Some ecophysiological aspects of *Sphagnum squarrosum* Cram Samml.

*D. K. Saxena, *Anuj Saxena and **Niharika Shankar

*Department of Botany, Bareilly College, Bareilly, U.P.
**Department of Plant Science, M.J.P. Rohilkhand University, Bareilly, U.P.

Saxena D.K., Saxena Anuj & Shankar, N. 2003. Some ecophysiological aspects of *Sphagnum squarrosum* Cram Samml. *Geophytology* 31(1&2): 97-102.

Present study demonstrates the differences in distance dependant distribution of Pb and Ni and their bioaccumulation pattern at interspecific level. A distinct relationship existed between the metal content (Pb and Ni) of *Sphagnum squarrosum* and it was found reciprocal to the distance from the pollution source. It also attempts to correlate the different density dependant parameters of *Sphagnum squarrosum, viz.*, leaf area, shoot density, mire depth, etc.

Key-words— Ecophysiology, *Sphagnum*, Mineral uptake

INTRODUCTION

SPHAGNUM constitutes one of the important components of the bog and poor fen communities and occupies different ecological niches along moisture and ionic gradients (Jeglum 1971; Vitt *et al.,* 1975; Vitt & Slack, 1975, 84; Slack *et al.*, 1980; Aulio, 1985; Hayward & Clymo, 1982; Vitt & Balyley, 1985). Approximately 1% of the earth's surface is occupied by *Sphagnum* and its peat (Clymo, 1984). *Sphagnum* is important in the cycling of metals as it itself and its peat both are well known metal accumulator (Aulio, 1985). The principal nutrient inputs into the moss communities are from dry deposition and precipitation (Malmer; 1962; Malmer & Nihlgard, 1980). Species are well adapted to the mire conditions, possessing more cation binding sites per unit area of cell walls than other plants (Clymo, 1963; Pakarinen & Tolonen, 1976). Because of their specific characters to the mire condition, species of *Sphagnum* have been used extensively as pollution monitors (Gignac, 1987; Ho *et al.*, 1995, 1996a, b) for air and water bodies. Clymo and Hayward (1982) have summarized admirably the physiological ecology of *Sphagnum,* and Glime and Vitt (1987) have discussed the physiological adaptations of aquatic mosses, *viz.,* their ability to grow in a broad and low temperature range and the retention of metals.

The *Sphagnum* mire of Kumaon Hills are restricted to high altitude and unusual in having a nearly complete *Sphagnum squarrosum* carpet at most of the places or in patches at few places, with little differentiation of hummock or hollow topography. This study reports a primary survey of the vegetation and stratigraphy, made with strictly limited resources, and intended to direct the planning for further work.

The objective of present study was to analyse the distance dependent distribution of metal (Pb and Ni) content and eco-physiological aspects of *Sphagnum squarrosum* occupying different niches along the pollution gradients.

MATERIAL AND METHOD

a) Study site : Kosi, district Almora is located at an altitude of 1878 m on Kumaon hills. Its climate varies throughout the year. It is quite cold (2~8°C) in winters and mild warm through May-June (28~34°C) followed by monsoon rains till October. The average rainfall is 200 cm, maximum and minimum temperatures are 2°C to 34°C and relative humidity is 60~85%, highest in the month of July-August and lowest in January. Specimens of *Sphaghum squarrosum* were collected from the above site and partly preserved in herbarium of Bareilly College in quadrplicate and indexed as 971006, 971010, 971025, 971029, 971030. Duplicates were deposited in the herbaria of Missouri Botanical Garden, U.S.A., and Forest Research Institute, Dehradun, India.

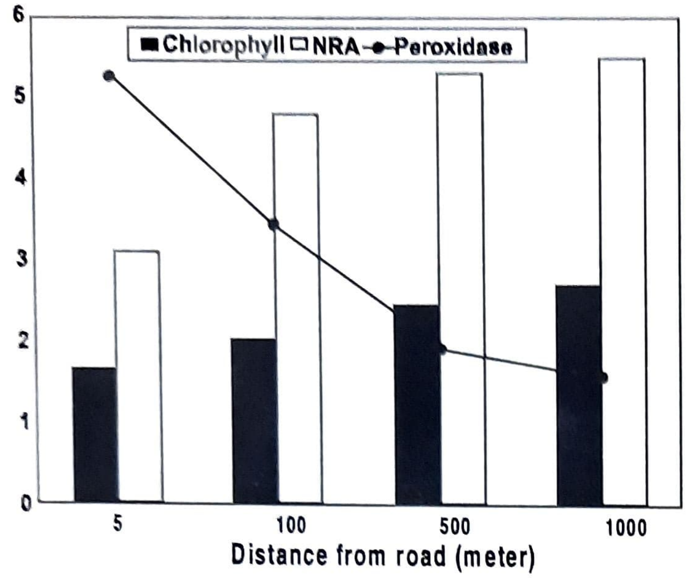

Fig. 1: Variation in chlorophyll content (mg g^{-1} Fr. wt.), nitrate reductase (n mol NO_2-h^{-1} g^{-1} F. W.) and peroxidase activities (O.D. min-1 g^{-1} F.W.) with distance (meter) from road

b) Sampling : Specimens of *Sphagnum squarrosum* were brought to the laboratory in polythene bags, surface washed for several times and sorted for gametophyte only. Sampling was done on random basis.

c) Biological studies : *Sphagnum squarrosum* collected from Kosi were analysed for biochemical and physiological parameters. *In vivo* nitrate reductase activity was measured by the methods of Srivastava (1975) using KNO_3 as substrate, while peroxidase was estimated by the method of Putter (1974). Chlorophyll was estimated according to modified method of Arnon (1949) by extracting the pigment in 80% acetone. Method of Shimwell and Laurie (1972) was adopted for metal analysis by digesting 1 g of oven dried material (80 °C for 6 hours) in concentrated (1 : 3) $HClO_4$: HNO_3. The optical density was recorded using atomic absorption spectrophotometer (Perkin-Elmer model).

d) Estimation of shoot density, shoot length and leaf area: Four sampling areas (each of one cm^2) from moss tufts were selected growing naturally on along the gradients of Kainchi (Kumaon hills), India located at 1870 m. The number of shoots were counted for each sampling unit and number of leaves were counted for five selected shoots of each sample. The area of 10 leaves from each of these selected five shoots was

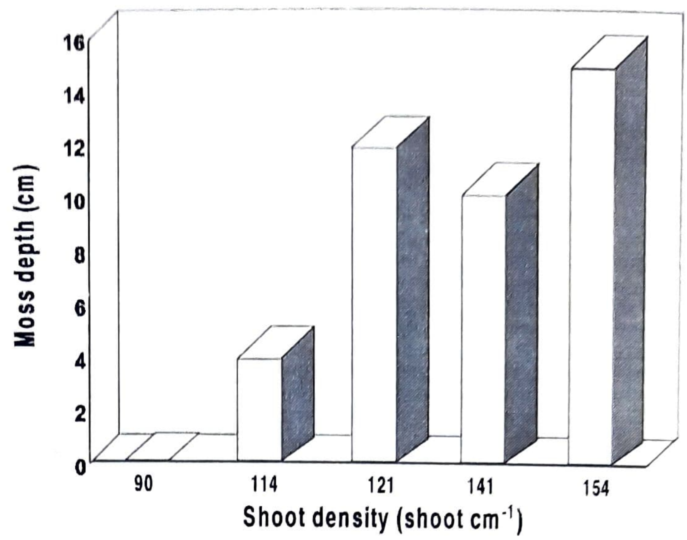

Fig. 2: Effect of shoot density on moss depth

measured. Leaf area indices were then calculated by multiplying mean leaf area per shoot and mean number of shoots per cm^2 (that is expressed as leaf area per cm^2 of moss tuft). Data presented show mean values and variability for these parameters.

RESULT

The Pb and Ni concentration in soil at a distance of 5, 100, 500, 1000 metre, from road was found to be 464.3, 296.4, 137.8, 54.15 µg g^{-1} D.W and 26.46, 8.86, 5.16 and 2.94 µg g^{-1} D.W, respectively. In plant samples the maximum bioaccumulation potential for Pb (105.6, 47.7, 27.0 and 8.1 µg g^{-1} D.W) and Ni (5.4, 1.8, 0.96 and 0.53 µg g^{-1} D.W) at 5, 100,500 and 1000 metre distances was observed in *Sphagnum*.

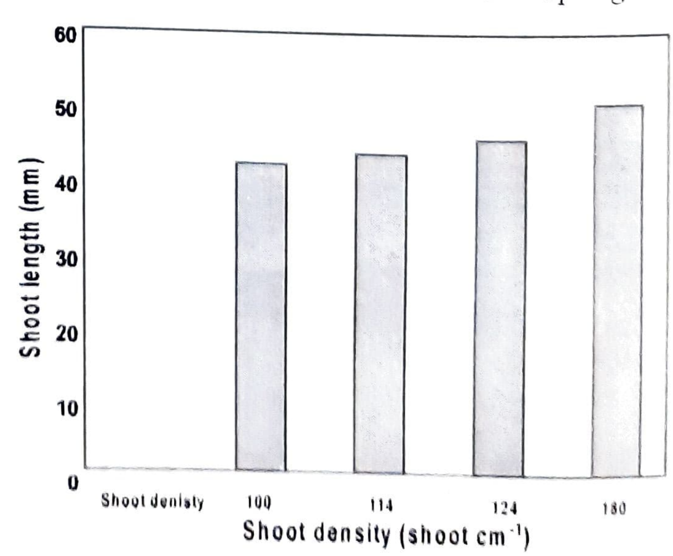

Fig. 3: Effect of shoot density on shoot length

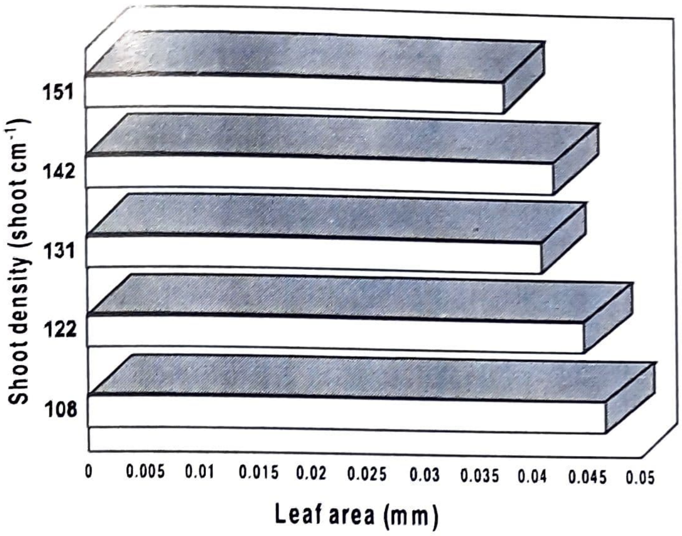

Fig. 4: Effect of shoot density on leaf area of *Sphagnum*

Studies related to the ecophysiological biochemical parameters show an increase in chlorophyll content and nitrate reductase activity with concomittant decrease in peroxidase activity in the *Sphagnum* samples collected from 5, 100, 500 and 1000 metre distance from road (Figs. 1, 5).

Higher moss depth was observed in the mires having high shoot density, which was equivalent to 0.03, 6.0, 12.0, 10.0 and 15 cm in the mire having 90, 114, 128, 141 and 154 shoot density per cm^2 (Fig.2, 3). Individual leaf area of *Sphagnum* leaf was found to be 0.48, 0.46, 0.41, 0.43 and 0.38 mm when the shoot density of the quadrat was 108, 122, 161, 142 and 151 shoot per cm^2, respectively (Fig. 4). A positive correlation was found between shoot length

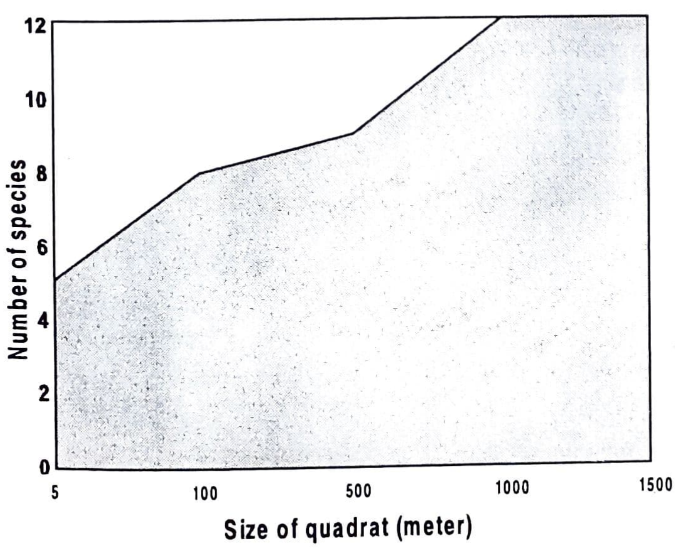

Fig. 5: Minimum size of quadrat studied

(42.89, 44.31, 46.18 and 50.67 mm) and shoot density (100, 114, 120 and 150).

DISCUSSION

An analysis of metal content in soil and naturally growing *Sphagnum* revealed that the concentration of Pb goes down with distance, however, not in a linear proportion. It was interesting to note that Pb content at 1000 m was about 13 time lesser while Ni content was about 9 times lesser only in *Sphagnum* and soil both. This difference in the dilution of metal concentration with distance could be attributed to the differences in distance dependant distribution of Pb and Ni and their differences in solubility, leachability, capacity to form complexes of different nature, back ground levels and the pH of the surroundings.

A species specific difference was also noted in bioaccumulation potential in the tested species. *Sphagnum* has shown about 5-7 and 1.5-2.3 times higher Pb accumulation in all the cases in comparison to *Marchantia* and *Plagiochasma,* respectively. A species specific difference in Ni accumulation was also observed. Bioaccumulation capabilities of *Sphagnum* for Ni was about 1.6 ~ 2.9 times higher than *Plagiochasma* and about 5.8 ~ 8.7 times higher than *Marchantia.* High divalent metal accumulation of *Sphagnum* is well established (Aulio, 1985; Kirchhoff *et al.,* 1988; Saxena *et al.,* 1999) and may be due to presence of high cationic binding capabilities of its cell walls (Clymo, 1963; Clymo & Hayward, 1982). Accumulation of metals in low amount reflect its poor bioaccumulation potentialities.

Almost a clean ecological status at the distance of 1000 metre was represented by thick forest cover i.e. the high abundance of perennial macrophytic flora. As *Woodfordia fruticosa* (L.) Kurz, *Macaranga pustulata* King ex HK. f., *Mallotus philippensis* (Lamk.) Muell., *Rhododendron arboreum* Sm. and *Murica esculenta* Buch Ham. ex Dum. were growing luxuriently at deeper range along with leafy liverworts, *Frullania squarrosa, Ptychanthus* sp. and *Porella densifolia. Aerobryidium* sp., *Anomodon minor, Anomodon rugelii, Cryptolaptodon* sp., *Thuidium* sp. and *Trachypodopsis* were amongst the pleurocarpous mosses growing in the dense forest cover. However, *Pinus roxburghi* Sarg. and *Quercus glauca* were more or less uniformly distributed throughout the entire range.

During quadrat analysis it was found that *Sphagnum* was more abundant at 100 metre distance while *Marchantia* distribution starts from 500 metre and increase further as we proceed away from the road. Low abundance of *Marchantia* at proximity to roads could be due to its high sensitivity to pollutants. Quadrate analysis also showed that generally *Sphagnum* grows as continuous mire at all the studied sites with a few exceptions. The high abundance of *Sphagnum* may be attributed to its oxylophytic nature which is fulfilled by the formation of carbonic acids or HSO_3 from CO_2 or SO_2 spewed out from automobile exhaust or due to some tolerance mechanism (Saxena & Saxena, 1999). The particular low pH requirements of *Sphagnum* may be responsible for its growth in isolated patches or continuous cover.

Species distribution study show higher distribution of tolerant species and lesser distribution of sensitive species close to the road. While a reversible trend was observed as we proceed in deeper forest cover (data not given). Ecological studies also revealed that the number of species became constant only at 1000 metres i.e. minimum size of quadrat is 1000 meters.

An attempt has been made to correlate the shoot density with shoot length and leaf area. An increase in shoot length and decrease in individual leaf area was observed with increase in shoot density, although with some exceptions as well. Interactions between bryophyte shoots mainly concern water and light supplies since lack of nutrients usually does not seems to be an important factor limiting growth (Van Tooren *et al.*, 1990). The high shoot length at high shoot density may be due to the light which act as a limiting factor at higher shoot densities. Decrease in leaf area with increase in shoot densities could be a natural adaptation and does not seem to have any effect on moss productivity as chlorophyllous green shoot is capable of synthesizing enough food at its own. Besides in *Sphagnum* the shoot density never increases beyond a permissible limits. At very high shoot densities light stress in the lowest part of a vegetation could lead to death of smallest individuals. This self thinning reduces the size inequality of the population (Ford, 1975; Weiner & Whigham, 1988). Low individual leaf area of *Sphagnum* at higher shoot densities has been reported (Saxena *et al.*, 2000). Some environmental factors viz. high CO_2 close to surface, may also be responsible for variation in shoot density, shoot length and leaf area. Moss growth, shoot density and leaf area are influenced mainly by light and humidity (Saxena *et al.*, 2000). In general, moss growth is usually considered to be water rather than light affected (Skre and Oechel, 1981; Proctor, 1982). But in Kosi hills light seems to act as a limiting factor since water and humidity are not the limitation. Competition for light between individuals might be expected, which should lead to a high shoot length (Van der Hoeven & During, 1997).

Light penetration into natural moss cushions is naturally restricted to only a few cm (Van der Hoeven *et al.*, 1993) and leaves that are placed deeper in the canopy than few cm seems to die due to light stress (Rydin, 1995). Thus, it is clear that in spite of the tolerance for low light levels, negative interactions between bryophyte shoots in terms of light availability are expected at higher shoot densities.

A correlation was made between the shoot density and the age of mire. The depth of peat was taken as a criteria for considering the age of mire. The data suggested that shoot density increases with the depth of peat or with age of mire. Although the equation does not hold good in all cases yet the criteria is quite useful in case of young mires.

The study concludes-

a) Distribution of metals are distance dependent and vary from metal to metal.

b) Species distribution depend on the sensitivity of species to the pollutants, provided other factors remain constant. As a result tolerant species survive well while sensitive species gradually disappear near the source.

c) Bryophyte physiology, productivity and metabolism are greatly influenced by the intensity of pollutants and their toxicity.

ACKNOWLEDGEMENT

For the present study, the support from University Grants Commission, New Delhi (F.3~16/97 SR~I), is gratefully acknowledged. Authors wish to extend their sincere thanks to Prof. Janice M. Glime, Michigan Technological Institute, for critical suggestions from time to time and to late Prof. H. S. Srivastava, Head, Department of Plant Science, M.J.P. Rohilkhand University, Bareilly for encouragement.

REFERENCES

Aulio, K 1985. Metal accumulation capacity of five species of *Sphagnum* moss. *Bull. Environ. Contam. Toxicol.* **35**: 439-442.

Clymo, RS 1963. Ion exchange in *Sphagnum* and its relation to bog ecology. *Ann. Bot.* **27**: 309-324.

Clymo, RS 1984. *Sphagnum* dominated peat bog: a naturally acid ecosystem. *Phil. Trans. R. Soc. Lond. B.,* 305: 487-499.

Clymo, R S & Hayward, PM 1982. The ecology of *Sphagnum*. In *Bryophyte Ecology* (ed) A. J. E. Smith, Chapman and Hall, London, pp 229-289.

Ford, ED 1975. Competition and stand structure in some even-aged plant monocultures. *J. Eco.* **63**: 311-333.

Gignac, LD 1987. Ecological tolerance and niche structure of *Sphagnum* along a pollution gradient near Sudbury, Ontario, Canada. *Can. J. Bot.* **65**: 1268~1274.

Glime, JM & Vitt, DH 1987. A comparison of bryophyte species diversity and niche structure of montanestreams and stream banks. *Can. J. Bot.* **65**: 1824~1837.

Hayward, PM & Clymo, RS 1982. The growth of *Sphagnum*. experiments of light flux and water table depth. *J. Ecol.* **71**: 845~863.

Ho, YS, Wase, DAJ & Forster, CF 1995. Batch nickel removal from aqueous solution by *Sphagnum* moss peat. *Water Research* (U. K.), **29 (5)**: 1327~1332.

Ho, YS, Wase, DAJ & Forster, CF 1996a. Kinetic studies of competitive heavy metal absorption by *Sphagnum* moss peat. *Environmental Technology* (U. K.), **17 (1)** : 71~77.

Ho, YS, Wase, DAJ & Forster, CF 1996b. Removal of lead ions from aquous solution using *Sphagnum* moss peat as absorbant. *Water-SA* (South Africa), 22 **(3)** : 219-224.

Jeglum, J. K. 1971. Plants indicators of pH and water levels in peatlands at Candle Lake, Saskatchewan. *Can. J. Bot.* **49**: 1661~1676.

Kirchhoff, M., Rudolph, H., Struck, C & Deising, H 1988. Heavy metal analysis of *Sphagnum*. In *Methods in Bryology,* (ed) J.M. Glime, Proc. Bryol. Meth. Workshop, Mainz. pp 221~226, Hattori Bot. Lab., Nichinan.

Malmer, N. 1962. Studies on mire vegetation in the Archean area of southwestern Gotaland (south Sweden). Distribution and seasonal variation in elementary constituents on some mire sites. *Opera Botany* **7**: 1~67.

Malmer, N. and Nihlgard, B. 1980. Supply and transport of nutrients in subarctic mire. In Ecology of a Subarctic mire. *Ecology Bulletin* (Stockholm). **30**: 63-95.

Pakarinen, P. & Tolonen, K. 1976. Regional survey of heavy metals in peat mosses (*Sphagnum*). *Ambio* **5**: 38-40.

Procter, MCF 1982. Physiological ecology : water relations, light and temperature responses, carbon balance : In *Bryophyte Ecology* **(ed)** AJE Smith, Chapman and Hall, Cambridge, pp. 333-382.

Putter J 1974. In *Methods of Enzymatic Analysis 2* (Ed Bergmeyer) Academic Press, New York, P. 685.

Rydin, H. 1995. Effects of density and water level on recruitment, mortality and shoot size in *Sphagnum* populations, *Journal of Bryology***18**: 439~453.

Saxena, DK & Saxena, A 1999. Bio-monitoring of SO_2 phytotoxicity on *Sphagnum squarrosum* Cram. Samml. *Jour Indian bot. Soc.* **78**: 367~374.

Saxena, DK, Saxena, A & Glime, JM 2000. Leaf area index and shoot densities of *Sphagnum squarrosum* Cram. Samml. and *Ceratodon purpureus* (Hedw.) Brid. *Geophytology* **29** (1 & 2) : 61-63.

Saxena, DK, Saxena, A & Srivastava, HS 1999. Heavy metal accumulation and *in vivo* nitrate reductase activity in the *sphagnum Squarrosum* Cram. Samml. *Proc. Natn. Acad. Sci.*, India, **69** (B), III & IV, 307-312.

Shimwell, DW & Laurie, AE 1972. Lead and zinc contamination of vegetation in the Southern Pennines. *Environ Pollut.* **3**: 291 - 301.

Skre, O & Oechel, WC 1981. Moss functioning in different ecosystems in interior Alaska. I. Seasonal, phenotypic and drought effects on photosynthesis and response pattern. *Occologia* **48**: 50~59.

Slack, NG, Vitt, DH & Horton, DG 1980. Vegetation gradients of minerotrophically rich ferns in western Alberta. *Can J. Bot.* **58**: 330-350.

Srivastava, HS 1975. Distribution of nitrate reductase in ageing bean seedlings *Plant & Cell Physiol.* **16** : 995~999.

Van der Hoeven, EC & During HJ 1997. The effect of density on size frequency distributions in chalk grassland bryophyte populations. *Oikos* **80**: 533~539.

Van der Hoeven, EC, Huynen, CIJ & During HJ 1993. Vertical profiles of biomass, light intercepting area and light intensity in chalk grassland mosses. *Jour. Hatt. Bot. Lab.* **74**: 261~270.

Van der Hoeven, EC & During HJ 1997. Positive and negative interactions in bryophyte populations. In *The Ecology and Evolution of Clonal Plants* (ed) H. de Kroon and J. van Groenendael, Backhuys Publishers, Leiden, The Netherlands, pp 291~310.

Van Tooren, BF, Van Dam, D & During, HJ 1990. The relative importance of precipitation and soil as sources of nutrients for *Calliergonella cuspidata* (Hedw.) Loeske in chalk grassland. *Functional Ecology* **4**: 101~107.

Vitt, DH, Crum, H & Snider, JA 1975. The vertical zonation of *Sphagnum* species in hummock~ hollow complexes in northern Michigan. *Mich. Bot.* **14**: 190~200.

Vitt, DH, & Slack, NG 1975. An analysis of the vegetation of *Sphagnum* dominated kettle~hole bogs in relation to environmental gradients. *Can. J. Bot.* **53**: 332~359.

Vitt, DH & Bayley, S 1985. The vegetation and water chemistry of four oligotrophic basin mires in northwestern Ontario. *Can. J. Bot.* **62**: 1485~1500.

Weiner, J & Whigham, DF 1988. Size variability and self thinning in wild rice (*Zizania aquatica*). *Am. J. Bot.* **75**: 445~448.