FACTORS AFFECTING THE ASCORBIC ACID CONTENT OF CABBAGE LINES[1]

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INTRODUCTION

Recent summaries of quantitative estimates of vitamin content of plant and animal foods give bewildering ranges in the readings. It has been shown that concentration of the same vitamin varies from tissue to tissue in the same organ (*3*),[2] from fruit to fruit on the same tree (*6*), from season to season on the same variety (*5*), and, of especial interest to the plant breeder, from variety to variety (*2*). A study of ascorbic acid content in cabbage from Ohio (*2*) showed that among 30 varieties grown there in the summers of 1938 and 1939 there were significant differences with average vitamin C content for 2 head samples each ranging from 0.48 mg. per gram of fresh weight for the variety All Head Select to 1.81 for Midseason Market, 2 varieties having practically the same average weight. This high reading of head leaves of the latter exceeds the previously recorded maximum of 1.58 mg. per gram for head leaves reported in 1939 from Texas (*4*); it places maximum readings for cabbage ahead of those for citrus juices, tomatoes, and strawberries as sources of ascorbic acid in the American dietary (*3*).

MATERIALS AND METHODS

A study of some factors determining variability in ascorbic acid content in cabbage was conducted with 25 breeding lines planted in a randomized-block design having 3 replicates in the fall of 1941 and 3 in the spring of 1942. The randomized-block design permitted study of the variability of ascorbic acid readings with and without the correlated effect of head weight.

Variance of ascorbic acid alone was compared with the covariance of ascorbic acid on head weight; and covariance was found as the errors of estimate when the main terms were compared by Snedecor's method (*9, pp. 249–273*) with the error term. The mean unadjusted ascorbic acid readings were adjusted by the following formula:

$$X = Y - bx$$

where Y = individual ascorbic acid readings
b = regression coefficient of the error term
x = departure of weight from the general mean
X = adjusted individual ascorbic acid reading.

The breeding lines selected for this study are shown in table 1. All lines were obtained from survivors of the low temperatures of the fall of 1938.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 329.

Head characters were classified in the field at the time of harvest, and ascorbic acid content was obtained as soon as possible afterward by Morell's (*8*) rapid adaptation of the Bessey (*1*) and Mindlin and Butler (*7*) procedure. Samples were obtained by cutting the heads through the axis, removing an aliquot segment of each carefully with a large knife, and then macerating the tissue as described by Morell (*8*).

TABLE 1.—*Mean weight and ascorbic acid readings for 25 breeding lines of cabbage grown in 2 seasons, fall 1941 and spring 1942, together with adjusted ascorbic acid values*

Breeding lines	Head weight		Ascorbic acid per gram				Ranking of adjusted values	
			Unadjusted		Adjusted [1]			
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
	Pounds	*Pounds*	*Milligram*	*Milligram*	*Milligram*	*Milligram*		
Self-pollinated Volga:								
534-5-1-3	3.7	2.4	0.48	0.50	0.48	0.49	21	21
534-5-1-4	3.3	1.9	.54	.54	.52	.49	12	21
534-5-3-1	3.9	1.6	.50	.66	.51	.59	14	6
534-5-5-1	2.3	2.2	.36	.51	.31*	.48	25	23
534-7-4-2	3.7	2.9	.51	.46	.51	.48	14	23
534-15-4-1	3.6	2.5	.56	.52	.56	.51	7	18
534-16-2-1	3.4	2.3	.58	.50	.57	.48	4	23
Open-pollinated Charleston Wakefield (F_3):								
543-0_1-3-1	1.9	1.5	.80	.68	.73*	.61	1	2
543-0_1-3-4	2.9	1.7	.52	.67	.49*	.61	20	2
543-0_1-3-29	3.5	3.4	.58	.54	.57	.59	4	6
543-0_1-3-40	3.2	1.6	.62	.58	.60	.51	2	18
543-0_1-3-47	3.0	2.1	.53	.64	.50*	.61	18	2
543-0_1-5-3	2.7	2.5	.54	.54	.50	.53	18	16
543-0_1-5-12	1.9	2.1	.67	.60	.60	.57	2	10
543-0_1-7-4	4.9	2.8	.52	.57	.57	.58	4	9
543-0_1-7-7	5.3	3.3	.45	.54	.51	.59	14	6
543-0_1-11-19	4.9	2.8	.43	.55	.48	.56	21	11
543-0_1-11-23	3.8	2.8	.56	.52	.56	.53	7	16
543-0_1-11-26	5.3	3.4	.46	.49	.52	.54	12	13
543-0_1-11-32	4.2	3.4	.53	.55	.55	.60	9	5
Controlled cross (Volga×Charleston Wakefield):								
BCC 2-1-10 (F_3)	3.8	2.6	.44	.55	.44*	.55	24	12
Open-pollinated All Head Early:								
537-0_1-1-3	3.9	2.9	.47	.49	.48	.51	21	18
All Head Select:								
539-0_1-1-1	5.1	2.4	.48	.55	.53	.54	11	13
539-0_1-5-3	3.5	2.7	.52	.53	.51	.54	14	13
Wisconsin Ballhead:								
550-0_1-9-1	3.8	2.9	.55	.64	.55*	.66	9	1
General mean	3.70	2.57	.529	.553	.530	.564		

[1] * indicates that fall and spring values were significantly different. A difference of 0.11 mg. was necessary for significance at 5-percent point.

RESULTS

Table 1 gives the mean head weights and the unadjusted and adjusted ascorbic acid readings for 25 breeding lines. The smaller average head weight of the spring crop, 2.57±0.07 pounds, compared with that of the fall crop, 3.70±0.10 pounds, was accompanied by a higher average ascorbic acid content, 0.553±0.007 mg. In the fall the average content was 0.529±0.007 mg. The differences between general means for the two variables are statistically significant at the 1-percent point, 1.13±0.12 pounds for weight and 0.024±0.009 mg. for ascorbic acid.

Table 2 shows *F* values for the variance in ascorbic acid and for the covariance of ascorbic acid on head weight for the two seasons singly and combined. The standard error of a single determination, 0.067 in the fall and 0.062 in the spring, and the correlations between weight of head and ascorbic acid, viz —0.55** [3] in fall and —0.61** in spring for error sources of variance, are practically the same. Variance for lines is highly significant, but that for replicates is not significant.

When seasons are combined, there is a highly significant seasonal effect in the variance of ascorbic acid, 7.88**, but when regression on weight is considered as in the covariance of season compared with error, the significance is eliminated, 2.97. The significance of the variety term in variance, 5.90**, and covariance, 5.51**, is above the 1-percent point. Ascorbic acid readings are adjusted to the regression data for general mean head weight in columns 6 and 7 of table 1.

TABLE 2.—*Analysis of variance and regression data for values in table 1*

Sources of variability	Variance		Regression data			
	Degrees of freedom	*F* values [1]	Degrees of freedom	*F* values for covariance [2]	Regression coefficient	Correlation coefficient
Fall 1941:						
Lines	24	5.04**		5.22**		
Replicates	2	.84		.22		
Error			47		—0.0378	—0.5527**
Total			73		—.0434	—.5282**
Spring 1942:						
Lines	24	2.85**		2.79**		
Replicates	2	2.15		1.25		
Error			47		—.0669	—.6144**
Total			73		—.0695	—.6348**
Both seasons:						
Lines	24	5.90**		5.51**		
Replicates [3]	4	1.45		.97		
Season	1	7.88**		2.97		
Seasons × lines [2]	24	2.14**		2.59**		
Error			95		—.0453	—.5607**
Total			148		—.0448	—.5597**

[1] Standard errors for a single determination are fall, 0.067; spring, 0.062; both, 0.065.
[2] *F* values for covariance when the interaction term is used instead of the error term are for lines 2.06*, and for season, 0.53.
[3] Variability of replicates within seasons.
** = Significant at the 1-percent point.

Inconsistency in behavior of these 25 lines in the 2 seasons is shown by the *F* value of 2.06* for the comparison (footnote 2, table 2) of the covariance for lines with the interaction term. The details of the inconsistency are seen in the columns of table 1 giving mean unadjusted and adjusted ascorbic acid values. Furthermore, the coefficient of correlation between 1941 and 1942 unadjusted mean readings is 0.4616*, whereas between the adjusted readings it is 0.3353.

DISCUSSION

Table 2 shows a highly significant degree of negative correlation between ascorbic acid and head weight, —.5607**, for the combined-seasons error term; this is low enough, however, to indicate that head weight is not a major factor in affecting concentration of ascorbic acid.

The relative importance of heredity (line sources of variability) and environment (replicates and seasons) in producing ascorbic acid

[3] Values marked ** are statistically significant at the 1-percent point; those marked * at the 5-percent point.

differences between breeding lines is shown in table 2 by the relative sizes of *F* values for variance and covariance analyses. Column 3 shows these relative values when the effect of head weight is not eliminated (variance), and column 5 when it is (covariance).

The *F* values for variance suggest that seasonal effect, 7.88**, is more important than line effect, 5.90**, and that both effects are significant at the 1-percent point, whereas no significance is attached to replicates (soil variability). The *F* values for covariance, where head weight influence is eliminated, show highly significant line variability, but nonsignificant seasonal variability. In other words, variability in ascorbic acid between breeding lines is determined mainly by hereditary factors, and seasonal influence operates mainly on head size and therefore to a lesser degree on ascorbic acid content.

Comparison of the covariance for lines with that of the interaction term discloses a significant degree of inconsistent varietal (line) behavior from season to season. The extent of inconsistency is shown after adjustment of the ascorbic acid readings according to the regression coefficients for the two seasons in the last four columns of table 1. The new values in ascorbic acid content are best shown by their relative rankings.

There is greater variability in ascorbic acid in the fall than in the spring, and some lines apparently do better in one season than another. Application of the size of a significant difference between seasons, 0.11 mg., to the data for adjusted mean readings in ascorbic acid discloses six significant differences. Most, but not all, of these differences favor the spring. The outstanding exception is line 543–0_1–3–1, which, although always near the lead, apparently does significantly better in the fall.

As far as temperature is related to ascorbic acid there appears to be evidence that the ultimate effect, whether enhancing or depressing, depends on the genetic constitution of the line in question.

A noteworthy line is 550–0_1–9–1, which in addition to being consistently high in ascorbic acid, is also above average in head weight and serves, with lines 543–0_1–7–4 and 543–0_1–11–32, to demonstrate that small weight is not a primary factor in producing high ascorbic acid.

SUMMARY

There is a significant degree of negative correlation between ascorbic acid concentration and head weight among 25 breeding lines of cabbage grown as 3 replicates in the fall and 3 in the spring.

Of the six lines with more consistently high ascorbic acid content, judged by adjusted ranking, three were above average in head weight.

Regression data show that hereditary differences are more important than seasonal or positional differences in producing ascorbic acid differences between breeding lines.

Seasonal effect on ascorbic acid is expressed chiefly on head size and secondarily on genetic constitution.

Only six lines differed significantly in ascorbic acid content from season to season. In only one of these was the content higher in the fall than in the spring.

LITERATURE CITED

(1) Bessey, O. A.
1938. A METHOD FOR THE DETERMINATION OF SMALL QUANTITIES OF ASCORBIC ACID AND DEHYDROASCORBIC ACID IN TURBID AND COLORED SOLUTIONS IN THE PRESENCE OF OTHER REDUCING SUBSTANCES. Jour. Biol. Chem. 126: 771–784.

(2) Burrell, R. C., Brown, H. D., and Ebright, V. R.
1940. ASCORBIC ACID CONTENT OF CABBAGE AS INFLUENCED BY VARIETY, SEASON, AND SOIL FERTILITY. Food Res. 5: 247–252.

(3) Fixsen, M. A. B., and Roscoe, M. H.
1940. TABLES OF THE VITAMIN CONTENT OF HUMAN AND ANIMAL FOODS. II. Nutr. Abs. and Rev. 9: 795–861.

(4) Floyd, W. W., and Fraps, G. S.
1939. VITAMIN C CONTENT OF SOME TEXAS FRUITS AND VEGETABLES. Food Res. 4: 87–91.

(5) Hamner, K. C., Lyon, C. B., and Hamner, C. L.
1942. EFFECT OF MINERAL NUTRITION ON THE ASCORBIC ACID CONTENT OF THE TOMATO. Bot. Gaz. 103: 586–616, illus.

(6) Harding, P. L., and Thomas, E. E.
1942. RELATION OF ASCORBIC ACID CONCENTRATION IN JUICE OF FLORIDA GRAPEFRUIT TO VARIETY, ROOTSTOCK, AND POSITION OF FRUIT ON THE TREE. Jour. Agr. Res. 64: 57–61.

(7) Mindlin, R. L., and Butler, A. M.
1938. THE DETERMINATION OF ASCORBIC ACID IN PLASMA, A MACROMETHOD AND MICROMETHOD. Jour. Biol. Chem. 122: 673–686.

(8) Morell, S. A.
1941. RAPID PHOTOMETRIC DETERMINATION OF ASCORBIC ACID IN PLANT MATERIALS. Indus. and Eng. Chem., Analyt. Ed., 13: 793–794, illus.

(9) Snedecor, G. W.
1940. STATISTICAL METHODS APPLIED TO EXPERIMENTS IN AGRICULTURE AND BIOLOGY. Ed. 3, 442 pp., illus. Ames, Iowa.

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