Polar Biosci., 15, 108–113, 2002

Scientific note

Relationships between soil moisture content and root morphology of three herbs on alpine scoria desert of Mt. Fuji

G. M. Anisuzzaman[1*], Takashi Nakano[2] and Takehiro Masuzawa[3]

[1]*Department of Environmental Science, Graduate School of Science and Engineering, Shizuoka University, 836 Ohya, Shizuoka 422-8529*
[2]*Natural Environmental Research Division, Yamanashi Institute of Environmental Sciences, 5597-1, Kenmarubi, Kamiyoshida, Fujiyoshida 403-0005*
[3]*Department of Biology and Geosciences, Faculty of Science, Shizuoka University, 836 Ohya, Shizuoka 422-8529*

Abstract: *Artemisia pedunculosa, Polygonum cuspidatum* and *P. weyrichii* are co-dominant species on the Hoei second crater of Mt. Fuji. The aim of this study is to describe root systems and the relationship between soil moisture and root morphology of these species. Most of the root distribution of *A. pedunculosa* was restricted within 20 cm depth and was widely spread in the surface soil. More than 1 m vertical and shorter horizontal root extension was found for the latter two species. The fine root mass per leaf area (FRMLA) of *A. pedunculosa* was more than 7 times and 3 times greater than these of *P. weyrichii* and *P. cuspidatum*, respectively. From the above results, *A. pedunculosa* depends on a large area of surface soil water, while the two *Polygonum* species depend on deep-layer soil water. The vertical root extension of the two *Polygonum* species is assumed to support their establishment on slope sites where surface soil movement is frequent and moisture content is low.

key words: soil moisture content, scoria, fine root, leaf area, Mt. Fuji

Alpine regions of the volcanic mountains are characterized by more stressful environments than other regions, mainly due to porous volcanic soils (Chapin and Bliss, 1988). Black porous volcanic soil "scoria" has low water holding capacity (Anisuzzaman *et al.*, 2001) and high absorption of solar radiance (Masuzawa *et al.*, 1991); therefore, summer drought periods are common on gravelly desert areas of volcanic mountains (Chapin and Bliss, 1988). Under such circumstances, water deficiency may be more severe in plants growing in the alpine zone on a volcanic mountain compared to other alpine areas, resulting in less vegetation cover (Franklin and Dyrness, 1973). It is well known that the soil on such slopes is unstable and movement is frequent (Chujo, 1983). Therefore, root system structure plays an important role in plant distribution in a scoria-dominated area, especially on slopes.

Mt. Fuji is a volcanic high mountain and gravelly desert area extending above timberline. *Artemisia pedunculosa* Miq., *Polygonum cuspidatum* Sieb. *et* Zucc. and *Polygonum weyrichii* F. Schmit var. *alpinum* Maxim. are co-dominant species on the Hoei second crater of Mt. Fuji. These have different distribution patterns. The first is

*E-mail: r5644006@ipc.shizuoka.ac.jp

restricted to the crater bottom. The latter two are distributed on both slopes and the bottom of the crater. *P. cuspidatum* is less abundant than *P. weyrichii* on the uppermost slopes. The aim of this study is to describe root systems and the relationship between soil moisture and root morphology of the three above-mentioned species.

The present study was carried out on Hoei second crater (about 2400 m above sea level) on Mt. Fuji (3776 m a.s.l.). In this investigation three co-dominant species (*A. pedunculosa, P. cuspidatum* and *P. weyrichii*) of herbaceous perennials were used.

In order to examine root morphological characteristics, three small plants were selected from each species at the crater bottom on August, 2000 and a quadrat (40×40 cm) was set up around the plant. The intact aboveground parts were collected first, and then soil in the quadrat containing root systems of plants were collected at 10 cm depth increments and brought in laboratory. Aboveground parts of plants were separated into stems, green leaves, dead leaves, flowers and seeds. The total leaf area was measured by using area analysis software (LIA 32 for windows 95 ver. 0.372) for each individual plant. After measurement of leaf area, aboveground parts were dried at 80°C for 72 hours and weighed. The roots and rhizomes were collected from the soils (in the case of two *Polygonum* species all rhizomes, coarse roots and fine roots were collected, but only a portion of total coarse roots and fine roots found in the 40×40 cm quadrat were collected for *A. pedunculosa*) and separated into three groups, fine roots ($\leqq 1.0$ mm in diameter), coarse roots (>1.0 mm in diameter) and rhizomes. Thereafter, belowground parts were washed with water, dried at 80°C for 72 hours and weighed.

Fine root mass per leaf area (FRMLA) was calculated by the following equation,

$$FRMLA= (FR_{(dw)} / L_{(area)}), \quad (1)$$

where $FR_{(dw)}$ is the total dry weight (g) of fine roots of an individual plant (total fine roots for two *Polygonum* species and a portion of total fine roots found in the 40×40 cm quadrat for *A. pedunculosa*) and $L_{(area)}$ is the total leaf area (m^2) of green leaves of each respective plant.

A further observation was carried out to measure maximum vertical and maximum horizontal root distribution. Three plants of almost the same size as in the above observation selected for each species, dug out carefully and their maximum vertical root penetration and horizontal extension of roots from the plant stems were measured.

Around the study area three sites (upper slope, middle slope and crater bottom) were selected for measurement of soil moisture. The soil moisture was measured on August 6 2000 (after 7 rainless days), by using a handy TDR (time domain reflectometry, Campbell Scientific Australia Pty. Ltd.) at three soil depths (0–12, 20–32 and 40–52 cm). Ten replications were used for each site. The scoria of the slope site easily slides down, therefore we could not dig and measure soil moisture content below 52 cm.

Differences in FRMLA among the species were examined with ANOVA. Mean comparisons were made using the Bonferroni/Dunn least significant difference test with $P<0.05$.

The root system of a plant plays a significant and unique role to establish the plant within its habitat by the several ways, such as by physical support, water uptake, and storage of water and nutrients (MacFall *et al.*, 1991; Hofstede and Rossenaar, 1995). In the present investigation, different morphologies of roots were found among the study species. More than 90% of the total belowground dry weight of *A. pedunculosa* was distributed at 0–20 cm and no root were found below 40 cm depth from the ground surface (Fig. 1). In the case of the two *Polygonum* species, roots were distributed from the surface to more than 1 m depth, although most of those were rhizome and coarse roots in *P. cuspidatum* and coarse roots in *P. weyrichii* (Fig. 1, Table 1).

The root systems of the two *Polygonum* species were deep-rooted, which helped them resist the unstable soil at the upper slope site where soil moisture was less than 2%

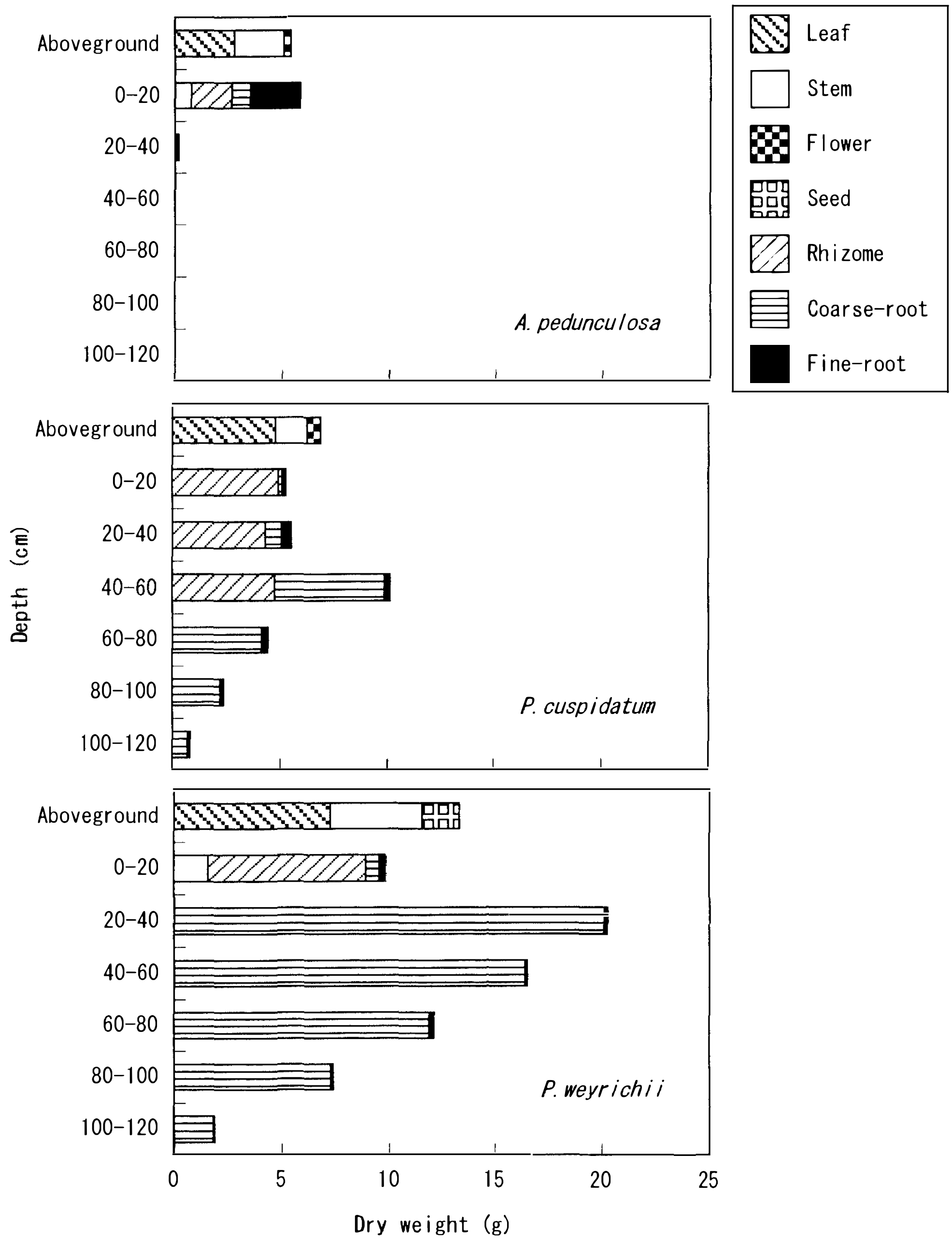

Fig. 1. Partitioning of total plant biomass in to aboveground (leaves, stems, flowers and seeds) and belowground parts (rhizomes, coarse roots and fine roots) of three herb species on Mt. Fuji.

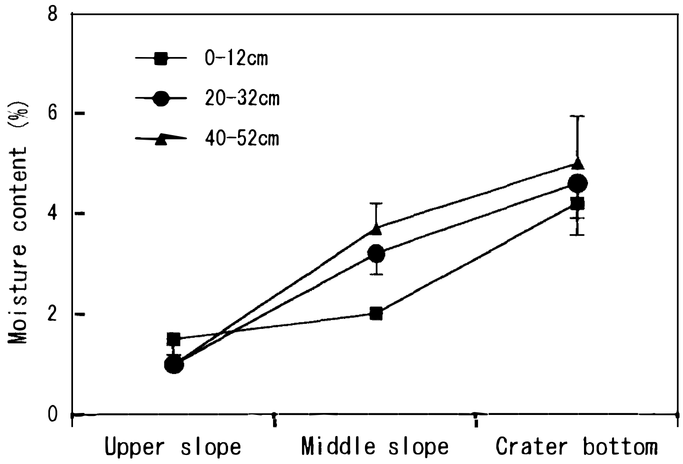

Fig. 2. Depth profile of soil moisture content on the upper slope, middle slope and crater bottom at the Hoei second crater. The soil moisture was measured by using a handy TDR with 12 cm long sensor after 7 successive rainless days.

(Fig. 2).

A plant with a deep root system depends on deep soil water rather than surface soil water, while a shallow-rooting plant exploits soil water in the surface layer supplied by summer rainfall (Ehleringer *et al.,* 1991). The roots of *A. pedunculosa* are widely spread within surface soil (Fig. 1, Table 1). The root morphology of such species may inhibit their establishment on the slope site. *Artemisia pedunculosa* produced more fine roots compared to the two *Polygonum* species. Fine root mass per leaf area (FRMLA) of *A. pedunculosa* was more than 7 times greater (70.8 gm^{-2}) than that of *P. weyrichii* (8.9 gm^{-2}) and 3 times greater than that of *P. cuspidatum* (21.0 gm^{-2}) (Fig. 3).

In the case of the two *Polygonum* species whole fine roots were used for calculation of FRMLA, because the root distribution did not exceed 10 to 25 cm horizontally in

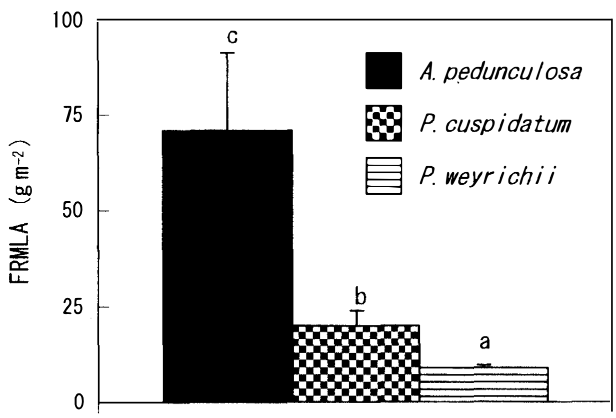

Fig. 3. Fine roots biomass per leaf area of three herb species within 40 × 40 cm quadrat. Different letters indicate significant differences among the species at the 5% level by the Bonferroni/Dunn test. Bar indicates SD.

Table. 1. Maximum vertical and horizontal root extensions of three herb species on the bottom of Hoei second crater on Mt. Fuji.

Species	Max. root depth (cm)	Max. horizontal root extension (cm)
Artemisia pedunculosa	37.0 ± 4.47	92.0 ± 19.24
Polygonum cuspidatum	118.7 ± 16.66	23.3 ± 6.73
Polygonum weyrichii	114.0 ± 9.62	13.0 ± 3.41

length (Table 1). On the other hand, in the case of *A. pedunculosa* only a portion of the total fine roots found in the 40×40 cm quadrat were used in the calculation, because the horizontal root extension of this species is more than 90 cm (Table 1). Therefore, the actual FRMLA of this species is probably greater than the present result.

Fine roots had much greater efficiency of uptake of water and nutrients than the taproots or lateral roots (MacFall *et al.*, 1991). The FRMLA is the ratio of fine roots and leaf area. Therefore, the transpirational water loss and/or water uptake capacity depends on the value of FRMLA. High FRMLA indicates lower water loss or higher water uptake capacity of the plant.

In this study area it is rare to have more than 10 successive rainless days during the growing season. According to Maruta (1976) after 5 rainless days the 18–20 cm layer of scoria soil on Mt. Fuji retains high moisture content, whereas the 0–2 cm layer attains a near permanent wilting percentage after three rainless days. The soil moisture data of the present investigation (collected after 7 rainless days) indicate sufficient water availability in the soil at the rooting zone of mature plants on the crater bottom site. Therefore, severe water deficiency is unlikely to occur for mature plants, especially on the crater bottom. It is assumed that *A. pedunculosa* is able to maintain stomatal conductance and sufficient transpiration to use widely spread absorbing roots (fine roots), despite their shallow-rooting system.

From the above results it can be concluded that root morphology plays an important role in the distribution patterns of plants on scoria soil on Mt. Fuji. The distribution of *A. pedunculosa* is restricted to crater bottom sites due to its shallow-rooting system. Deep-rooting characteristics of the two *Polygonum* species may contribute to the establishment of these species on slope sites, despite low surface soil moisture content and frequent soil movement. According to Chujo (1983), plants with deep taproots are able to resist frequent soil movement on slope sites, while shallow-rooted plants are unable to resist such movement. The water uptake and water use strategy of these species may differ from each other due to their different morphological characteristics of roots. Therefore, the study will be extended to examine water related characteristics of these species.

Acknowledgments

We are grateful to Dr. Takeshi Kibe for his encouragement and advice on many aspects of the investigations throughout the period of this study. This study was partly supported by a grant from the Ministry of Education, Science and Culture, Japan (No. 12680566) for G. M. Anisuzzaman.

References

Anisuzzaman, G. M., Suzuki, H., Kibe, T. and Masuzawa, T. (2001): Response of germination and seedling growth to soil particle size of three herbaceous perennials on alpine zone of Mt. Fuji. Polar Biosci., **14**, 88–98.

Chapin, D. M. and Bliss, L. C. (1988): Soil-plant water relations of two subalpine herbs from Mount St. Helens. Can. J. Bot., **66**, 809–818.

Chujo, H. (1983): Alpine vegetation and periglacial movement of slope materials on Mt. Ontake, central Japan: factors controlling the *Cardamine nipponica* community. Jap. J. Ecol., **33**, 461–472 (in Japanese with English summary).

Ehleringer, J. R., Phillips, S. L., Schuster, W. S. and Sandquist, D. R. (1991): Differential utilization of summer rains by desert plants. Oecologia, **88**, 430–434.

Franklin, J. F. and Dyrness, C. T. (1973): Natural Vegetation of Oregon and Washington. USDA For. Serv. Tech. Rep., PNW–8.

Hofstede, R. G. M. and Rossenaar, A. J. G. A. (1995): Biomass of grazed, burned, and undisturbed Páramo grasslands, Colombia. II. Root mass and aboveground: belowground ratio. Arc. Alp. Res., **27**, 13–18.

MacFall, J. S., Johnson, G. A. and Kramer, P. J. (1991): Comparative water uptake by roots of different ages in seedlings of loblolly pine (*Pinus taeda* L.). New Phytol., **119**, 551–560.

Maruta, E. (1976): Seedling establishment of *Polygonum cuspidatum* on Mt. Fuji. Jap. J. Ecol., **26**, 101–105.

Masuzawa, T., Nishitani, S., Suzuki, J-I., Kibe, T. and Aihara, E. (1991): Seasonal changes in the soil temperature over three-year period at the timberline on Mt. Fuji. Rep. Fac. Sci., Shizuoka Univ., **25**, 69–78.

(Received April 27, 2001; Revised manuscript accepted May 23, 2001)