decreased from 102 to 78-80 ppm. For shallow and saline soils, Ca increased from 271 to 513-523 and 92 to 125 ppm, Mg from 345 to 556-570 and 132 to 171 ppm and S from 0.83 to 1.68-1.84 and 1.21 to 2.34 ppm (Table 3). Soil chemical properties changed after one year of planting vetiver grass because of increasing microbial population in the rhizosphere that transformed inorganic substances to available nutrients or decomposed organic substances from root residue to raise humus content in the soil (Tate 1995).

Table 3. Change in micronutrient and soil moisture content in the vetiver rhizosphere

Soil type	Without vetiver grass				*Vetiveria zizanioides*				*Vetiveria nemoralis*			
	Ca ppm	**Mg ppm**	**S ppm**	**MC %**	**Ca ppm**	**Mg ppm**	**S ppm**	**MC %**	**Ca ppm**	**Mg ppm**	**S ppm**	**MC %**
Acid sulphate	782	1,121	102	26.1	951	1,460	78	22.8	887	1,134	80	23.0
Shallow	271	345	0.83	5.83	513	570	1.84	8.63	523	556	1.68	7.15
Saline	92	132	1.21	7.17	125	171	2.34	9.76	--	--	--	--

Soil moisture in the vetiver rhizosphere of shallow and saline soil was raised from 5.83 to 7.15-8.63 and 7.17 to 9.76% because the dense fibrous root system conserved water; moisture content was increased in both problem soils, but moisture content in the acid sulphate soil was decreased from 26.1 to 22.8-23.0% (Table 3), due to increased soil aggregation and soil aeration.

Correlation analysis

The correlation coefficient between the population of some specific micro-organisms and some plant nutrients in the vetiver rhizosphere was analyzed. The *Vetiveria zizanioides* group indicated that VAM changed nutrient elements; this related significantly to P increment by multiple linear regression (R^2 was 0.698). Cellulolytic micro-organisms, non-symbiotic N-fixing microbes and PSM were not correlated to macro- and micronutrient changes. Organic matter showed positive correlation with plant nutrient elements and significantly influenced changes in N, P and Mg (by R^2 0.933, 0.899 and 0.944, respectively, Figure 6).

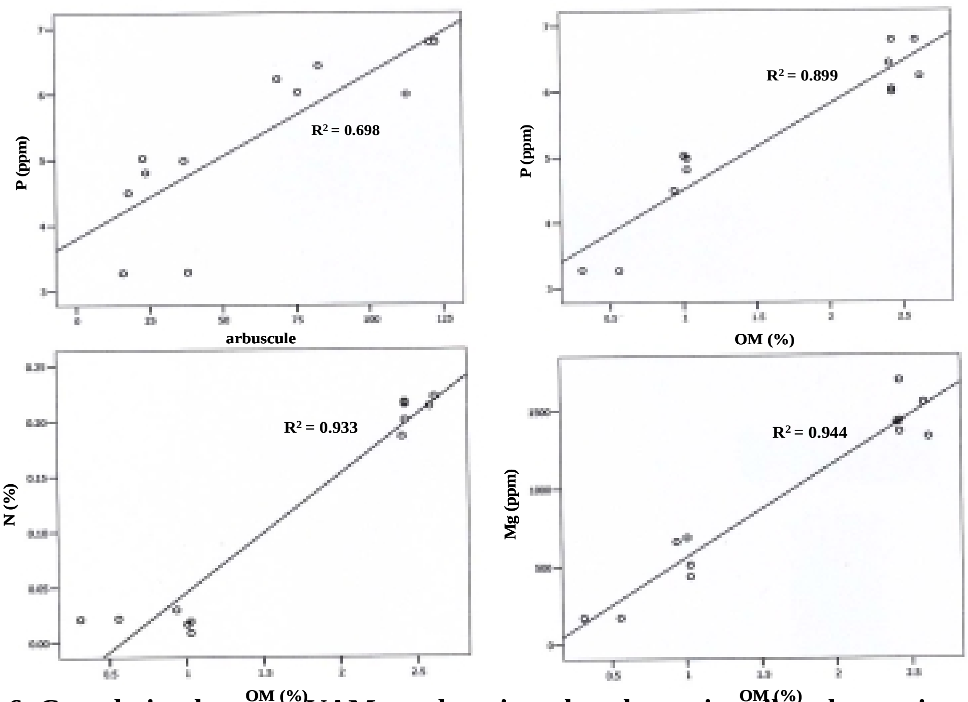


Figure 6. Correlation between VAM on changing phosphorus in soil and organic matter correlated with plant nutrients of *Vetiveria zizanioides*

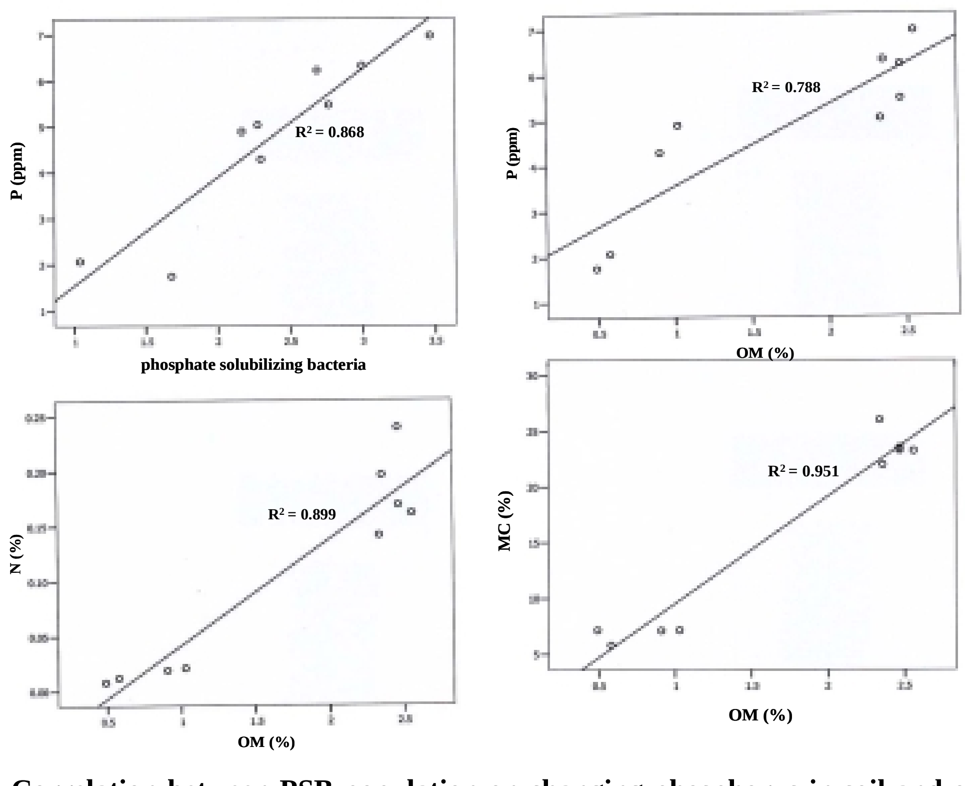


Figure 7. Correlation between PSB population on changing phosphorus in soil and organic matter correlated with macronutrient and soil moisture content of *Vetiveria nemoralis*

The correlation coefficient between several kinds of *Vetiveria nemoralis* and control revealed that the PSB population significantly correlated with increased nutrients in the soil, especially the release of available P; P change could be predicted by multiple linear regression (R^2 was 0.868). Additionally, the total content of organic matter had a close positive correlation with N, P and moisture content (R^2 were 0.899, 0.788 and 0.951, respectively, Figure 7). Other nutrient increments did not correlate to increase of organic matter.

Conclusion

The populations of soil micro-organisms in the vetiver rhizosphere (*Vetiveria zizanioides* and *Vetiveria nemoralis*) of acid sulphate soil, shallow soil and saline soil were higher than those of the control. Microbial populations adjacent to the vetiver roots in *Vetiveria zizanioides* and *Vetiveria nemoralis* soil were not different in the acid sulphate soil but micro-organisms in the rhizosphere of *Vetiveria zizanioides* were higher than *Vetiveria nemoralis* in the shallow soil. Total macronutrient, micronutrient, organic matter and moisture contents in the three problem soils were higher in two vetiver ecotype plantations than control. VAM changed nutrient contents in the *Vetiveria zizanioides* rhizosphere and PSB acted likewise for *Vetiveria nemoralis*, which related significantly to P increment. Organic matter content in the rhizosphere of *Vetiveria zizanioides* significantly influenced N, P and Mg content but for *Vetiveria nemoralis*, organic matter was correlated closely and positively to N, P and moisture content.

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