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LEACHING OF CATIONS FROM *MISCANTHUS FLORIDULUS* AND ITS ASSOCIATED SOILS[1,2]

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Abstract

The aqueous leachate of *Miscanthus floridulus* constitutes not only organic compounds but also some cations. By using an atomic absorption spectrophotometer, the cation content of Na, Ca, Cu, Fe, Zn, Mn and K in the leachate of plant and its associated soils was determined. It was found that the amount of cations leached from the plant and soils were significantly different; the amounts of Ca, Na, and K were far greater than those of Cu, Mn, Fe, and Zn. The leaching of cations from *Miscanthus* was increased with time of washing. However, the amounts of cations released by means of soaking process were obviously different between monovalent and divalent cations. The leachability of cations was drastically changed during the soaking period of 24 to 36 hr. Thus, the theoretical curves of leachability exhibited by monovalent and divalent cations were altogether different. When the *Miscanthus* leaves were heated the amount of cation leaching was increased, but beyond 120°C it was decreased.

Introduction

Leaching of metabolites from plants has been recognized as a fundamentally ecological process (Tukey, 1966). The plant leachate constitutes a variety of substances, such as minerals, amino acids, carbohydrates, phenolics, and alkaloids (Börner, 1960; Muller and Chou, 1972; Tukey, 1971; Whittaker, 1971). These substances are leached out by means of four ways. First, large amounts of organic and inorganic sustances are leached from above ground plant parts by rainfall, mist, fog, and dew (Chou and Muller, 1972; Tukey, 1966). Second, volatile terpenoids are leached from plant foliage and may affect the growth of other species nearby (Muller, 1966). Third, metabolites can be exuded from roots (Woods, 1960; Rovira, 1969). Fourth, leaves and other plant parts

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fall to the ground, resulting in a large amount of substance leached out. The study on substances leached from plants has been reviewed in detail by Tukey (1971). In that review he stated that this phenomenon has been found by Hales since 1727. In addition, many research articles based on this investigation were appeared in various journals. However, research carried out in the subtropical area of Taiwan has scarcely been performed. It is assumed that leached substances from the forests or herbaceous vegetations of Taiwan would be greatly different from those of other areas.

Chou and Chung (1974) reported that the artificial raindrip of *Miscanthus floridulus*, a common dominant glassland species, contained a large amount of substances which could inhibit the growth of lettuce. Organic constituents of the *Miscanthus* leachate have mostly been identified; however, the inorganic part has not been determined. Naturally, the cation constituents are equally as important as the organic ones as far as the allelopathic study is concerned. Therefore, it is the aim of this study to report the leachability of some cations from *Miscanthus* leaves and its associated soils.

Materials and Methods

Preparation of aqueous leachate of ***Miscanthus*** *leaves*

Simulating the natural leachate by rainfall, an artificial raindrip of *Miscanthus floridulus* was obtained by using the techniques described by Chou and Chung (1974). To 8 kg of *Miscanthus* leaves spreaded evenly on a leaching apparatus, one meter square, 2000 ml of distilled water was spreaded over the leaves by using a garden sprayer. The first leachate was collected after 3 days of leaching, while the subsequent one was obtained at the tenth day of leaching. The leachate was then filtered and further centrifuged at 4000 rpm if necessary to clean the filtrate.

Aqueous extracts of ***Miscanthus*** *leaves and soils*

The air-dried leaves of *Miscanthus* were chopped into small piece of about 2.5 cm long. To 50 g of chopped leaves, 350 ml of distilled water was added. The leaves were soaked for the time intervals of 6, 12, 18, 24, and 72 hr. The extracts were obtained by using the techniques described by Chou and Chung (1974).

To further understand the leachability of *Miscanthus* leaves under a forest fire, an experiment was designed. Fifteen grams of the chopped leaves were heated separately by temperatures of 30, 60, 90, 120, 150, and 210°C in an oven for 2 hr. After temperature treatment, each sample was added with 100 ml of distilled water, and shaken for 2 hr. The aqueous extracts were then obtained by using the same techniques mentioned earlier.

Cation contents in various soils were also determined. The soils were collected from the areas as follows: (A) underneath the *Miscanthus* stands, (B) between two bunches of stands, (C) an open area without plant growth, (D) the *Miscanthus* root soil, (E) the herb growth area adjacent to rice field. The soils were air-dried and screened with a 2 mm sieve to carefully remove all possible root fragments. To 100 g of each soil, 200 ml of distilled water was added and shaken for 2 hr. The filtrate was then centrifuged at 8000 rpm.

Cation determination of solutions

The cation content of each solution mentioned above was determined by an atomic absorption spectrophotometer (Perkin-Elmer, model 300) (called AAS). At the present time only the hallow cathod lamps of Ca, Cu, Fe, Mn, Na, and K are available, thus the cation contents of these elements in each solution are determined, using the techniques described in "Analytical methods for atomic spectrophotometry" (Perkin-Elmer, 1971).

Statistical analysis.

The data obtained by the AAS were subjected to be statiscally analyzed. Thus, the least significant difference (L. S. D.) and curvilineal regression analysis were used.

Results

*Leachability of cations from **Miscanthus** leaves*

The artificial drindrip of *Miscanthus* obtained from the third and the tenth day of leaching was analyzed by the atomic absorption spectrophotometer (AAS). Results based on the cation content (gram per gram of fresh leaves) are shown in Fig. 1. It was shown that the cation content of Cu, Zn, Fe, and Mn was below 1 ppm, while that of the K, and Na was above 37 ppm. In general, the amount of cation leached was increased with time of leaching.

The aqueous extract of *Miscanthus* leaves treated by the soaking process was also analyzed for its cation content. The data were then analyzed by using curvilineal regressions analysis. From this analysis the theoretical values of the experiment were obtained. Thus, the curves of each cation varied with time intervals are shown (Fig. 2). The amount of cation excretion by the soaking process was far greater than that of the artificial raindrip. The pattern of curves shown in Fig. 2 was obviously different between the monovalents and the divalents. For the monovalent cation of Na, the amount leached out was increased with time of soaking up to 24 hr, and

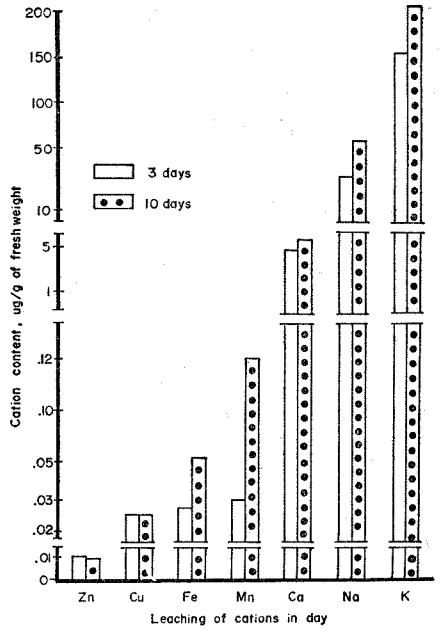

Fig. 1. The cation content in the artificial raindrip of *Miscanthus floridulus*. The raindrip was obtained at the third and the tenth day of leaching by spraying with distilled water.

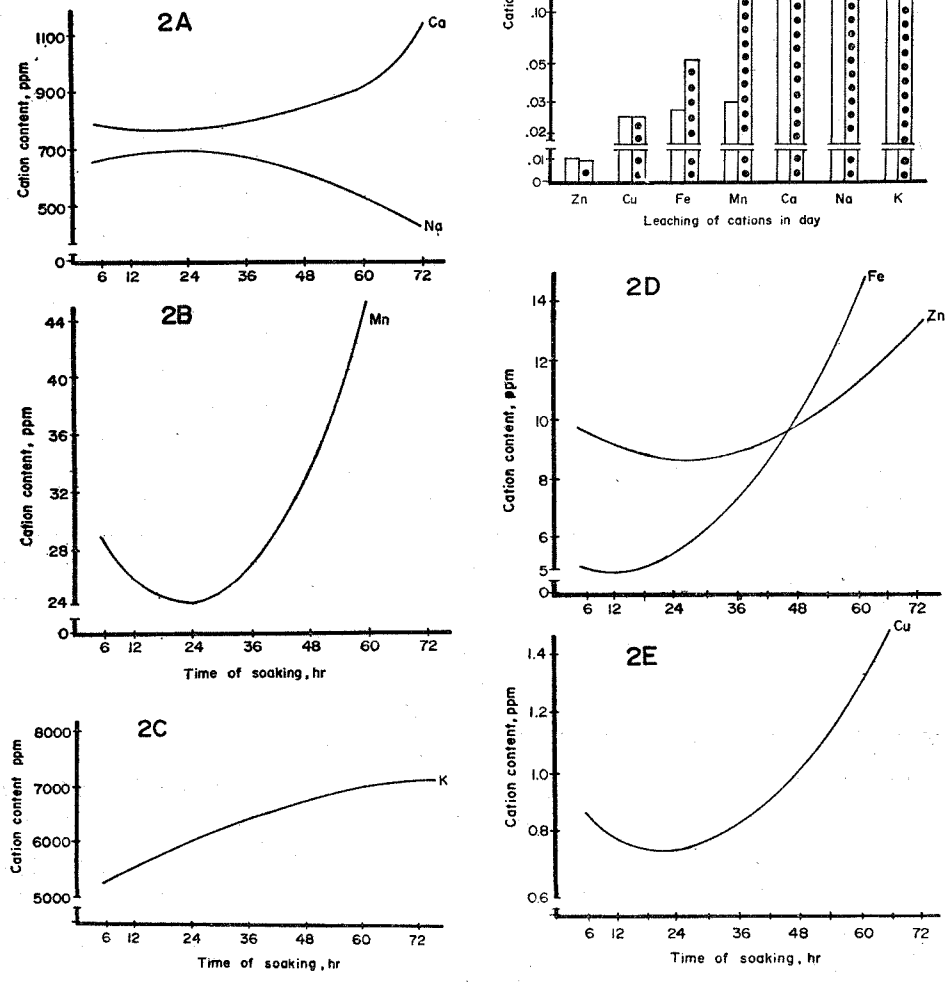

Fig. 2. The cation content in the aqueous extracts of *Miscanthus* leaves. Leachate was obtained by soaking with time intervals. The curves were expressed by the theoretical values calculated from the experimental data, using the curvilineal regression analysis.

decreased thereafter (Fig. 2). Although the curve exhibited by K was continually increased with time, it might go down after 72 hr of treatment. The pattern of curves shown by the divalent cations was altogether different. In these curves, the refraction points were found generally at the time interval of 24–36 hr. The remarkable increase of divalent cations was found after 36 hr.

Leaching of cations from the ***Miscanthus*** *associated soils*

The cations in the aqueous extracts of soils were also determined by the AAS. Results are given in Table 1. The content of Na, K, and Ca was much higher than that of Cu and Zn, which was below 0.2 ppm. The cations, except Fe, present in the *Miscanthus* root soil was higher than that in other soils. However, the content of Fe in the control soil (herb growth area adjacent to rice field) was higher than that in the other soils.

Table 1. *The cation concent in the aqueous extracts of soils.*
Data were obtained from the means of three replications.

Soil sample*	Concentration, μg/g soil						
	Na	K	Ca	Cu	Fe	Mn	Zn
A	14.4	9.0	11.4	0.12	0.26	0.06	0.03
B	16.0	6.8	8.6	0.16	0.56	0.10	0.04
C	11.4	7.3	13.4	0.08	0.30	0.10	0.03
D	18.4	14.0	11.0	0.12	0.18	5.34	0.29
E	14.4	8.0	10.4	0.14	1.74	0.02	0.01
L. S. D. between soils	5%=0.23 1%=0.31			L. S. D. between elements		5%=0.27 1%=0.35	

* A: from the area underneath the *Miscanthus* stands
B: between the bunches of the stands
C: an open area without plant growth
D: the *Miscanthus* root soil
E: the herb growth area adjacent to rice field.

Effect of temperature on the leachability of ***Miscanthus***

The leachability of *Miscanthus* leaves is thought to be varied when a fire occurs. Thus, the determination of leachability of cations in the heated leaves was performed. The results of analysis are shown in Fig. 3. The pattern of leaching is similar to those shown in Fig. 2. It was found that the amount of cation released from leaves was increased with temperatures up to 120°C, then it was decreased after 150°C.

Discussion

Leaching of metabolites in the tropical and subtropical vegetation obviously

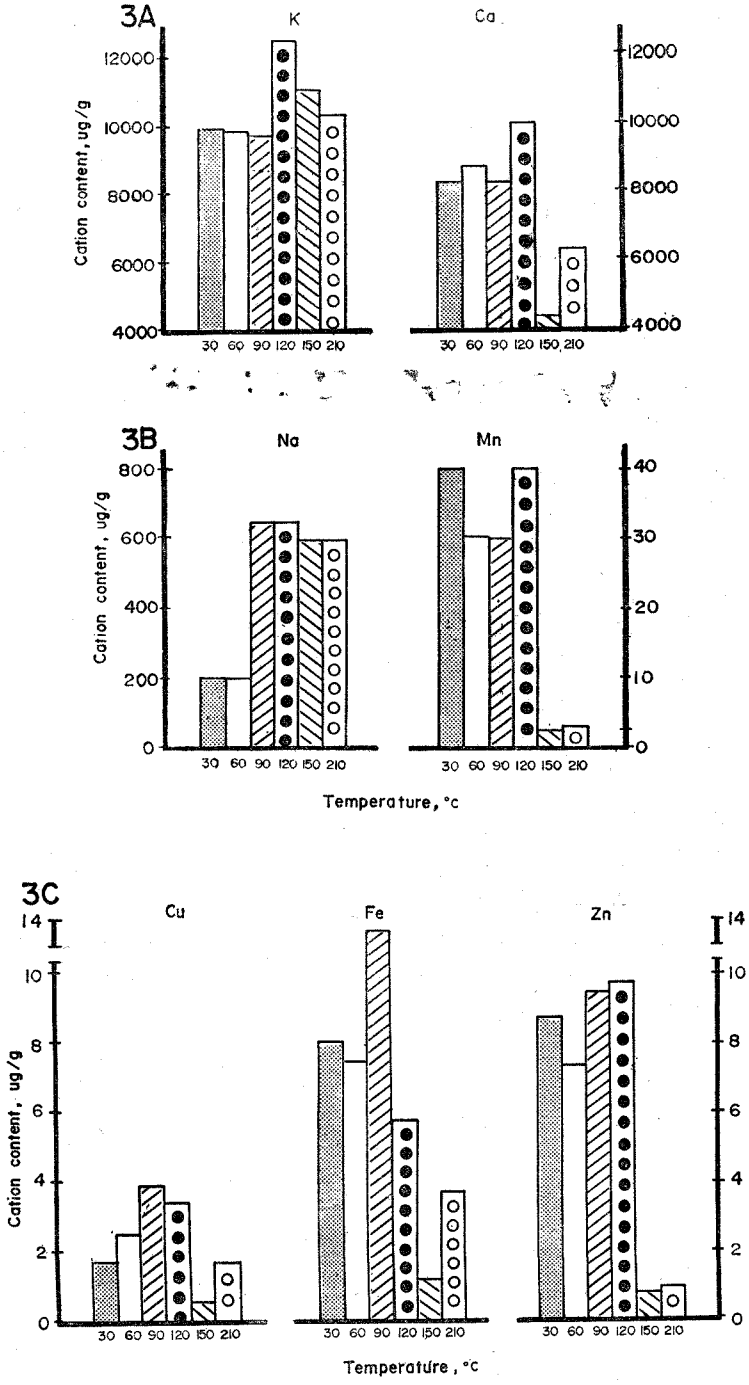

Fig. 3. The cation content in the aqueous extracts of *Miscanthus* leaves as affected by temperatures.

is an important ecological phenomenon. Substances leached out from plants differ with species and are also influenced by a number of factors, both internal and external to the plant. Tukey (1966) indicated that the internal factor included the type and nature of plants, leaf characteristics, physiological age of leaf, plant nutrient status and physiological disorders, while the external factors were temperature, light-darkness, duration of leaching period, intensity and amount of rain, injury, dew and nutrition in root medium. *Miscanthus floridulus*, a perennial herbaceous plant, is a tall grass about one meter high with thick branches of leaves. It receives a large amount of precipitation due to a long rainy season and the characteristics of leaf form. The artificial leaching experiment showed that the amount of cations leached out was higher in 10-day period than that in 3-day period (Fig. 1). This indicated that the cations reserved in the tissue were not fully being leached out in a short period of time. Under the natural conditions, the leaching of substances from *Miscanthus* is continually going on in the rainy season, and it also uptakes nutrients from soil. Thus the mineral cycling in the system should be maintained in balance. However, the cation contents in the top 10 cm layer of soil were much lower than those in the leaf leachate (Table 1). It was thought that a great amount of leachate from plants could be lost due to the sharp slope of mountains, particularly in this study area.

In Fig. 2, the most striking thing was the pattern of leaching exhibited by monovalent and divalent cations. Generally, the leaching of monovalent Na had rapid initial rate before it leveled off, while the curves of divalents were up side down. The refraction point of curves was generally being found between 24 to 36 hr. This suggested that some drastic changes of the tissues occurred during this period. Some cations of Ca, K and Na were therefore released in a great quantity after 36 hr of treatment. However, it should be realized that this leachate was obtained from the soaking process. The decrease of Na in the leachate after 36 hr of soaking could be a result of either reabsorption or the utilization by microorganisms, or by both of them. While the increase of divalents in leachate after that period appeared to be natural in the ecological process.

On the physiological point of view, plants constitute a certain amount of macromolecules, such as Na, Ca, and K. Epstein (1972) pointed out that plants needed a great quantity of Ca which was regarded as a "luxury consumption." Additionally, Evans and Sorger (1966) confirmed that plants required pottassium to activate enzyme reaction in many cases. Hiatt and Evans (1960) indicated that pottassium could form a potassium-enzyme complex when the concentration of K was at 5–10 mM. It was found that the contents of Ca and K in the *Miscanthus* leaf leachate were considerably high (Fig. 2). The inter-

action of these macroelements in relation to the leachability is yet not clear.

Furthermore, plant leachate may not always beneficial to other plants, and in fact it is detrimental to the adjacent species. Chou and Muller (1972) has demonstrated that the aqueous leachate of *Arctostaphylos* contains some toxic substances which may inhibit the growth of several herbaceous plants. In the *Miscanthus* leachate, it has been reported that this leachate does contain some toxic phenolics which are able to suppress the growth of lettuce, while the inorganic part of cations has no detrimental effect (Chou and Chung, 1974). However, when a fire occurs on the *Miscanthus* vegetation, most of cations would be returned to the ground. Under a severe fire as the temperature goes up to 150°C, the leachability of cations mentioned would decrease as an indication of experimental results shown in Fig. 3. Thus, the cations returned to the ground by the process of either leaching or a natural fire appear to be ecologically significant.

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Literature Cited

BÖRNER, H. 1960. Liberation of organic substances from higher plants and their role in the soil sickness problem. Bot. Rev. **26**: 393-424.

CHOU, C. H. and Y. T. CHUNG. 1974. The allelopathic potential of *Miscanthus floridulus*. Bot. Bull. Academia Sinica **15**: 14-23.

CHOU, C. H. and C. H. MULLER. 1972. Allelopathic mechanisms of *Arctostaphylos glandulosa* var. *zacaensis*. Amer. Midl. Nat. **88**: 324-347.

EPSTEIN E. 1972. Mineral nutritions of plants: principles and perspectives. John Wiley and Sons, Inc., New York, London, Sydney, Toronto. 412 pp.

EVANS, H. J. and G. J. SORGER. 1966. Role of mineral elements with emphasis on the univalent cations. Ann. Rev. Plant Physiol. **17**: 47-76.

HIATT, A. J. and H. J. EVANS. 1960. Influence of certain cations on activity of acetic thiokinase from spinach leaves. Plant Physiol. **35**: 673-677.

MULLER, C. H. 1966. The role of chemical inhibition (allelopathy) on vegetational composition. Bull. Torrey Bot. Club **93**: 332-351.

MULLER, C. H. and C. H. CHOU. 1972. Phytotoxins: an ecological phase of phytochemistry. *In*: Phytochemical ecology (J. B. Harborne, ed.), pp. 201-216. Academic Press. London and New York.

PERKIN-ELMER, 1971. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer Corp. Norwalk, Connecticut, U. S. A.

ROVIRA, A. D. 1969. Plant root exudates. Bot. Rev. **35**: 35-59.

TUKEY, H. B., Jr. 1966. Leaching of metabolites from above-ground plant parts and its implications. Bull. Torrey Bot. Club **93**: 385-401.

TUKEY, H. B., Jr. 1971. Leaching of substances from plants. *In*: Biochemical interactions among plants, pp. 25-32. National Academy of Sciences, Washington, D. C.
WHITTAKER, R. H. 1971. The chemistry of communities. *In*: Biochemical interactions among plants, pp. 10-18. National Academy of Sciences, Washington, D. C.
WOODS, F. W. 1960. Biological antagonisms due to phytotoxic root exudates. Bot. Rev. **26**: 546-569.

五節芒及其相關土壤所淋溶出的陽離子

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五節芒 (*Miscanthus floridulus*) 的水溶淋出液不但含有機物質且含無機物質。用原子吸收析光儀可測出淋溶液中 Ca, Cu, Fe, K, Mn, Na 及 Zn 的含量。五節芒葉中所淋出的陽離子含量顯著地大於土壤所淋出者。其中 Ca, Na 及 K 的含量遠高於 Cu, Zn, Mn 及 Fe 等的含量。此元素含量隨淋溶時間的延長而增加。淋溶出的離子含量與淋溶時間所繪出的二次曲線，理論值因單價陽離子及雙價陽離子而異，單價陽離子的曲線有一最大值，而雙價者有一最小值，其最大與最小值落在24及36小時之間。當五節芒的葉子用溫度處理後，其淋溶率 (leachability) 因溫度的上升而增加，但在 120°C 以上時則降低。