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DRYING METHOD EFFECTS ON EXTRACTABLE PHOSPHORUS LEVELS IN PLANT TISSUE

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ABSTRACT

The level of soluble tissue phosphorus (PO_4-P) may be correlated with the plant P nutritional status, but the amount extracted depends upon dry matter losses or the amount of enzymatic or heat-induced hydrolysis of organic P compounds during sample drying.

Alfalfa (*Medicago sativa* L) and sugarbeet (*Beta vulgaris* L) plant parts grown under low and high soil P conditions, were freeze-dried or oven-dried at 40, 56, 70, or 100 C. Total K, P, and 0.35 N acetic-acid-soluble P (measured as PO_4-P) were determined. Dry matter losses were 0, 6.5, 3.6, 5.5, and 4.9 percent for the respective drying methods. The total-P values, once corrected for dry matter losses, were not affected by the drying methods. The corrected PO_4-P values were 0.15, 0.17, 0.16,

0.16, and 0.19 percent, while the $(PO_4\text{-}P)/P$ values were 0.63, 0.69, 0.67, 0.68, and 0.78 for each of the respective drying methods.

The potential utility of extractable PO_4-P in describing the plants' P nutritional status will depend upon rigorous sample-drying techniques. Freeze-drying was the most satisfactory method tested, since it resulted in the least dry-matter loss and least organic P hydrolysis.

INTRODUCTION

Chemical analysis of plant tissues is utilized to determine the effectiveness of nutritional treatments and to help detect nutrient deficiencies. Two approaches commonly used are (1) a soluble fraction is extracted from either fresh or dried material, or (2) the total nutrient concentration is determined. The chief advantage of the former is the substantial time savings. However, the choice of procedure should be based on the degree to which the measured level reflects the nutritional status. In this respect, we[4] have found that soluble PO_4-P levels (acetic-acid-soluble) better represent the P nutritional status of sugarbeets than do total P levels.

Commonly used drying methods can alter or even destroy certain chemical constituents, e.g., carbohydrates and water-soluble N, resulting in C and dry-matter losses[2, 3]. Since organic P compounds may be hydrolyzed upon heating, the PO_4-P extractability from plant materials possibly could be influenced by the sample preparation technique. This effect could reduce the

utility of PO_4-P as a measure of plant P nutritional status, or require rigorous control of the sample preparation methods. The objective of this study was to determine the influence of drying methods on the extractability of PO_4-P from two plant materials.

MATERIALS AND METHODS

Second-cutting alfalfa (*Medicago sativa* L) at the one-tenth bloom stage, and sugarbeet (*Beta vulgaris* L) petioles from the most recent, fully-expanded leaves were harvested in midsummer from P-fertilized and nonfertilized field plots.

Plant tissues were chopped into 1-cm lengths, and within 1 hour after harvest the samples were subjected, in triplicate, to either freeze-drying (FD, 70 hours), or forced-draft oven-drying at 40 C (45 hours for alfalfa/112 hours for sugarbeet petioles), 56 C (22/41 hours), 70 C (22/41 hours), or 100 C (22/22 hours). Dried tissue was ground to pass through a 0.42-mm sieve. Drying was continued over evacuated anhydrous calcium chloride for 26 days.

Total K was determined by flame photometer and total P by the vanodate-molybdate method[1] on plant material digested in a 3:1 mixture of HNO_3:$HClO_4$. The PO_4-P was determined by the vanodate-molybdate method on an extract prepared by shaking 1-g plant material, 0.5-g carbon black, and 50-ml 0.35 N acetic acid (2%, V/V) together for 25 minutes and filtering through Whatman #40 or equivalent paper.

Data were processed by the analysis of variance and Duncan's multiple range test.

RESULTS AND DISCUSSION

Significant ($P \leq 0.01$) differences in mineral concentrations between the two plant materials and between the two P fertilizer treatments are evident (Table 1). An average of 46% of the total P in alfalfa, and 92% of the total P in sugarbeet petioles was extracted as PO_4-P. As expected, a larger percentage of P (72% average for both crops) was extracted from tissue of the P-fertilized plants than from the tissue of unfertilized plants (66%). The small but significant decrease in K level in the tissue from the P-fertilized plants is attributed to dry matter dilution by the growing crop. The P-fertilized first-cutting alfalfa yielded 30% more dry forage than the unfertilized treatment. Petioles from the P-fertilized sugarbeets were larger in diameter and longer than petioles from the unfertilized treatment, however the P fertilization did not increase sugarbeet root yields.

Drying methods had a significant ($P \leq 0.01$) effect on measured mineral concentrations (Table 1). This effect may have resulted from a dry-matter loss, an alteration in the organic P compounds, or both. Using the K concentrations in the oven-dried samples relative to the concentration in freeze-dried material[2] as a measure of dry-matter loss, we calculated the following losses (in percent): FD = 0, 40 C = 6.5, 56 C = 3.6, 70 C = 5.5, and 100 C = 4.9. These losses accounted for the differences in total P concentration among the various drying methods. The extractable PO_4-P values

TABLE 1

Apparent and corrected concentration values for K, P, acetic acid extractable PO_4-P, and the proportion of acid-soluble P in plant material as affected by drying method (DM), P-fertilizer treatment, and plant material.* (See text for added detail.)

Treatment	Total K	Total P	Extractable PO_4-P	$(PO_4\text{-P})/P$	DM loss	Corrected for DM loss: P	Corrected for DM loss: PO_4-P
			%				
Drying method**							
Freeze-dry	3.09 b	0.23 b	0.15 d	63 c	0	.23	.15
40 C	3.29 a	0.25 a	0.18 b	69 b	6.5	.23	.17
56 C	3.20 a	0.24 a	0.17 c	67 b	3.6	.23	.16
70 C	3.26 a	0.24 a	0.17 c	68 b	5.5	.23	.16
100 C	3.24 a	0.24 a	0.20 a	78 a	4.9	.23	.19
Plant material							
Alfalfa	2.17	0.22	0.10	46			
Sugarbeets	4.26	0.27	0.25	92			
P-fertilizer status							
− P	3.34 x	0.23 y	0.16 y	66 y			
+ P	3.08 y	0.25 x	0.18 x	72 x			

* Data values are rounded off and values corrected for dry matter loss are shown without multiple range test, since raw data were not amenable to analysis of variance.

** Data (uncorrected for dry matter loss) were processed by the analysis of variance (drying method × plant material × P-fertilizer status) and Duncan's multiple range test. Comparable means, within treatment groups, followed by no letter in common are significantly different at the 1% level of statistical significance.

were similar for tissues dried at 56 and 70 C, but these values were greater than those for freeze-dried tissue ($P \leq 0.01$) and less than those for tissues dried at 100 C ($P \leq 0.01$). Correcting the extractable PO_4-P levels for dry matter losses did not rectify the treatment differences. Thus, the amount of PO_4-P relative to total P in the plant tissue was significantly altered ($P \leq 0.01$) by the oven-drying procedures. Trends (data not shown) in the extractable PO_4-P and $(PO_4\text{-P})/P$ were similar for the two crops and two P-fertilizer treatments, with no significant interactions ($P < 0.01$) calculated by the analysis of variance.

In a previous study involving alfalfa, sugarbeet petioles, and bean plants (*Phaseolus vulgaris* L) (unpublished), we found that the 0.35 N acetic acid extractable SO_4-S levels (same extraction as used for PO_4-P), as compared with total S levels, were not significantly ($P \leq 0.05$) changed by the choice of drying method (FD, 60 C, and 100 C-ambient − 3 hours at 100 C, followed by drying at ambient temperatures). However, $(PO_4\text{-P})/P$ values were 0.52, 0.54, and 0.72 and (hot water-soluble N)/total N values were 0.71, 0.79, and 0.67 for the respective drying methods. The analysis of variance indicated significant ($P \leq 0.01$) effects of drying method on both extractable P and extractable N, and their proportions relative to total P and total N.

The wide range in extractable PO_4-P levels obtained between freeze-dried and oven-dried tissue in this study strongly suggests the need for rigorous control of sample drying methods before attempting to correlate PO_4-P to plant P nutritional status.

Freeze-drying was the best drying method tested, since it resulted in the least dry-matter loss and least apparent hydrolysis of organic P compounds.

REFERENCES

1. Chapman, H. D., and P. E. Pratt. 1961. Methods of analysis for soils, plants, and waters, 309 p. Univ. Calif.

2. Mayland, H. F. 1968. Effect of drying methods on losses of carbon, nitrogen, and dry matter from alfalfa. Agron. J. 60:658-659.

3. Smith, D. 1973. Influence of drying and storage conditions on nonstructural carbohydrate analysis of herbage tissue - a review. J. Brit. Grassld. Soc. 28:129-134.

4. Westermann, D. T., G. E. Leggett, and J. N. Carter. 1977. Phosphorus fertilization of sugarbeets. J. Am. Soc. Sugar Beet Technol. 19:262-269.