J. Aquat. Plant Manage. 21: 87-92

Variation of Nitrogen, Phosphorus, and Potassium Contents of Hydrilla in South Florida[1]

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Single samples of hydrilla [*Hydrilla verticillata* (L.f.) Royle] collected from five locations in south Florida were analyzed for nitrogen and phosphorus. Phosphorus content increased from the North New River Canal, Holiday Park, Loxahatchee National Wildlife Refuge, Lake Trafford, to Lake Okeechobee. For nitrogen, the order was the same except that the lowest amount was found in plants collected from Loxahatchee National Wildlife Refuge. Additional samples of Hydrilla collected from Lake Okeechobee and North New River Canal were examined for within location (sample) variability and for between location variability for phosphorus, nitrogen, and potassium content. Extensions of this study for the determination of sample sizes to estimate nutrients present in populations of hydrilla plants are discussed.

Key words: Hydrilla, South Florida, nitrogen, phosphorus, potassium, sampling, plant nutrients.

INTRODUCTION

Decisions involved in management of aquatic weeds include an evaluation of the potential effectiveness of the method, availability of equipment and personnel, and the intended use of the water. Of the various methods available, mechanical harvesting is generally assumed to be an expensive method for managing aquatic weed problems; however, utilization of harvested plants may help mitigate these costs.

Information on the nutrient content of a particular aquatic weed problem will be of help in arriving at a decision to manage the plants. For example, it is generally assumed that following a herbicide application, nutrients from the decaying weeds are released back into the ecosystem. These nutrients may then contribute to regrowth of new weed problems or to the regrowth of the plant originally controlled. On the other hand, benefits generally associated with mechanical harvesting include an immediate removal of the nuisance vegetation, elimination of nutrients contained in the weeds from the aquatic ecosystem, and minimal long-term impact (6). Weeds high in nutrient content, therefore, may best be controlled with mechanical methods. The cost of mechanical control would be offset somewhat by removal of those plants high in nutrients. Conversely, weeds low in nutrients may be controlled more inexpensively with herbicides than with mechanical methods, and these plants would return a low nutrient concentration to the aquatic ecosystem.

Little information is available on the number of samples which must be collected in order to estimate the nutrient content of aquatic weeds. We, therefore, collected samples of hydrilla from infestations at various locations in south Florida and examined the concentration of phosphorus, nitrogen, and potassium contained in them.

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[1]Contribution of the University of Florida Agricultural Research and Education Center at Fort Lauderdale and the Department of Statistics at Gainesville. Published as a Journal Series No. 3606 of the Florida Agric. Exp. Sta. Agricultural Research Service. Southern Region, Florida Area, USDA cooperating. Supported in part by the Florida Department of Natural Resources, Bureau of Aquatic Plant Control.

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MATERIALS AND METHODS

A. Survey to estimate variability between locations.

Hydrilla was collected during the time period of 27 September to 16 October 1979 from five locations in south Florida. These locations were the Harney Pond area of Lake Okeechobee, north end of Lake Trafford, south side of the Loxahatchee National Wildlife Refuge approximately 4 km west of the boat launch area, just west of University Drive along State Road 84 in the North New River Canal, and in a canal about 0.8 km west of Holiday Park (Figure 1). A single sample of plants which included primarily the upper shoot portion of the plant was collected from a mat of hydrilla in each location. An individual reached over the side of a boat and pulled up as much hydrilla as could be collected in a large handful. The plants were not washed, but simply allowed to drain of excess water in order to simulate that which would occur with mechanical harvesting of plants. The samples after drying in a forced-air oven at 60 C weighed 40 to 50 g. The dried plant material was ground to 40 mesh and phosphorus content determined on nine subsamples of each sample by the ascorbic acid method (1) following digestion with nitric and perchloric acids. Nitrogen was determined on six subsamples of each sample by the Kjeldahl method (2).

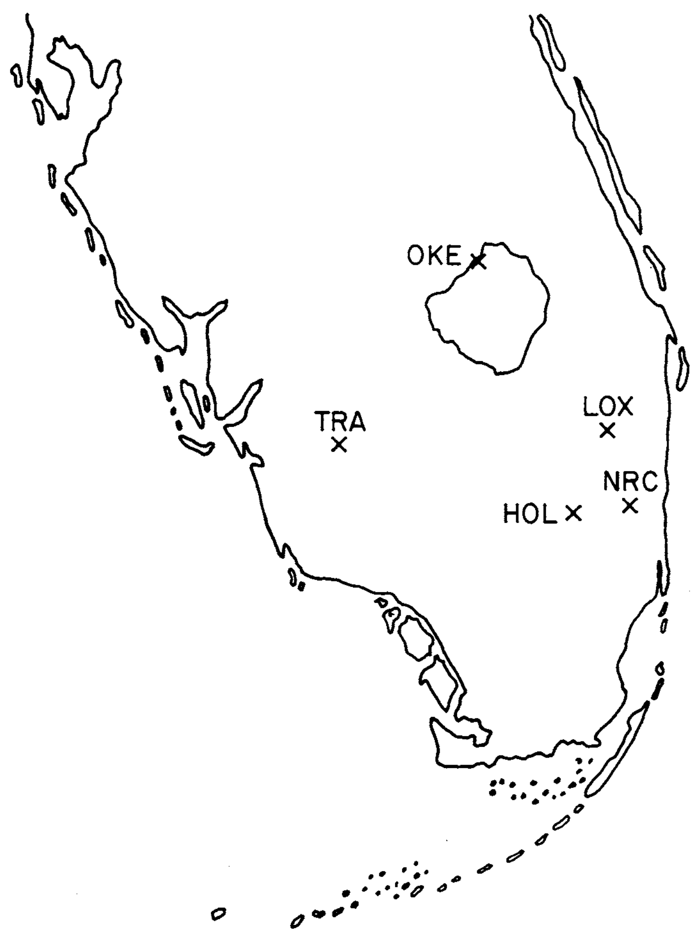

Figure 1. Hydrilla sampling locations in south Florida. (LOX = Loxahatchee Natural Wildlife Refuge, NRC = North New River Canal, HOL = Holiday Park, TRA = Lake Trafford, and OKE = Lake Okeechobee).

B. Survey to estimate variability between samples within location.

Based on phosphorus content of the hydrilla collected in the first part of this study, 10 samples were collected at random some 3 to 4 m apart from mats of hydrilla in Lake Okeechobee (29 January 1980) and North New River Canal (30 January 1980). These samples were of approximately the same weight and processed similarly to the previous samples with the exception that their potassium content was determined on nitric-perchloric acid digested material with Atomic Absorption Spectroscrospy. In order to examine within sample variability six subsamples of each sample were used to determine phosphorus, potassium, and nitrogen of the plants.

Results were analyzed statistically using the Statistical Analysis System (SAS). Important characteristics of the data are presented using box displays (8,11), the construction of which is illustrated in Figure 2. Information on between sample and within sample variability was used to describe the precision of measurements made in the area under study. In addition, this information was used to estimate sample size requirements for further investigation of the same or similar variables in similar environments. Two additional pieces of information were required to determine this: (1) how accurate one would like the estimate of the overall mean to be, and (2) an estimate of the costs of collecting the samples.

Assume an aquatic weed manager wanted to collect sufficient numbers of samples from Lake Okeechobee, North New River Canal, or a similar location to be assured of

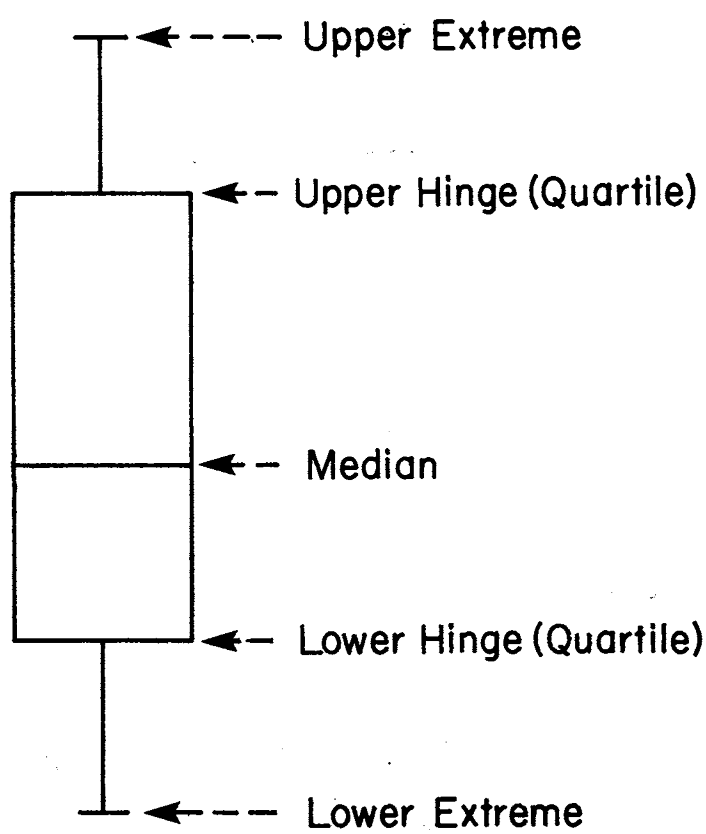

Figure 2. Characteristics of box plots used to describe data collected on nutrient content of hydrilla.

estimating the overall mean for nitrogen, phosphorus, and potassium to be within 5% of the true mean in order to determine an overall management strategy for these areas. Costs associated with the collection of these samples are an important consideration and may be determined in the following manner: C_1 = cost of collecting a sample, and C_2 = cost of preparing and processing a subsample.

Estimates for the standard deviation of the overall mean (S_m), the percent of total variance due to between sample differences (P_b), and within sample differences (P_w) are obtained from the survey as described in this paper. The goal of the aquatic weed manager is to determine the number of samples (n_1) and number of subsamples (n_2) required to obtain a specified accuracy on nutrient content using the method described by Snedecor and Cochran (10).

The cost of sampling for a given nutrient concentration, apart from fixed overhead costs, was approximated by: $C = C_1n_1 + C_2n_1n_2$. Total cost is given by C^* = overhead + C.

Sample size requirements for the two sites were examined using costs estimates which were obtained as follows: Fixed overhead costs include time and travel expenses from the Agricultural Research and Education Center at Fort Lauderdale to the general area where the samples were collected. Sampling costs were determined from the time needed to collect a sample. Subsampling costs include preparation time as well as analysis fees estimated to be $45 per sample. Cost for the two locations are given in Table 1.

Table 2 provides the information on between and within sample variability which enables estimation of sample sizes. The estimated number of samples and subsamples necessary to estimate nitrogen, phosphorus, and potassium content in hydrilla collected from Lake Okeechobee and North New River Canal is presented in Table 3. Two situations are presented. One presenting sample sizes required to estimate the average to within 5% of its true value and another presenting sample sizes required to estimate to within 10% of the true value.

To illustrate the calculations consider sample size for nitrogen for Lake Okeechobee. From Table 2 we have $P_w = .79$, $P_b = .21$, $S_m = .88$ and $\bar{X} = 2.51$. Thus,

$$n_2 = \sqrt{\frac{P_w}{P_b} \cdot \frac{C_1}{C_2}} = \sqrt{\frac{.79}{.21} \cdot \frac{12.50}{47}} = 1.00025.$$

This value is rounded up to 2. Then

$$n_1 = \left(P_b + \frac{P_w}{n_2}\right)\left(\frac{S_m}{(.05 \cdot \bar{y})}\right)^2$$

$$= \left(.21 + \frac{.79}{2}\right)\left(\frac{.88}{(.05)(2.51)}\right)^2 = 29.75.$$

This estimate is also rounded up to 30. Hence the total cost is

$$C^* = \text{Overhead} + C_1n_1 + C_2n_1n_2,$$
$$= \$250 + (\$12.50)(30) + (\$47)(30)(2) = \$3445.$$

For 10% accuracy the estimate for n_1 is

$$n_1 = \left(.21 + \frac{.79}{2}\right)\left(\frac{.88}{(.1)(2.51)}\right)^2 = 7.43$$

TABLE 1. ESTIMATED COST PER SAMPLE AND SUBSAMPLE.

Location[a]	Lake Okeechobee	North New River Canal
Overhead	$250.00	$75.00
C_1	12.50	12.50
C_2	47.00	47.00

[a]C_1 = cost per sample.
C_2 = cost per subsample.

TABLE 3. NUMBER OF SAMPLES (N_1) AND SUBSAMPLES (N_2) NECESSARY TO ESTIMATE THE MEAN TO WITH 5% AND 10% OF TRUE VALUE ASSUMING COSTS (C^*) FROM TABLE 1.

Nutrient	Accuracy 5% n_1	n_2	Total	C*($)	Accuracy 10% n_1	n_2	Total	C*($)
A. Lake Okeechobee								
Nitrogen	30	2	60	3445	8	2	16	1027
Phosphorus	5	1	5	547	2	1	2	369
Potassium	7	1	7	666	2	1	2	369
B. North New River Canal								
Nitrogen	24	1	24	1503	6	1	6	432
Phosphorus	10	1	10	670	3	1	3	253
Potassium	28	1	29	1800	8	1	8	551

TABLE 2. MEANS, STANDARD DEVIATION OF THE MEAN, COEFFICIENT OF VARIATION (CV), AND WITHIN SAMPLE AND BETWEEN SAMPLE VARIABILITY OF HYDRILLA PLANTS COLLECTED FROM LAKE OKEECHOBEE AND NORTH NEW RIVER CANAL.

Nutrient	Mean[a]	Standard deviation of the mean	CV (%)	Percent of total variance due to differences: Within samples P_w	Between samples P_b
A. Lake Okeechobee					
Nitrogen	2.51	0.88	35	79	21
Phosphorus	8,259	875	11	44	56
Potassium	52,137	6,893	13	53	47
B. North New River Canal					
Nitrogen	1.91	0.46	24	22	78
Phosphorus	2,062	321	16	50	50
Potassium	32,117	8,584	27	60	40

[a]Each value is the mean of 10 samples with six subsamples in each. Units for nitrogen are %, and for phosphorus and potassium μg per g dry weight of plant material.

which is rounded up to 8. The total cost here is

$$C^* = \$250 + (\$12.50)(2) + (\$47)(8)(2) = \$1027.$$

The variance of the overall mean is

$$Sm^2 = \frac{P_b S_m^2}{n_1} + \frac{P_w S_m^2}{n_1 n_2}.$$

In specifying accuracy we used the constraint that the standard deviation of the overall mean estimate (S_m) be 5% of the mean estimate. For practical purposes, n_2 is usually rounded to the next largest integer, then inserted into the equation for n_1. The n_1 value is generally rounded to the next largest integer.

The choice of the number of subsamples, n_2, can often be made without being too specific about the cost. This is due to the fact that the same value of n_2 will be obtained for a wide range of ratios C_1/C_2. Discussion of additional cost functions and methods for three stage sampling can be found in Cochran (7).

RESULTS AND DISCUSSION

A nitrogen content of 3.3% measured in hydrilla samples collected from Lake Okeechobee was the highest of the samples collected from the five locations in south Florida (Figure 3). The lowest nitrogen content of 1.8% was found in those samples collected from the Loxahatchee National Wildlife Refuge. Phosphorus content of hydrilla samples collected from Lake Okeechobee was 7,201 μg per g dry weight of plant material, and again was the highest of the five locations (Figure 4). For this nutrient, however, the lowest concentration of phosphorus of 1,686 μg per dry weight of plant material was measured in those samples collected from the North New River Canal. This low value for phosphorus in hydrilla collected from the North New River is somewhat surprising since it is generally assumed that runoff from urban areas is a major source of nutrients.

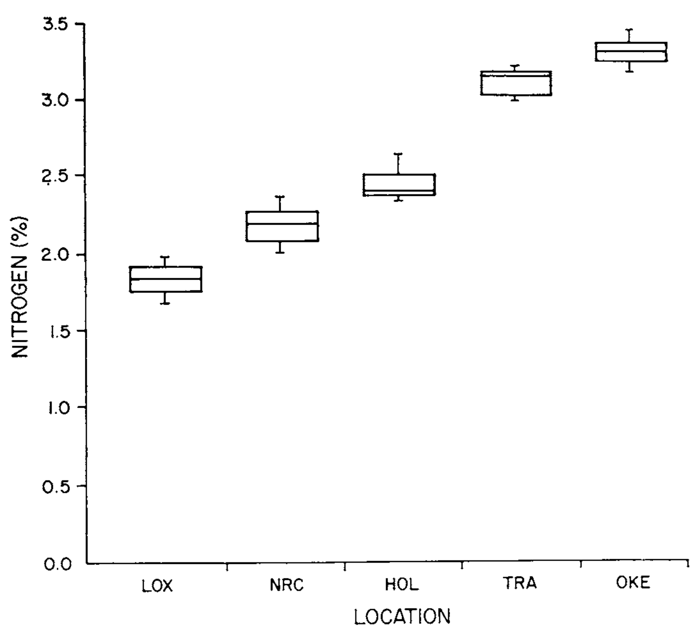

Figure 3. Nitrogen content of hydrilla collected from five locations in south Florida.

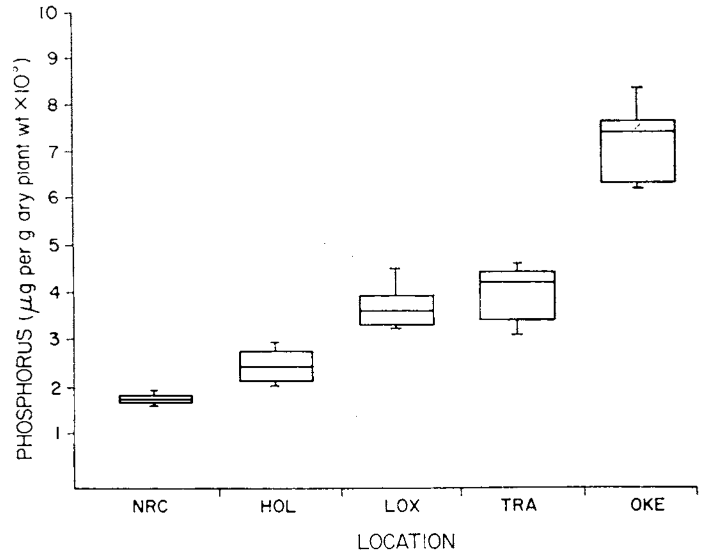

Figure 4. Phosphorus content of hydrilla collected from five locations in south Florida.

For phosphorus content of hydrilla, in addition to observing differences in location, the variation in measurements at the different locations was also found to be different. This is illustrated in Figure 4 by the different sizes of the boxes at the different locations. From this figure we also note that the variance of observations increases as the observation mean increases. Similar differences in variances were not observed for nitrogen content of the hydrilla.

The suggestion of a relationship between average concentration and the variance of samples used to calculate these averages indicated a need to explore in more detail the nature of the phosphorus content in hydrilla. In the first survey, nine subsamples from a single sample at each location were examined. In the second survey, six subsamples from ten samples at two locations, Lake Okeechobee and North New River Canal, were analyzed. The hydrilla at each location was assumed to be homogeneous mats of plants. The object of this second survey was to determine how variable nitrogen, phosphorus, and potassium content was between subsamples within samples and also between samples within locations. Results from the second survey are presented in Table 2 and Figures 5 to 9.

Overall, the average nitrogen content for hydrilla collected from Lake Okeechobee was 31% greater than the nitrogen content of those plants in the North New River Canal. This was expected in view of the results of the first survey. Of more interest were differences among the samples within each location (Table 2). For Lake Okeechobee the variability due to differences in sample averages for nitrogen accounts for 79% of the total variability in the samples. This indicates the presence of fairly homogeneous subsamples but much more variability in nitrogen content from sample to sample. For hydrilla collected from the North New River Canal the opposite was observed, with only 22% of the total variability due to differences in sample average.

The average phosphorus content of hydrilla collected from Lake Okeechobee was four times that of samples from

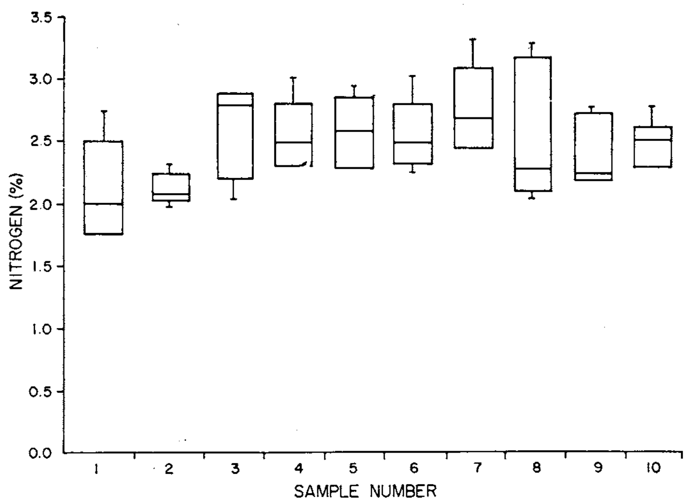

Figure 5. Nitrogen content of 10 samples of hydrilla collected from Lake Okeechobee.

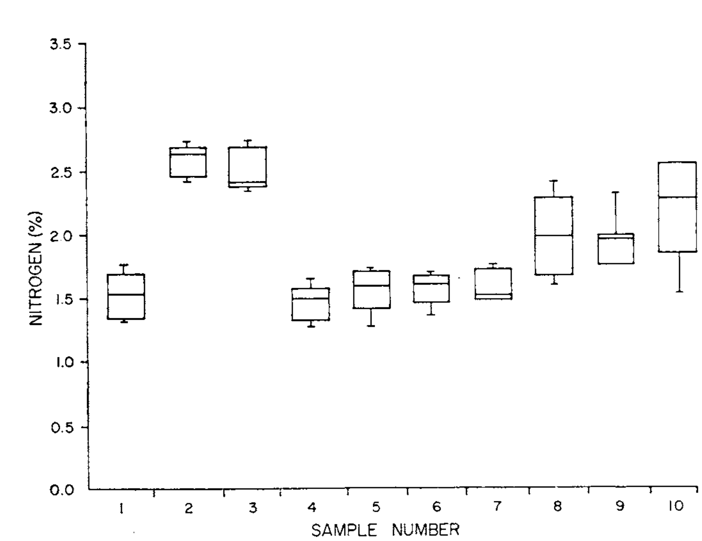

Figure 6. Nitrogen content of 10 samples of hydrilla collected from North New River Canal.

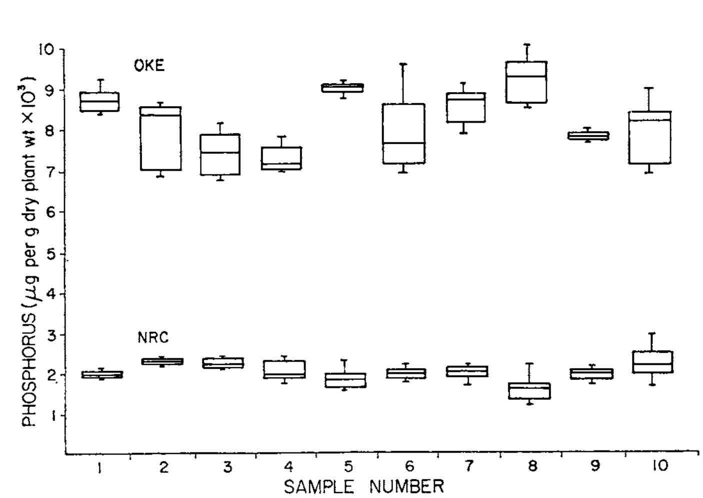

Figure 7. Phosphorus content of 10 samples each of hydrilla collected from Lake Okeechobee and North New River Canal.

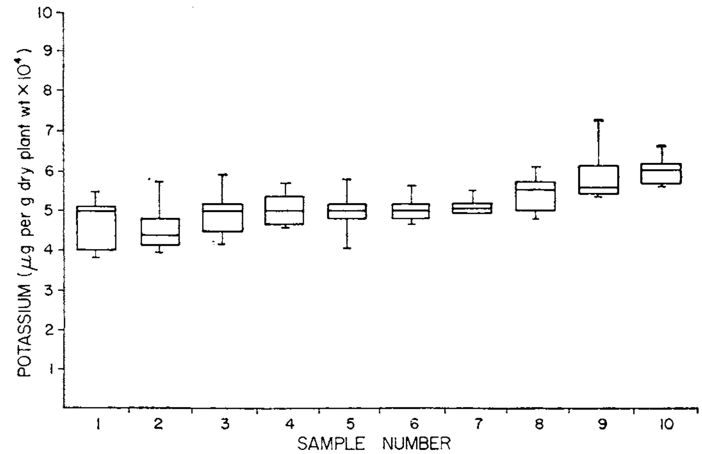

Figure 8. Potassium content of 10 samples of hydrilla collected from Lake Okeechobee.

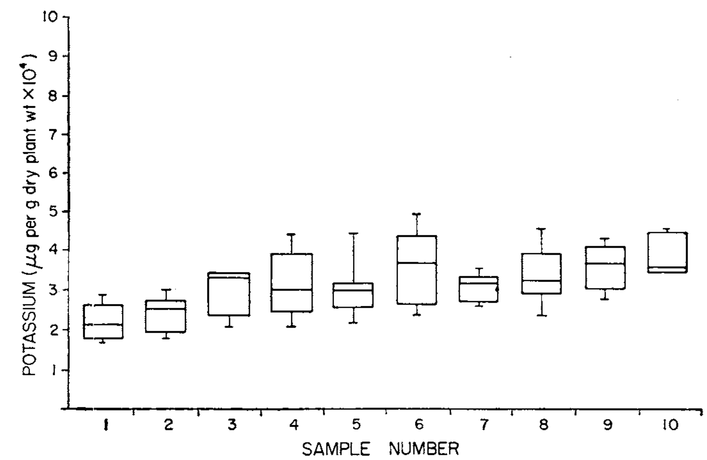

Figure 9. Potassium content of 10 samples of hydrilla collected from North New River Canal.

North New River Canal (Table 2 and Figure 7). Significant differences in sample averages were observed at both locations. Between sample and within sample variance components were approximately equal for North New River Canal. For Lake Okeechobee, however, the variance due to differences between sample means was slightly higher than that due to differences within samples (Table 2).

Potassium content in hydrilla plants from Lake Okeechobee averaged 62% more than samples collected from the North New River Canal (Table 2, and Figures 8 and 9). For both locations the within sample variability accounted for over 50% of the total variance.

From Table 3 it is clear that in almost all cases, single stage sampling ($n_2 = 1$) is the preferred method for obtaining the required accuracy. This is the result of the large differential in cost assigned to samples and subsamples and the fact that total variability is nearly evenly split between the within and between samples components. It should also be noted that the larger the coefficient of variation (CV) the larger the sample size needed to obtain the prespecified accuracy.

Number of samples as well as overall cost can be reduced if less accuracy is required of on the mean estimate. The effect will be more noticeable for those factors which have a high CV. The effect is not linear, that is a 5% reduction does not result in only a 5% decrease in sample size but of a much larger decrease.

For phosphorus and potassium content of hydrilla in Lake Okeechobee, approximately one-fifth the samples would be required as compared to that for nitrogen. No similar pattern was found for these same nutrients in hydrilla plants collected from the North New River Canal. For both locations fewer samples would be required to measure phosphorus content of hydrilla than for nitrogen or potassium.

These data indicate the need for caution in arriving at the nutrient content of hydrilla in these two locations. Emphasis must not only be placed on the location but also on the number of samples required for a particular nutrient. If the aquatic weed manager was interested in only phosphorus, then only a few samples would be necessary as contrasted to that required for nitrogen or potassium.

Costs involved in the analyses of sufficient samples for an accurate estimate of nutrients in a mat of aquatic weeds may make it impractical for routine management of aquatic plant problems. These data suggest that a single subsample of weeds would provide an indication of the nutrient content of the plants. In Lake Okeechobee for example, the estimates ranged from a high where a single sample of plants was 24% higher in nitrogen than for the ten samples to a low where ten samples contained 13% more phosphorus than a single sample. For plants collected from the North New River Canal, the difference for the estimate of the nutrient content for one sample as compared to ten was not as great as in those plants collected from Lake Okeechobee. These differences may not be sufficient to warrant a detailed examination of the plants for management purposes.

It is well known that the availability of mineral elements in the water and hydrosoil, species of plant, and time of year influence the nutrient content of aquatic weeds (3,4,5,9). These relationships as well as sampling schemes must be taken into account by the aquatic weed manager in evaluating the consequences of various available management strategies for controlling a nuisance aquatic plant in a particular body of water. In addition, as more research is generated on possible use of aquatic weeds and impact of management technology, the results from these studies will help the aquatic weed manager decide which method or methods might be most appropriate for a given aquatic weed problem.

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