that 2C4F was not an effective herbicide, as determined by defoliation tests, for the control of oak and hickory, but 2C4F was much more effective in the defoliation of certain species of hawthorn than 2,4,5-T.

In the latter part of June a comparison of the decarboxylation rates of 2,4-D in a number of woody species was made (Table 2). The rates of decarboxylation were quite low for all species. The rate of decarboxylation was highest in persimmon, next highest in blackjack oak, and very low in green ash, sweet gum and winged elm. The susceptibilities of these species to 2,4-D as listed by Elwell[3] and others (8) do not correlate with the ability of these species to decarboxylate 2,4-D. Green ash and winged elm are apparently the most resistant to 2,4-D but showed the lowest rates of decarboxylation. Sweet gum, which is intermediate in susceptibility, also showed a low rate of decarboxylation. Persimmon decarboxylated 2,4-D to some extent and is also readily defoliated by 2,4-D; however, regrowth usually occurs. Blackjack oak, which is among the most susceptible of these species, decarboxylated 2,4-D to some extent. Apparently other factors are more important than decarboxylation in determining the susceptibility of these species to 2,4-D.

Table 2. Per cent decarboxylation, with standard deviations, of 2,4-D by some woody plants during a 22-hour period. Average of eight determinations.

Species	Per cent 2,4-D taken up which was decarboxylated	Relative susceptibility[a]
Persimmon	0.89 ± 0.36	I-R
Blackjack oak	0.65 ± 0.20	I
Green ash	0.14 ± 0.05	I-R
Sweet gum	0.11 ± 0.07	I-R
Winged elm	0.08 ± 0.05	R

[a]From reference (8), in which R indicated resistant, I intermediately susceptible and S susceptible to 2,4-D.

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Silica in Medusahead[1]

Charles F. Swenson,[2] Duane Le Tourneau and Lambert C. Erickson[3]

Abstract. Collections of plants of medusahead, *Elymus caput-medusae* L., were made from natural infestations in Nez Perce County and Washington County in northern and southern Idaho, respectively. The ash and silica content (dry weight basis) decreased as the plant matured. The total ash of the entire plant contained from 72–89 per cent silica. Similar percentages of silica in ash were obtained in the culms, heads, and seeds of the plant. X-ray diffraction patterns and polarizing microscope examinations showed the mineral form of silica to be opal. Heavy deposition of silica was found in the barbs of awns, in the epidermis of the leaves, culms, glumes and seeds, and in strands beneath the epidermis.

Introduction

Earlier research on the chemical composition of medusahead (*Elymus caput-medusae* L.), a winter annual grass which is currently a major range weed problem in Idaho and all Pacific Coast states, showed a high ash and silica (silicon dioxide) content (1). A comparison of the silica content of medusahead with that of other plants which accumulate silica (7) indicated that medusahead ranks among the highest. It has been suggested that this high silica content of medusahead may be partially if not totally responsible for its harshness and unpalatability to livestock, and for its resistance to decomposition on the range (1, 10). Since this high silica content may contribute to its non-utilization and consequent persistence as a weed, this study was made to determine the amount of ash and silica in medusahead at different stages of growth, the quantitative deposition of silica in several plant parts, and its mineral nature.

Materials and Methods

The vegetation samples for this study were collected from two locations, one in northern and one in southern Idaho. The samples from northern Idaho, selected from a typical infestation with reference to topography and density of stand, were obtained on the breaks of the Clearwater River in Nez Perce County, northeast of Lewiston, Idaho.

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[2]Formerly Research Assistant, Agronomy Department, University of Idaho, presently Soil Scientist, Soil Conservation Service, Grangeville, Idaho.

[3]Agricultural Biochemist and Associate Agronomist, respectively, Agricultural Experiment Station, University of Idaho, Moscow, Idaho.

Plant samples were collected at weekly intervals from April 13 to July 7, 1960. Growth stages between these dates progressed from early seedling to maturity. Individual plants were clipped at the soil surface and bulked. Precautions were taken to avoid contaminating the sample with soil and with other species in the mixed grass complex.

Individual samples of whole emerged plants, and culms, heads, and seeds were collected at intervals as the plants developed and matured. As the individual samples were collected, they were immediately placed in air-tight plastic bags. On return to the laboratory the samples were weighed, dried overnight in an electric oven at 100 C., placed in a desiccator for 1 hour, reweighed, and per cent moisture calculated.

The southern Idaho site was in the Crane Creek area in Washington County, about 250 miles south of the northern Idaho site. Medusahead was collected in the same manner from May 12 to July 6, 1960, and mailed immediately to Moscow. Moisture percentages were determined, but due to the longer interval required for their transit to the laboratory, the main interest in the southern Idaho samples was the ash and silica determinations for comparison with those from the northern location.

The methods of Piper (8) were used for duplicate ash and silica determinations. A petrographic microscope (Leitz, DIALUX-POL) was used for determining the areas of deposition and the mineral form of silica. A General Electric model XRD-5 X-ray diffractometer with a copper target X-ray tube was used in the X-ray diffraction studies.

Results and Discussion

The results of the ash, silica, and siliac in ash determinations on medusahead collected at different stages of growth from Nez Perce and Washington Counties are listed in Tables 1 and 2. The moisture content of seedling stage plants from Nez Perce County was 55.4 per cent, which increased to 68 per cent at the time of sheath elongation and gradually decreased to between 5 and 7 per cent at maturity. In general, plants collected from Washington County contained more moisture at similar growth stages than plants collected from Nez Perce County.

Table 1. The composition of medusahead from Nez Perce County. Percentages other than moisture are expressed on a dry weight basis.

Date	Growth stage	Per cent in whole plant			
		Moisture	Ash	Silica	Silica in ash
April 13.....	Seedling	55.4	17.8	13.9	78
April 17.....	Early sheath elongation	54.3	16.1	13.0	81
May 4.....	Late sheath elongation	67.9	16.4	13.2	80
May 11.....	Swelling in sheath	60.9	16.6	13.1	79
May 18.....	Awn emergence	65.2	16.5	13.2	80
May 25.....	Head emergence	65.6	14.6	11.7	80
June 1.....	Anthesis	58.5	14.3	11.5	80
June 8.....	Early dough	47.5	14.8	12.8	86
June 16.....	Early dough	47.2	12.0	10.5	87
June 23.....	Mid-dough	41.7	13.3	11.8	89
June 29.....	Late dough	29.8	13.1	11.2	86
July 7.....	Mature	5.7	11.8	9.6	81

Table 2. The composition of medusahead from Washington County. Percentages other than moisture are expressed on a dry weight basis.

Date	Growth stage	Per cent in whole plant			
		Moisture	Ash	Silica	Silica in ash
May 12.....	Awn emergence	69.5	14.7	10.7	73
May 19.....	Head emergence	66.9	14.8	11.0	75
May 30.....	Anthesis	68.0	14.3	10.3	72
June 7.....	Early dough	62.6	14.0	10.4	75
June 13.....	Early dough	56.1	12.1	9.9	82
June 26.....	Late dough	46.6	11.8	9.9	84
July 6.....	Mature	6.7	11.5	9.8	85

The results show a gradual decrease in the percentage of ash and silica as the medusahead matured. Bovey et al., (1) have previously reported a slight increase in ash content with advancing plant maturity which may have been due in part to sampling and collection methods. The results of the present study do not mean that total ash or silica was actually lost but that the amounts of other plant components increased more rapidly as the plant matured.

While the percentages of ash and silica in the entire plant decreased with maturity, the per cent silica in the ash remained fairly constant until flowering. At this developmental stage there was a distinct increase in per cent of silica in ash. Thereafter, the per cent silica in ash again remained fairly constant. The increase in the per cent silica in ash at anthesis could have resulted from a redistribution of elements or a sudden increase in the amount of silica taken up by the plant. Regardless of the growth stage, the ash of medusahead contained 72–89 per cent silica. When compared to other plants (7), it can be concluded that medusahead is one of the most effective silica accumulators ever reported.

At all stages of growth, except in mature plants, there was a higher percentage of silica in medusahead collected from Nez Perce than from Washington County. Bovey[4] found a significant difference in the total ash content of medusahead collected from the same area in different years. Previous research has shown that silica uptake is dependent on a number of factors including precipitation (9), pH (11), fertility (2), and the amount of silica in solution (11). Thus, the difference in the silica content of medusahead from the two areas may be due to such edaphic differences. The mean annual precipitation, July temperature, and soil pH in the two areas are rather similar. Several analyses were made on mature plants grown under higher fertility and moisture on the Plant Industry Farm at Moscow and harvested on July 14, 1960. This vegetation had a lower ash (9.5%) and silica (7.8%) content than plants grown in the more arid regions. Nevertheless, silica still comprised about 82 per cent of the ash of medusahead grown at Moscow.

Table 3 shows the high moisture retention in this species at anthesis and the sudden reduction at mid-dough through maturity. The per cent ash and silica in the culm (Table 3) increased after flowering and then remained relatively constant. From anthesis to maturity, the per cent silica in ash was again very high and tended to increase with maturity. Similar trends were also noted in

[4]R. W. Bovey, Master's Thesis, University of Idaho Library, June, 1959.

Table 3. The composition of heads and culms of medusahead from Nez Perce County. Percentages other than moisture are expressed on a dry weight basis.

Date	Growth stage	Per cent in sample			
		Moisture	Ash	Silica	Silica in ash
		Heads			
June 1.....	Anthesis	58.9	12.7	9.3	73
June 8.....	Early dough	49.4	15.9	13.7	86
June 23.....	Mid-dough	46.2	14.6	12.8	87
June 29.....	Late dough	31.1	15.0	13.4	89
July 7.....	Mature	6.5	12.8	10.6	83
		Culms			
June 1.....	Anthesis	55.3	11.4	9.2	81
June 8.....	Early dough	53.3	12.7	10.7	84
June 23.....	Mid-dough	36.0	12.1	10.6	88
June 29.....	Late dough	19.6	12.7	10.8	85
July 7.....	Mature	9.0	12.2	10.9	89

analyses of the heads (including the rachis, seeds, and awns). In general, heads contained more ash and silica than the culms. Several analyses were made on mature medusahead seed collected from the Nez Perce site. This seed (6.6% moisture) contained 10.0 per cent ash and 7.8 per cent silica on a dry weight basis. It thus appears that the rachis and glumes must be proportionately higher in ash and silica than the seed.

While the above studies indicated the gross amounts of silica present in various plant parts, they did not indicate where within the cellular structure the silica occurred or the mineral form of the silica. In a series of recent studies Lanning and co-workers (3,4,5,6) have shown that two different forms of silicon dioxide, opal and alpha-quartz, can occur in plants.

The ashed plant material which had been treated with HCl according to the method of Piper (8) was viewed under the petrographic microscope. This material was clear, colorless, and isotropic with an index of refraction of 1.45. These properties show the mineral form of silica to be opal, $(SiO_2H_2O)_n$. This identification was verified by X-ray diffraction pattern.

Further microscopic examination of the ashed material (Figure 1) showed that the silica was evident in the cell walls of the epidermis of the leaves, awns, glumes, and seeds and particularly on the barbs of the awns. This

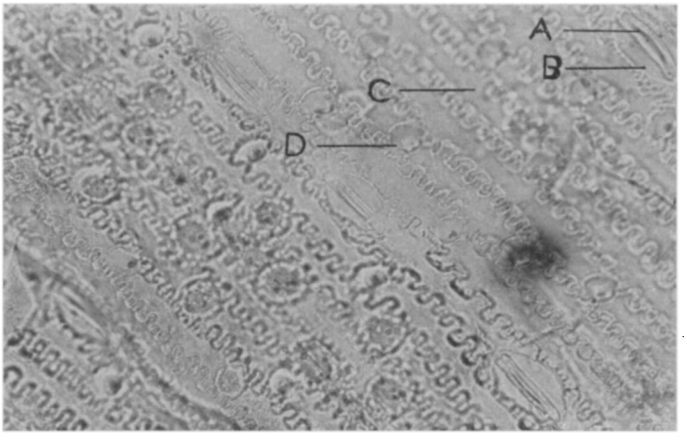

Figure 1. Silica deposition in the epidermis of an ashed leaf of medusahead (× 270). A—guard cell. B—subsidiary cell. C—long epidermal cell. D—short epidermal cell.

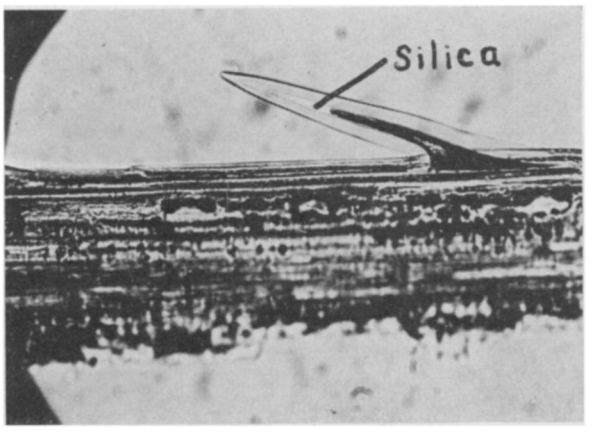

Figure 2. A silicified barb on the awn of unashed mature medusahead suspended in an oil immersion and viewed through a petrographic microscope (× 270) (light areas are silica).

silicified epidermal layer on the awns was very evident on both unashed and ashed material (Figure 2). In addition to this accumulated silica in the epidermis, strands of sausage-shaped opal deposits were observed to comprise the inner structure beneath the epidermis in the awns and stems parallel to the surface. The results of the microscopic examinations on medusahead agree in general with those reported for other species of grasses (5, 6).

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