attributed to microbiological metabolism. This study should also serve as a basis for further investigations on the chemical composition of amino acids and urea of the mushroom. For the first time, an attempt has been made to account for a nitrogen balance sheet of the soluble nitrogens obtained from cultivated mushrooms (*Agaricus bisporus*).

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BARLEY SILICA

Relation of Silicon in Barley to Disease, Cold, and Pest Resistance

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The silica content of the various parts of five varieties of barley was determined both in the fall and, again, in the spring when the plants were heading. The content varied from an average of 0.51% for developing heads to 5.8% in spring roots. On the average, leaves and roots had twice as much silica in the spring as in the fall. The silica content of barley differed from silica contents previously reported for wheat and oats. By means of spodograms, the actual patterns of silica deposits in the various parts of barley plants were determined. Index of refraction studies showed the silica to be opal. The results showed no direct relationship between total silica content and resistance to greenbugs, cold, or diseases.

SILICA IN BARLEY (*Hordeum vulgare*) has been of interest because of its nutritional value and its relationship to disease. Brenchley, Maskell, and Warington (*1*) made a considerable study of the relationship of silica to phosphate in the growth of barley plants. They found that significant increases in dry weight of barley plants occurred in water culture with addition of silica if available phosphate was quite low. They believed that silica might act within the plant by releasing phosphate from relatively quiescent parts of the plant and enable phosphate to be transferred to assimilation and growth regions.

Toth (*11*) reported definite increases in barley yield when either calcium or magnesium silicate was added to the soil. Barley markedly absorbed silica when grown in these silicated soils. Okawa (*9*) reported that silica was a nutrient of young barley plants, and that they appeared to be protected from cold injury when colloidal silica was present in the culture solution.

Germar's (*2*) research showed that cereals, well supplied with silica, were more resistant to mildew infections, apparently because deposition of silica in the epidermis makes the latter more resistant to attack by enzymes secreted by the fungus hyphae. Resistance to fungi that enter through stomata was not increased by silica. In laboratory experiments, Wagner (*12*) found that the amount of mildew infection in barley was related inversely to available silica.

None of the workers mentioned studied the silica content of individual parts of the barley plant or depositional patterns, as Lanning and coworkers have done for sorghum (*7, 8*), rice (*5*), and wheat (*6, 8*). Jones, Milne, and Wadham (*3, 4*) studied silica content of various parts of the oat plant rather completely, and reported the percentages of silica: leaf blade 5.34%, leaf sheath 4.55%, root 1.84%, and seed 0.12%.

This study was initiated to obtain more complete data on silica deposition in various parts of barley plants and to relate the silica to insect, disease, and cold resistance.

Materials and Methods

The barley plants (*Hordeum vulgare*) studied were grown in experimental plots on the Agronomy Farm of Kansas State University. Available silica content of the soil was high, approximately 20 mg. per 100 grams of soil (*7*). The pH of the soil was 5.2 at 1 to 1 dilution. The five varieties studied were Hudson (CI 8067), Dicktoo (CI 5529), Meimi (CI 5136), Chase (CI 9581), and Will (CI 11652). Dicktoo and Will resist attack by greenbugs, and Will resists mildew and loose smut also. Dicktoo is the most winter hardy and Hudson the least hardy. The Hudson variety winterkilled 50% while none of the other varieties were affected. The first samples were collected December 6, 1964; the second, from the same plots April 13, 1965, when all varieties except Hudson were heading. The plants were separated into roots, stems, leaves, sheaths, and heads. All were washed, thoroughly and then, dried at 110° C.

Silica and ash contents of plant materials were determined by classical gravimetric techniques. The material was ashed at about 600° C. After being weighed, the ash was treated repeatedly with 6*N* hydrochloric acid to remove other mineral impurities. The silica was filtered out and ignited. Silicon dioxide content was determined as difference of weights before and after hydrofluoric acid treatment. All determinations were made in duplicate. The depositional pattern of silica was studied by the spodogram technique described by Ponnaiya (*10*) and used by Lanning, Ponnaiya, and Crumpton (*8*).

Samples used in petrographic microscope studies were obtained by completely ashing the dried plant material at 600° C. The ash was treated repeatedly with hydrochloric acid to remove mineral impurities and the silica dried at 110° C.

Results and Discussion

Petrographic microscope studies of silica from ash of barley plants show it to be clear, colorless, and isotropic with an index of refraction of 1.45, properties typical of the mineral opal (*8*). Results of silica and ash analyses are given in Table I. All plant parts had higher silica contents in the spring than corresponding parts had in the fall. On the average, leaves and roots had twice as much silica in the spring as in the fall.

Silica percentages were highest in roots, lowest in developing heads, and quite low in stems. The leaves had a little over one-half as much silica as the roots, and the sheaths had an amount between that of leaves and roots. Hudson barley, which winterkilled, had next to the highest silica content in roots and the highest in stems in the Dec. 6 sampling. Will, which had about the same silica content, did not winterkill. The most hardy variety, Dicktoo, had a low silica content. Although silica contents of the plants studied varied considerably, none was low in silica, probably because of the soil's high silica content. An extreme in variation in silica content in a plant part was that of Hudson sheaths' 6.01% to that of Will sheaths' 2.95% silica.

Silica content of barley differs considerably from that reported for oats by Jones, Milne, and Wadham (*4*). For example, oat roots had only 1.84% SiO_2 compared with barley's 5.87%. Leaf blade of oats (5.34% SiO_2) was considerably higher than the average SiO_2 percentage in barley leaf blade. Barley sheath averaged 0.5% less than the 4.55% reported for oats.

Barley also differs from wheat (*6*, *8*). Silica content was somewhat lower in barley leaves and sheaths than in corresponding parts of wheat plants. Barley stems had slightly more silica than wheat stems. Roots of barley plants collected in the spring had considerably more silica than roots of wheat collected at the same time (5.87 and 3.85%). The opposite was true for roots collected in the fall (2.98 and 4.20%). Ash content

Table I. Silica and Ash in Barley Plants (% Dry Matter)[a]

	Roots		*Sheath*		*Stems*		*Leaves*		*Heads*[b]	
Variety	*Ash*	*Silica*	*Ash*	*Silica*	*Ash*	*Silica*	*Ash*	*Silica*	*Ash*	*Silica*
Collected Dec. 6, 1964										
Hudson CI 8067	10.32	3.60	9.02	2.91	13.10	0.96	6.50	1.95		
Will CI 11652	10.90	3.66	12.30	2.42	10.80	0.89	8.50	2.32		
Dicktoo CI 5529	7.65	2.10	12.90	2.22	8.90	0.49	10.40	2.30		
Meimi CI 5136	10.25	2.85	15.50	1.85	12.85	0.61	8.50	1.14		
Chase CI 9581	9.70	2.69	14.50	3.64	10.00	0.46	10.05	1.06		
Average	9.76	2.98	12.84	2.61	11.13	0.68	8.79	1.75		
Collected April 13, 1965										
Hudson CI 8067	14.30	6.40	17.90	6.01	11.20	1.68	10.80	3.26		
Will CI 11652	12.60	5.50	14.10	2.95	9.40	0.98	13.60	3.85	5.00	0.27
Dicktoo CI 5529	14.50	6.24	16.10	3.83	10.50	1.28	13.80	2.56	5.30	0.83
Meimi CI 5136	11.92	4.80	15.90	3.01	8.70	0.72	12.60	3.58	5.47	0.58
Chase CI 9581	14.40	6.42	17.70	4.47	10.33	1.01	10.40	3.18	5.26	0.37
Average	13.54	5.87	16.34	4.05	10.02	1.13	12.24	3.29	5.21	0.51

[a] From an analytical standpoint, any difference of over 0.10% is significant.
[b] Heads were not developed, yet, for the December 6 analyses.

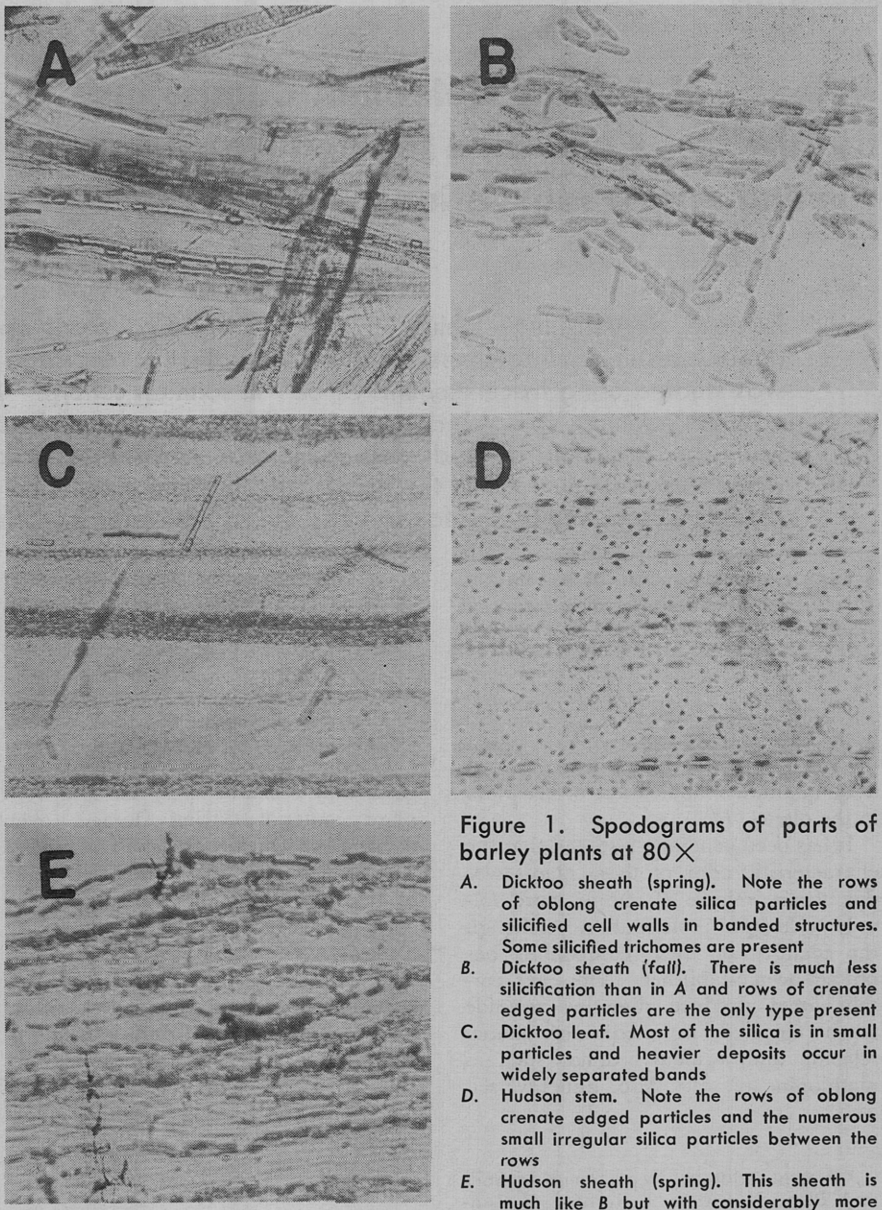

Figure 1. Spodograms of parts of barley plants at 80×

- A. Dicktoo sheath (spring). Note the rows of oblong crenate silica particles and silicified cell walls in banded structures. Some silicified trichomes are present
- B. Dicktoo sheath (fall). There is much less silicification than in *A* and rows of crenate edged particles are the only type present
- C. Dicktoo leaf. Most of the silica is in small particles and heavier deposits occur in widely separated bands
- D. Hudson stem. Note the rows of oblong crenate edged particles and the numerous small irregular silica particles between the rows
- E. Hudson sheath (spring). This sheath is much like *B* but with considerably more silicification

was highest in sheaths and lowest in developing heads. Ash content of all plant parts except stems was higher in spring than in fall. Stems were only slightly lower in the spring. Percentage of silica in the ash was highest in the roots in spring, averaging 43.3%, and was lowest in developing heads (average of 9.80%).

Spodograms representative of the silica deposition in various parts of the barley plants are shown in Figure 1. Considerable difference existed between the depositional pattern occurring in leaves and in sheaths. Rows of crenate edged silica particles, like those observed in barley sheaths, also, occurred in wheat sheaths (*6, 8*). The results showed no direct relationship between silica content and resistance to greenbugs, cold, or diseases. Both resistant and nonresistant varieties had high silica contents. There may be a relationship between early depositions and type of deposition to such resistance, as has been indicated by other workers.

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SELENIUM

Release of Volatile Selenium Compounds by Plants. Collection Procedures and Preliminary Observations

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Release of volatile selenium compounds by two plant species, *Astragalus racemosus* (Pursh.), a selenium-accumulating plant, and alfalfa, *Medicago sativa* (L.), a nonaccumulator, was studied using trace amounts of Se^{75} in solution culture. Methods for collection of the volatile selenium compounds are described. Amounts of volatile selenium released by both the accumulator and nonaccumulator species were qualitatively related to the amounts of selenium within the plant. With intact plants the release of the volatile compounds was mainly by the foliage and the rate of release varied throughout the day.

PLANTS growing on soils or in solution cultures containing substantial amounts of selenium often have a characteristic garlic-like odor. Indeed, many of the so-called primary accumulators have especially offensive odors, and it has been suggested by some workers that the intensity of the odor might be used as a qualitative indication of selenium in the plants (*14*).

It has been generally assumed that the characteristic odor of these plants was due to the release of one or more volatile selenium compounds, although the identity of these compounds has not yet been established. However, certain fungi produce dimethyl selenide when cultured in media containing selenate and a methyl donor such as methionine (*2, 4*). Also, dimethyl selenide is a respiratory excretion product of rats dosed with selenate or with dimethyl selenide (*10, 11*). Rosenfeld and Beath (*14*) have suggested that dimethyl selenide may also be released by higher plants, but experimental evidence on this point is lacking.

Evidence from numerous studies suggests that selenium may be lost from plant material during storage, oven drying, or chemical analysis. Thus Moxon and Rhian (*12*) reported losses of 4 to 73% when the grains of barley, corn, and wheat were stored for 3 to 5 years. In studies with *Astragalus bisulcatus*, Beath, Eppson, and Gilbert (*1*) found not only that analytical values for selenium decreased during drying at 20° C., but that the selenium compounds released could be trapped by bubbling air from the drying plant material through concentrated sulfuric acid. However, Hurd-Karrer (*8*) reported that when wheat seedlings were dried in the oven at 60° C. for 24 hours the odor characteristic of drying seleniferous plant material was not detected.

For the most part, volatilization of selenium was studied with plant tissues containing relatively large amounts of the element—so-called selenized plants containing from 5 to several thousand p.p.m. of selenium. These studies were of considerable interest because of the known toxic effects of selenized vegetation on animals.

However, with the more recent recognition of animal requirements for trace amounts of selenium, it became desirable to investigate the problem of volatilization of selenium by plants containing low level or trace amounts of the element. [The role of trace amounts of selenium in animal nutrition has been discussed in detail by a number of workers and is not considered here (*7, 13–16*).]

Analytical values for selenium in plant materials suspected of contributing to selenium-responsive disorders of ani-

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