山形大学紀要（農学）第10巻　第3号：557-562. 昭和63年1月
Bull. Yamagata Univ., Agr. Sci., 10(3) : 557-562. Jan. 1988

# Vesicular-Arbuscular Mycorrhizal Infection in Plants Grown in Yamagata Prefecture

Keitaro TAWARAYA, Satoshi MAEDA, Tadao WAGATSUMA and Renzo HONNMA

Laboratory of Soil Science and Fertilizer Science, Faculty of Agriculture, Yamagata University, Tsuruoka 997, Japan
(Received September 1, 1987)

**Summary**

Maize, soybean, orchardgrass and Japanese dock were collected from common upland field, rotational upland field, grassland and native pasture to survey vesicular-arbuscular (VA) mycorrhizal infection and to identify the factors affecting infection. VA mycorrhizal infection was observed in Sand-dune Regosols, Andosols, Brown Forest soils, Brown Lowland soils, Glay Lowland soils and Gley soils. The mean value of percentage infection was 26% in Japanese dock, 24% in soybean, 18% in orchardgrass and 11% in maize. The percentage infection of orchardgrass negatively correlated with phosphorus content of tops. There was no correlation between phosphorus content and percentage infection in other plants. The percentage infection of soybean and Japanese dock negatively correlated with Mg content of tops. From the results described above, it can be pointed out that more detailed mechanisms that phosphorus concentration of plant and other factors excepting phosphorus affect the mycorrhizal infection will be investigated.

## Introduction

The improvement of phosphorus uptake and plant growth by vesicular-arbuscular (VA) mycorrhiza is now well known in many crop plants under the pot experiments and the field trials[1~3]. The promotive effect on the plant growth is recognized clearly in the phosphorus-deficient soils than in the phosphorus-sufficient soils. The application of phosphate fetilizers to soils often decreases the mycorrhizal infection of plant roots[4)5)] : this inhibitory effests on mycorrhizal fungi is accepted to be arised not from the high phosphorus status of the soil but from that of the host plant[6)7)].

In Japan, however, as the level of available phosphorus in upland field soils is relatively high as a result of the heavy fertilizer dressing, the beneficial use of VA mycorrhiza may hardly be expectant. There are few studies on the effect of VA mycorrhiza on the plant growth and phosphorus uptake. The grassland soils in Japan, on the contrary, contain a relatively smaller amount of available phosphorus than the upland field soils, and therefore the improvement of the plant growth with VA mycorrhiza will be anticipated.

This study was undertaken (i) to survey the degree of VA mycorrhizal infection and (ii) to identify some factors affffecting the mycorrhizal infection concerning the four plant species grown in the soils of different fertility in Yamagata prefecture, the northeast of Japan.

## Materials and Methods

Four plant species were examined, namely, Maize (*Zea mays* L.), Soybean (*Glycine max* L.), Orchardgrass (*Dactylis glomerata* L.), Japanese dock (*Rumex japonicus* Houtt). Each of the plant and soil were collected from the common upland fields, the rotational upland fields, the grasslands and the native pastures in August, 1986. The roots and the soil samples were stored at 4℃ until use. Tops were washed carefully and dried.

The roots samples were gently washed with tap water, cleared with 10% KOH, acidified with 1% HCl[8] and finally stained with 0.05% trypanblue-lactic acid staining solution[9]. The stained roots were cut into 0.5 cm segments. Root segments randomly selected were mounted on the slide glass : the degree of mycorrhizal infection was determined by slide± methods[10]. The soil samples were airdried. Soil pH ($H_2O$)(soil : water= 1 : 2.5) was measured with a glass electrode. Available phosphorus of soil was extracted with 0.002 N $H_2SO_4$ at pH 3.0 and determined the phosphate in the solution colorimetrically[15]. Total phosphorus of the soil was determined colorimetrically by the vanado molybdate method after the digestion with $HNO_3-HClO_4-H_2SO_4$ mixture. Dry matter of plant tops was ground and digestid with a $HNO_3-HClO_4-H_2SO_4$ mixture. The content of phosphorus was determined colorimetrically by the vanado molybdate yellow method and K, Ca and Mg were determined by atomic absorption spectrophotometric method.

## Results and Discussion

*Characteristics of soils, the mineral status of plant tops, and the degree of mycorrhizal infection*

Maize

The collected soil samples belonged to Andosols, Brown Forest soils, Glay lowland soils and Gley soils (Table 1). The latter two soils were cultivated as a rotational upland field. The mean values of soil pH and of available phosphorus of soil were 5.7 and 45.6 mg $P_2O_5$/100 g dry soil, respectively. Gley soils contained much more available phosphorus and total phosphorus than the other soil groups did. The percentage infection was the lowest among four plant species. The phoshphorus content of tops was similar to that of soybean and orchardgrass. Little difference was recognized in magnesium content of tops of the whole maize sample.

Soybean

Table 1. Some characteristics of soils and plant tops, and mycorrhizal infection

| Plant species in each soil group | Number of soil samples | Soil properties | | | % root infected (%) | nutrients content of plant top | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | pH | Available P ($mgP_2O_5$/100 g) | Total P | | P | K (%) | Ca | Mg |
| Maize(whole) | 12 | 5.7 | 45.6 | 104.6 | 11 | 0.29 | 3.49 | 0.17 | 0.18 |
| Andosols | 3 | 5.5 | 17.4 | 102.3 | 14 | 0.25 | 3.26 | 0.20 | 0.17 |
| Brown Forest soils | 3 | 5.4 | 52.1 | 86.9 | 9 | 0.34 | 4.28 | 0.14 | 0.19 |
| Gray Lowland soils | 3 | 5.7 | 32.7 | 87.3 | 13 | 0.23 | 2.95 | 0.17 | 0.17 |
| Gley soils | 3 | 6.3 | 80.5 | 141.9 | 9 | 0.36 | 3.50 | 0.18 | 0.19 |
| Soybean(whole) | 18 | 5.5 | 56.0 | 94.9 | 24 | 0.30 | 2.74 | 0.75 | 0.43 |
| Andosols | 7 | 5.4 | 26.4 | 110.0 | 37 | 0.25 | 2.77 | 0.71 | 0.38 |
| Brown Forest soils | 5 | 5.5 | 68.4 | 77.3 | 17 | 0.32 | 3.15 | 0.66 | 0.49 |
| Brown Lowland soils | 3 | 6.6 | 107.7 | 100.1 | 19 | 0.41 | 2.92 | 0.83 | 0.39 |
| Sand-dune Regosols | 3 | 5.3 | 52.5 | 83.9 | 7 | 0.30 | 1.81 | 0.88 | 0.50 |
| Orchrdgrass(whole) | 14 | 6.5 | 20.9 | 78.2 | 18 | 0.32 | 3.31 | 0.24 | 0.24 |
| Andosols | 9 | 5.7 | 22.4 | 86.4 | 19 | 0.31 | 3.33 | 0.29 | 0.25 |
| Brown Forest soils | 4 | 5.2 | 11.2 | 64.1 | 20 | 0.31 | 3.18 | 0.16 | 0.23 |
| Brown Lowland soils | 1 | 6.5 | 46.6 | 61.7 | 6 | 0.42 | 3.71 | 0.12 | 0.26 |
| Japanese dock(whole) | 13 | 5.6 | 17.4 | 86.3 | 26 | 0.20 | 2.80 | 0.37 | 0.42 |
| Andosols | 8 | 5.9 | 10.7 | 96.6 | 28 | 0.25 | 3.06 | 0.45 | 0.47 |
| Brown Forest soils | 5 | 5.1 | 28.3 | 69.9 | 21 | 0.13 | 2.38 | 0.23 | 0.34 |
| Whole sample | 57 | 5.6 | 36.4 | 90.9 | 20 | 0.28 | 3.05 | 0.41 | 0.33 |

Soybean was collected from Andosols, Brown Forest soils, Brown Lowland soils and Sand-dune Regosols. The mean value of soil pH was 5.5 and available phosphorus, especially in Brown lowland soils, was highest among the whole soil sample (Table 1). The mean value of percentage infection was 24% and the highest percentage infection was observed in Andosols. The difference in percentage infection was clearly identified among soil groups. The calcium content of soybean tops was considerably higher than that of the other plants.

Orchardgrass

Orchardgrass was collected from Andosols, Brown Forest soils and Brown Lowland soils. The mean value of soil pH was highest among the whole soil sample, but on the other hand, that of available phosphorus was low (Table 1). The mean value of percentage infection was 18%. The phosphorus content of orchardgrass tops was a little higher than of the other plant tops.

Japanese dock

Japanese dock which was selected as the representative of common wild herbs in Yamagata Prefecture was collected from Andosols and Brown Forest soils. Available phosphorus of soils was lowest among the whole soil sample (Table 1). Total phosphorus of soils was almost similar in the whole soil sample. The percentage infection was highest among the whole plant sample. The phosphorus concentration in tops was lowest in Japanese dock. Other nutrient contents of Japanese dock tops in Andosols were higher than in Brown Forest soils.

*The relationship between the degree of mycorrhizal infection, the mineral status of plants tops and of soils*

The available phosphorus of the orchrdgrass-grown soils ranged from 1.3 to 88.3 mg $P_2O_5$/100 g and most soils contained less phosphorus than 30 mg (Fig. 1). The phosphorus content of orchardgrass tops increased linearly with available phosphorus. The percentage infection decreased with phosphorus content of tops (Fig. 2). Negative correlation was recognized between phosphorus content of orchardgrass tops and percentage infection. Percentage infection was negatively correlated with available phosphorus of soil (Fig. 3). Total soil phosphorus ranged from 29.9 mg to 135.0 mg and no correlation was recognized beween percentage infection and total phosphorus of soil (Fig. 4). This suggests that the total phosphorus

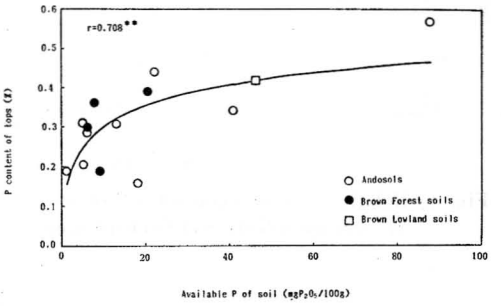


Fig. 1. Relationship between availabie P of soil and P content of tops of Orchardgrass. (** Significantly different at 1% level)

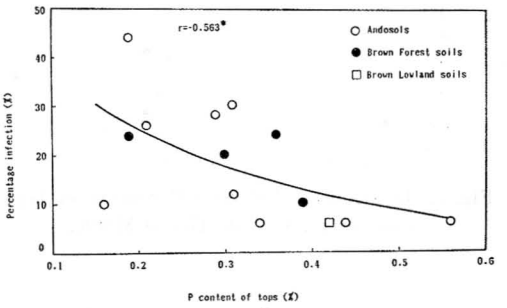


Fig. 2. Relationship between P content of tops and percentage infection of Orchardgrass. (** Significantly different at 5% level)

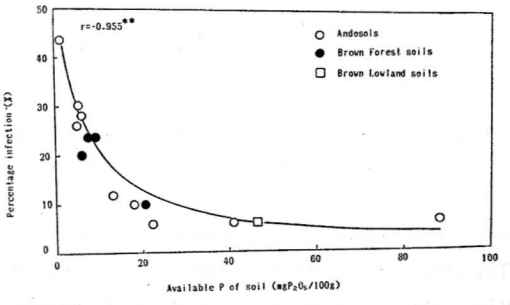


Fig. 3. Relationship between available P of soil and percentage infection of Orchardgrass. (** Significantly different at 1% level)

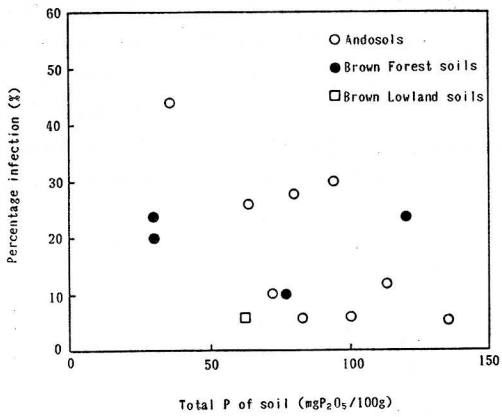


Fig. 4. Relationship between total P of soil and percentage infection of Orchardgrass.

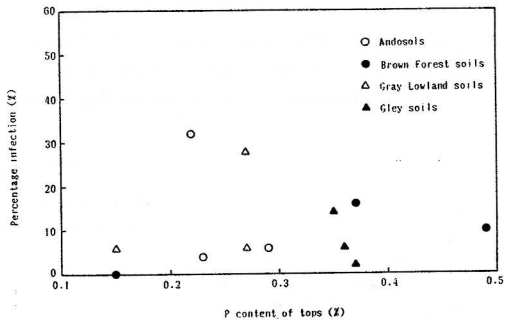


Fig. 5. Relationship between P content of tops and percentage infection of Maize.

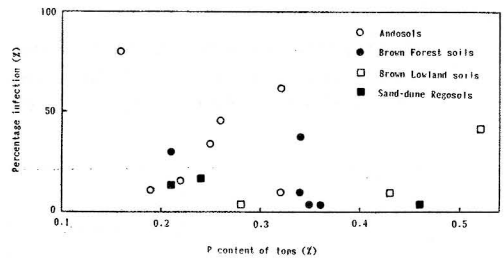


Fig. 6. Relationship between P content of tops and percentage infection of Soybean

of soil may not affect mycorrhizal infection directly. The phosphorus contents of maize tops ranged from 0.15 to 0.49% and did not correlate with percentage infection (Fig. 5). Soybean tops contained 0.16–0.52% phosphorus but no correlation was recognized

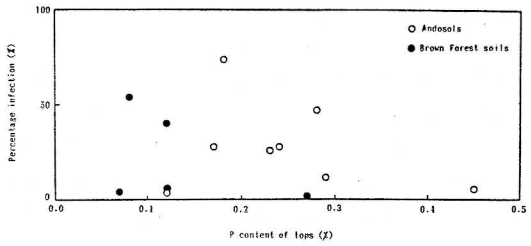


Fig. 7. Relationship between P content of tops and percentage infection of Japanese dock.

between phosphorus content of soybean tops and percentage infection (Fig. 6). Available phosphorus in Japanese dock-grown soils was low as in orchardgrass-grown soils. No correlation was recognized between phosphorus content of Japanese dock tops and percentage infection (Fig. 7). Moreover, no correlation was recognized between soil pH and percentage infection in the whole sample.

VA mycorrhizal infection was reported to decrease with available phosphorus of soil under the pot expriments and the field trials[11~13]. But in the farmer's soils of the diffrent fertility no correlation between percentage infection and levels of nitrogen and phosphorus in soils was also reported[14]. Factors, namely, the other nutrients level, soil moisture and application of agricultural chemicals, may affect mycorrhizal infection. Such factors were not determined in this experiment. In grassland available phosphorus of soils was less than in soils grown other plant and therefore other input might be low. It was conclusively pointed out that phosphorus content of tops affected mycorrhizal infection.

Effect of other nutrients on mycorrhizal infection has little been known. No correlations between K and Ca contents of tops and percentage infection were recognized in all four plants. In maize and orchardgrass, there were no correlations between Mg content of tops and mycorrhizal infection. For soybean and Japanese dock grown in Andosols, negative correlations were recognized between Mg content of tops and infection (Fig. 8 and 9).

Aknowledgement. We would like to thank Messrs

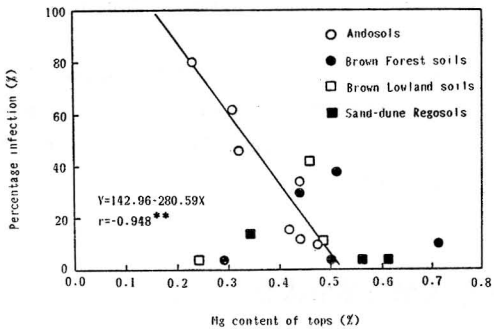


Fig. 8. Relationship between Mg content of tops and percentage infection of Soybean.
(** Significantly different at 1% level)

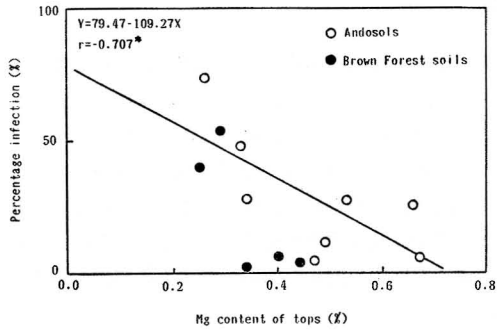


Fig. 9. Relationship between Mg content of tops and percentage infection of Jahanese dock.
(* Significantly different at 5% level)

K. Watanabe and M. Konno of the Yamagata Prefectural Agriculutural Experiment Station for the collection of samples from Shonai and Saihoku district, respectively.

## References

1) Mosse, B. : Advances in the study of vesicular-arbuscular mycorrhiza, Ann. Rev. Phtopathol., **11**, 171-186 (1973)
2) Gerdemann, J. W. : Vesicular-arbuscular mycorrhiza ; in The Development and Function of Roots, ed. J. G. TORREY and D. T. CLARKSON, p. 575-591, Academic Press, London (1975)
3) Hayman, D. S. : Practical Aspects of vesicular-arbuscular mycorrhiza ; in Advances in Agricultural Microbiology, ed. N, S, SUBBA RAO, p. 325-373 (1982)
4) Hayman, D. S. : The occurrence of mycorrhiza in crops as affected by soil fertility ; in Endomycorrhiza, ed. F. E. SANDERS, B. MOSSE and P. B. TINKER, p. 495-509, Academic Press, London (1975)
5) Stribley, D. P., Tinker, P. B. and Snellgrove, R. C. : Effect of vesicular-arbuscular mycorrhizal fungi on the relations of plant growth, internal phosphorus concentration and phosphate analysis, J. Soil Sci., **31**, 655-672 (1980)
6) Ratnayake, R. T., Leonard, R. T. and Menge, J. A. : Root exudation to supply of phosphorus and its possible relevance to mycorrhizal formation, New Phytol., **81**, 543-552 (1978)
7) Graham, J. H., Leonard, R. T. and Menge, J. A. : Membrane-mediated decrease in root exudation responsible for phosphorus inhibition of vesicular-arbuscuiar mycorrhiza formation, Plant Physiol., **68**, 548-552 (1981)
8) Phillips. J. M. and Hayman, D. S. : Improved procedures for cleaning roots and staining pasitic and vesicular-arbuscular mycorrhizal fungi for rapid assesment of infection, Trans. Br. Mycol. Soc., **55**, 158-160 (1970)
9) Kormanik, B. A. and Mcgraw, A.-C. : Quantification of vesicular-arbuscular mycorrhiza in plant roots ; in Methods and Principles of Mycorrhizal Research, ed. N. C. SCHENCK, p. 37-46, The American Phytopathological Society, St. Paul (1982)
10) Giovannetti, M. and Mosse, B. : An evaluation of techniques for measuring vesicular-arhuscular mycorrhizal infection in roots, New Phytol., **84**, 489-500 (1980)
11) Sparling, G. P. and Tinker, P.B. : Mycorrhizal infection in Pennine grassland I. Levels of infection in the field, J. Appl. Ecol., **15**, 943-950 (1978)
12) Powell, C. Ll. : Phosphate response curves of mycorrhizal and nonmycorrhizal plants. I. Responses to superphosphate, N. Z. J. Agric. Res., **23**, 225-231 (1980)
13) Jensen, A. and Jakobsen, I. : The occurrence of vesicular-arbuscular mycorrhiza in barley and

wheat grown in some Danish soils with different fertilizer treatments, Plant and Soil, **55**, 403-414 (1980)

14) Hayman, D. S., Barea, J. M. and Azcon, R.: Vesicular-arbuscular mycorrhiza in Southern Spain: its distribution in crops growing in soils of different fertility, Phytopath. Medit., **15**, 1-6 (1976)

15) Murphy, J. and Riley, J. P.: A modified single solution method for the determination of phosphate in natural waters, Anal. Chim. Acta., **27**, 31-36 (1962)

# 山形県における各種作物の VA 菌根菌感染状態

俵谷圭太郎・前田智志・我妻忠雄・本間廉造
（山形大学農学部土壌学・肥料学研究室）

## 摘　要

山形県各地の普通畑，転換畑，牧草地，野草地よりトウモロコシ，ダイズ，オーチャードグラス，ギシギシを採取し，VA 菌根菌の感染状態と感染に影響を及ぼす要因について調査した．調査した土壌は砂丘未熟土，黒ボク土，褐色森林土，褐色低地土，灰色低地土，グライ土の6土壌群で，すべての土壌においてVA菌根菌の感染が認められた．各植物の感染率の平均値はギシギシで26%，ダイズで24%，オーチャードグラスで18%，トウモロコシで11%であった．オーチャードグラスの地上部P含有率とVA菌根菌感染率との間に負の相関関係が認められた．トウモロコシ，ダイズ，ギシギシにおいては両者の間に一定の傾向は認められなかった．ダイズとギシギシにおいては地上部 Mg 含有率と感染率の間に負の相関関係が認められた．以上のことより，地上部P含有率が感染に及ぼす影響をさらに明らかにし，またP以外の要因と感染の関係を明らかにする必要性が示唆された．