PHOSPHORUS COMPOUNDS IN COTTONSEED KERNELS

Influence of Variety of Cottonseed and Environment

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The importance of the role of the several types of phosphorus compounds is recognized by investigators in the field of nutrition. Information about the types and amounts of these compounds present in cottonseed is basic to any comprehensive consideration of the nutritive value of cottonseed products. The present paper reports data for seven types of phosphorus compounds in 58 samples of cottonseed kernels selected so that the effects of varietal and environmental factors could be indicated. Statistical examination of the data indicated that the influence of environmental factors on the values for total, acid-soluble, phosphatide, inorganic, and phytin phosphorus calculated to either a moisture-free or moisture- and oil-free basis was highly significant statistically as compared to varietal factors. A significant correlation coefficient (+0.989) was obtained for the relationship between total phosphorus and phytin phosphorus contents of the moisture-free kernels. The regression equation for this relationship should prove useful for prediction purposes.

THE ROLE played by the several types of phosphorus compounds is important in the field of animal nutrition. Information about the types and amounts of these compounds present in cottonseed is basic to any comprehensive consideration of the nutritive value of cottonseed products.

Very few data concerning the phosphorus compounds of cottonseed have been reported in the literature, especially regarding the effect of environmental and varietal factors on the amounts of the various types present. From available sources in the literature (*3*, *4*) it would appear that the total phosphorus content of the kernel ranges from about 0.8 to 1.0%. About 75% of this phosphorus has been reported to be phytin phosphorus, 5 to 6% phosphatide phosphorus, and the remainder classed as phosphoproteins and insoluble phosphorus compounds (*4*).

The present paper reports data for seven types or classes of phosphorus compounds in 58 samples of cottonseed kernels selected so that the effects of varietal and environmental factors could be ascertained. It reports a part of a study of the influence of variety and environment on the chemical composition and physical properties of cottonseed and seed cotton.

Samples and Methods of Analysis

Samples of cottonseed of eight commercial varieties of cotton were obtained from experimental growths at 13 locations during 1947, 1948, and 1949. From these 312 samples, 58 lots of cottonseed were selected for use in the present investigation. These consisted of all varieties grown at Shafter, Calif., and Acala 1517W variety grown at all locations in 1947; all varieties grown at Statesville, N. C., and Deltapine 15 variety grown at 11 locations in 1948; and all varieties grown at Stoneville, Miss., and Mebane variety grown at 13 locations in 1949. The locations and varieties are listed in Table I. The plantings were irrigated at State College, N. M.; Sacaton, Ariz.; and Shafter, Calif.

The seed cottons were picked from freshly opened bolls and air-dried under cover. The ginned seeds were stored in sealed containers at 0° F., since previous work had shown that storage of seed containing less than 8% moisture under these conditions resulted in no significant change in chemical composition (*7*).

A representative 120-gram portion of each cottonseed sample was dehulled by passage through a Bauer mill, the meats were separated by screening, and ground in a Wiley mill equipped with a 2-mm. screen. The ground meats were analyzed for total, acid-soluble, phosphatide, inorganic, and phytin phosphorus using the previously described analytical system for the determination of these compounds in plant materials (*6*). The phosphorus present as nucleic acid and as carbohydrate esters of phosphoric acid was calculated from the data for the other types of phosphorus (*6*). Moisture was determined on the ground kernels by the American Oil Chemists' Society official method Ba 2-38 (*1*). Free fatty acids in the oil from the kernels were determined by method Aa 6-38 (*1*).

Results and Discussion

The amounts of the various types of phosphorus compounds in the 58 samples of cottonseed kernels are tabulated and summarized in Table I. From inspection of the 3-year ranges given in Table I, it is seen that most of the types of phosphorus cover a considerable range in values. The total phosphorus contents range from 6.92 to 13.15 mg. per gram, corresponding to 0.69 and 1.32%, respectively. The 3-year mean is 10.52 mg. per gram. The values for acid-soluble and phytin phosphorus vary over approximately the same range as total phosphorus. The phosphatide phosphorus contents range from 0.57 to 0.79 mg. per gram for the 3 years, with most of the values being about 0.7 mg. per gram. Although it would appear from the range given that the amounts of inorganic phosphorus in cottonseed kernels are rather variable, most of the values found for the present samples were approximately 0.2 to 0.3 mg. per gram and the 3-year mean was 0.24 mg. per gram. The two high values, 0.79 and 0.96 mg. per gram, were for

Table I. Amounts of Various Phosphorus Compounds in Cottonseed Kernels

Year, Location, and Variety	Phosphorus Compounds (Moisture-Free Basis), Mg./G. Total	Acid-soluble	Phosphatide	Inorganic	Phytin	Nucleic	Carbohydrate
Shafter, Calif., 1957							
Acala 4-42	11.93	10.99	0.68	0.22	9.73	0.26	0.97
Acala 1517W	11.55	10.58	0.71	0.22	9.28	0.26	1.01
Rowden 41B	11.60	10.65	0.70	0.18	9.25	0.25	1.13
Mebane	11.55	10.36	0.72	0.23	8.98	0.47	1.06
Stoneville 2B	10.32	9.29	0.70	0.17	8.16	0.33	0.89
Deltapine 15	10.51	9.52	0.67	0.15	8.50	0.32	0.81
Coker 100W	10.31	9.21	0.69	0.16	7.94	0.41	1.01
Coker Wilds	11.19	10.02	0.71	0.21	8.54	0.46	1.14
Mean	11.12	10.08	0.70	0.19	8.80	0.35	1.00
Standard deviation	± 0.65	± 0.63	±0.017	±0.031	± 0.57	±0.091	±0.113
Acala 1517W, 1947							
Statesville, N. C.	8.26	6.98	0.70	0.16	6.20	0.58	0.57
Florence, S. C.	11.39	10.17	0.72	0.28	9.17	0.50	0.66
Tifton, Ga.	9.92	8.48	0.74	0.25	7.54	0.70	0.64
Auburn, Ala.	10.91	9.65	0.77	0.23	8.52	0.49	0.84
Jackson, Tenn.	11.29	9.95	0.73	0.25	9.03	0.61	0.63
Stoneville, Miss.	12.65	11.29	0.79	0.33	10.19	0.57	0.71
St. Joseph, La.	12.87	11.61	0.77	0.32	10.34	0.49	0.88
Chickasha, Okla.	9.09	7.72	0.72	0.23	6.78	0.65	0.66
Greenville, Tex.	11.85	10.61	0.76	0.32	9.47	0.48	0.82
College Station, Tex.	12.10	10.74	0.73	0.24	9.95	0.63	0.51
State College, N. M.	8.67	7.67	0.65	0.14	6.55	0.35	0.92
Sacaton, Ariz.	10.35	9.18	0.66	0.19	7.93	0.51	0.99
Shafter, Calif.	11.55	10.58	0.71	0.22	9.28	0.26	1.01
Mean	10.84	9.59	0.73	0.24	8.53	0.52	0.76
Standard deviation	± 1.47	± 1.46	±0.042	±0.059	± 1.44	±0.121	±0.163
Statesville, N. C., 1948							
Acala 4-42	8.75	7.48	0.69	0.17	6.34	0.58	0.97
Acala 1517W	8.18	6.93	0.70	0.17	5.65	0.55	1.11
Rowden 41B	8.36	7.13	0.72	0.17	6.00	0.51	0.96
Mebane	8.64	7.22	0.68	0.18	5.95	0.74	1.09
Stoneville 2B	7.72	6.39	0.69	0.16	5.10	0.64	1.13
Deltapine 15	8.26	6.96	0.67	0.18	6.10	0.63	0.68
Coker 100W	8.19	6.76	0.67	0.16	5.84	0.76	0.76
Coker Wilds	7.83	6.38	0.65	0.16	5.32	0.80	0.90
Mean	8.24	6.91	0.68	0.17	5.79	0.65	0.95
Standard deviation	± 0.39	± 0.30	±0.019	±0.007	± 0.37	±0.105	±0.165
Deltapine 15, 1948							
Statesville, N. C.	8.26	6.96	0.67	0.18	6.10	0.63	0.68
Florence, S. C.	10.81	9.71	0.69	0.23	8.56	0.41	0.92
Tifton, Ga.	9.61	8.54	0.71	0.28	7.48	0.36	0.78
Auburn, Ala.	9.67	8.64	0.66	0.21	7.33	0.37	1.10
Jackson, Tenn.	9.32	8.12	0.71	0.23	7.21	0.49	0.68
St. Joseph, La.	11.23	10.16	0.70	0.26	8.60	0.37	1.30
Chickasha, Okla.	10.15	9.07	0.71	0.18	7.99	0.37	0.90
Greenville, Tex.	10.88	9.73	0.69	0.21	8.51	0.46	1.01
State College, N. M.	6.92	5.79	0.68	0.15	4.29	0.45	1.35
Sacaton, Ariz.	8.43	7.46	0.63	0.14	6.30	0.34	1.02
Shafter, Calif.	10.82	9.78	0.68	0.16	8.79	0.36	0.83
Mean	9.65	8.54	0.68	0.20	7.38	0.42	0.96
Standard deviation	± 1.30	± 1.38	±0.026	±0.045	± 1.36	±0.085	±0.225
Stoneville, Miss., 1949							
Acala 4-42	12.71	11.46	0.72	0.27	9.87	0.53	1.32
Acala 1517W	12.42	10.97	0.72	0.30	9.34	0.73	1.33
Rowden 41B	12.57	11.28	0.72	0.24	10.00	0.57	1.04
Mebane	12.65	11.15	0.73	0.28	9.92	0.77	0.95
Stoneville 2B	11.72	10.39	0.72	0.23	8.92	0.61	1.24
Deltapine 15	11.73	10.49	0.71	0.24	9.04	0.53	1.21
Coker 100W	12.14	10.76	0.74	0.23	9.70	0.64	0.83
Coker Wilds	12.43	11.08	0.75	0.31	9.78	0.60	0.99
Mean	12.30	10.95	0.73	0.26	9.57	0.62	1.11
Standard deviation	± 0.22	± 0.28	±0.009	±0.032	± 0.45	±0.088	±0.861
Mebane, 1949							
Statesville, N. C.	10.27	9.07	0.72	0.24	7.41	0.48	1.42
Florence, S. C.	12.08	11.10	0.65	0.79	9.36	0.33	0.95
Tifton, Ga.	10.75	9.55	0.57	0.96	8.44	0.63	0.15
Auburn, Ala.	11.40	9.94	0.71	0.25	8.92	0.75	0.77
Jackson, Tenn.	11.77	10.37	0.71	0.29	9.26	0.69	0.82
Stoneville, Miss.	12.65	11.15	0.73	0.28	9.92	0.77	0.95
St. Joseph, La.	13.15	11.69	0.73	0.41	10.69	0.73	0.59
Chickasha, Okla.	9.97	8.72	0.72	0.20	7.69	0.53	0.83
Greenville, Tex.	11.59	10.25	0.66	0.27	9.24	0.68	0.74
College Station, Tex.	10.24	9.02	0.71	0.22	7.97	0.51	0.83
State College, N. M.	8.97	7.71	0.67	0.16	6.60	0.59	0.95
Sacaton, Ariz.	10.20	9.01	0.69	0.20	8.08	0.50	0.73
Shafter, Calif.	9.14	7.82	0.70	0.16	6.67	0.62	0.99
Mean	10.94	9.65	0.69	0.34	8.48	0.60	0.82
Standard deviation	± 1.26	± 1.21	±0.044	±0.248	± 1.23	±0.127	±0.283
3-year-high	13.15	11.69	0.79	0.96	10.69	0.80	1.42
3-year-low	6.92	5.79	0.57	0.14	4.29	0.25	0.15
3-year-mean	10.52	9.29	0.70	0.24	8.11	0.53	0.91

Mebane variety grown in 1949 at Florence, S. C., and Tifton, Ga., respectively. The oils from these two samples contained 3.61 and 8.26% free fatty acids, respectively, whereas the free fatty acid contents of the oils from the other samples were low. It is believed that the high inorganic phosphorus and free fatty acid values might be associated in some way and reflect deterioration or damage to these two seed samples. The nucleic phosphorus values for the 3 years averaged 0.53 mg. per gram with a range of 0.25 to 0.80 mg. per gram. Variations in this type of phosphorus were governed to a large extent by changes in the acid-soluble values, since for a given total phosphorus value an increase in acid-soluble phosphorus usually resulted in a decrease in nucleic phosphorus, and vice versa. Similarly, variations in carbohydrate phosphorus for samples with similar total phosphorus values reflected changes in phytin phosphorus.

The data in Table I show that for each of the 3 years the location ranges are considerably larger than the variety ranges for total, acid-soluble, phytin, inorganic, and phosphatide phosphorus. For these types of phosphorus the standard deviations for locations for the 3 years average from 2.9 to 5.4 times as great as those for varieties, indicating considerably greater influence due to environmental than to varietal factors. In the case of nucleic and phosphatide phosphorus the differences between standard deviations for locations and for varieties are not so marked.

In order to evaluate the significance of these differences for each type of phosphorus, the variances due to locations and to varieties for the 3 years were compared by use of the F test. The F values for total, acid-soluble, phosphatide, inorganic, phytin, nucleic, and carbohydrate phosphorus, calculated to a moisture-free basis, were 8.90**, 9.68**, 6.11**, 34.7**, 8.22**, 1.45, and 2.11*, respectively. The F value calculated for inorganic phosphorus omitting the two samples having high inorganic phosphorus and high free fatty acid contents was 5.20**. An F value of 2.68 is required for statistical significance at the 1% level (**), and a value of 1.98 is required at the 5% level (*). This test of significance confirmed the observation, based on ranges for varieties and for locations, that environmental factors exerted more influence than varietal factors on each of the first five types of phosphorus. The difference between environmental and varietal effects for carbohydrate phosphorus was significant only at the 5% level. For nucleic phosphorus, the difference was not significant statistically.

The data given in Table I do not take into account the effect of the oil content

of the kernels which varied from 26.8 to 41.5%, moisture-free basis. Since cottonseed meal is an important feed stuff and most of the oil is removed from the kernels in the processing of the seed for meal and oil, the data in Table I were calculated to a moisture- and oil-free basis. The results, summarized in Table II, show the same trends as noted for moisture-free kernels in that environmental factors were of greater influence than varietal factors on the various types of phosphorus compounds.

The *F* values, calculated from the variance due to locations and to varieties, for total, acid-soluble, phosphatide, inorganic, phytin, nucleic, and carbohydrate phosphorus, calculated to a moisture- and oil-free basis, were 9.74**, 9.03**, 2.79**, 35.96**, 9.83**, 1.47, and 2.18*, respectively. These values are of the same magnitude and significance as those obtained for these types of phosphorus in moisture-free kernels.

It is apparent from the data in Table II that the amounts of total, acid-soluble, and phytin phosphorus in cottonseed meals vary over a considerable range. Since phytin accounts for the major proportion of the phosphorus in meals, variations in the amounts of total and acid-soluble phosphorus will largely reflect changes in phytin phosphorus. Though the amounts of the other types of phosphorus vary widely, their contribution to variation in total phosphorus is small because they are present in minor amounts.

The variety and station ranges and means for the various types of phosphorus compounds expressed as per cent of the total phosphorus in the kernels are given in Table III. The 3-year means for acid-soluble, phosphatide, inorganic, phytin, nucleic, and carbohydrate phosphorus are 88.0, 6.8, 2.3, 76.6, 5.1, and 9.0% of the total phosphorus, respectively. Although the 3-year range for phytin phosphorus is fairly large (62.0 to 82.2%), the 3-year mean of 76.6% agrees closely with the 75% value reported by Lishkevich (*4*) for 6 samples of kernels. The range in phosphatide phosphorus for the 3 years is 5.3 to 9.8%, with a mean of 6.8%. This range and mean are slightly greater than the 5 to 6% value previously reported (*4*).

The data were examined for trends indicating possible correlations between the various types of phosphorus and for correlations with mean temperature and rainfall during the period of development and maturation of the seed. The only relations which appeared promising were correlations between nucleic and carbohydrate phosphorus and between total and phytin phosphorus. A correlation coefficient of −0.252 was obtained for the first relation. This coefficient was not significant statistically, since 0.259 is required at the 5% level. It was found, however, that total phosphorus content was positively correlated with phytin phosphorus content and the correlation coefficient (+0.989) was highly significant statistically. The regression equation and standard error of estimate (S_{yz}) for this relationship were calculated, using total phosphorus as the independent variable. The equation was as follows: phytin phosphorus, mg. per gram = 0.957 (total phosphorus, mg. per gram) − 1.956. The regression coefficient indicates an increase of 0.957 mg. per gram of phytin phosphorus for 1 mg. per gram increase in total phosphorus. The regression line and the scatter diagram of the data for this relationship are shown in Figure 1. Since the standard error of estimate is relatively small (±0.23 mg. per gram) the regression equation should prove to be useful for prediction purposes.

A comparison of the present data for the types of phosphorus compounds in moisture-free cottonseed kernels with those previously reported (*2*, *4–6*) for a number of oilseeds and grains may be of value in nutritional considerations. Although the data for the samples other than cottonseed are limited, the following generalizations seem to be justified:

1. Cottonseed kernels are high in both total and phytin phosphorus contents, being exceeded only by rice bran.
2. Cottonseed kernels are at least equivalent to or slightly higher in phosphatide phosphorus than soybeans, and are much higher than the other common oilseeds and grains in this type of phosphorus compounds.
3. Cottonseed kernels are highest in carbohydrate ester type phosphorus.
4. Cottonseed kernels average among the lowest in inorganic phosphorus, being in the same range with sesame seed and peanut kernels for this type of phosphorus.
5. Cottonseed kernels are high in nucleic phosphorus content, being exceeded only by rice bran.
6. When considering types of phosphorus expressed as percentage of the total phosphorus, cottonseed kernels average lowest in inorganic phosphorus and almost as high in phytin phosphorus as sesame seed and rice bran.

Table II. Summary of Data for Phosphorus Compounds in Cottonseed Kernels

Year, Location, and Variety	Phosphorus Compounds (Moisture- and Oil-Free Basis), Mg./Gram						
	Total	Acid-soluble	Phosphatide	Inorganic	Phytin	Nucleic	Carbohydrate
Shafter, Calif. (8 varieties) (1947)							
High	18.82	17.33	1.15	0.36	15.35	0.74	1.83
Low	16.39	14.64	1.05	0.24	12.62	0.40	1.27
Mean	17.66	16.00	1.11	0.31	13.97	0.55	1.59
Standard deviation	± 1.04	± 1.08	±0.034	±0.051	± 0.97	±0.14	±0.18
Acala 1517W (13 locations) (1947)							
High	22.00	19.85	1.32	0.55	17.68	1.09	1.63
Low	12.79	10.80	1.05	0.23	9.60	0.42	0.84
Mean	17.42	15.42	1.17	0.39	13.72	0.84	1.22
Standard deviation	± 2.70	± 2.66	±0.080	±0.099	± 2.51	±0.19	±0.27
Statesville, N. C. (8 varieties) (1948)							
High	12.63	10.60	1.07	0.26	8.89	1.14	1.70
Low	10.78	8.92	0.92	0.22	7.12	0.76	0.93
Mean	11.78	9.87	0.98	0.24	8.27	0.93	1.36
Standard deviation	± 0.71	± 0.71	±0.061	±0.017	± 0.63	±0.14	±0.27
Deltapine 15 (11 locations) (1948)							
High	17.85	16.15	1.11	0.43	13.67	0.86	2.16
Low	11.07	9.26	0.92	0.22	6.86	0.52	0.93
Mean	14.55	12.89	1.03	0.31	11.12	0.63	1.46
Standard deviation	± 2.21	± 2.23	±0.060	±0.073	± 2.16	±0.10	±0.41
Stoneville, Miss. (8 varieties) (1949)							
High	19.78	17.82	1.18	0.48	15.55	1.19	2.12
Low	18.71	16.73	1.12	0.37	14.42	0.82	1.32
Mean	19.33	17.21	1.14	0.41	15.05	0.98	1.75
Standard deviation	± 0.41	± 0.39	±0.022	±0.045	± 0.45	±0.14	±0.31
Mebane (13 locations) (1949)							
High	21.66	19.26	1.20	1.54	17.61	1.20	2.25
Low	14.02	12.05	0.92	0.25	10.31	0.53	0.24
Mean	17.37	15.32	1.10	0.54	13.47	0.95	1.31
Standard deviation	± 2.20	± 2.09	±0.072	±0.40	± 2.07	±0.21	±0.45
3-year-high	22.00	19.85	1.32	1.54	17.68	1.20	2.25
3-year-low	10.78	8.92	0.92	0.22	6.86	0.40	0.24
3-year-mean	16.43	14.52	1.09	0.38	12.68	0.82	1.42

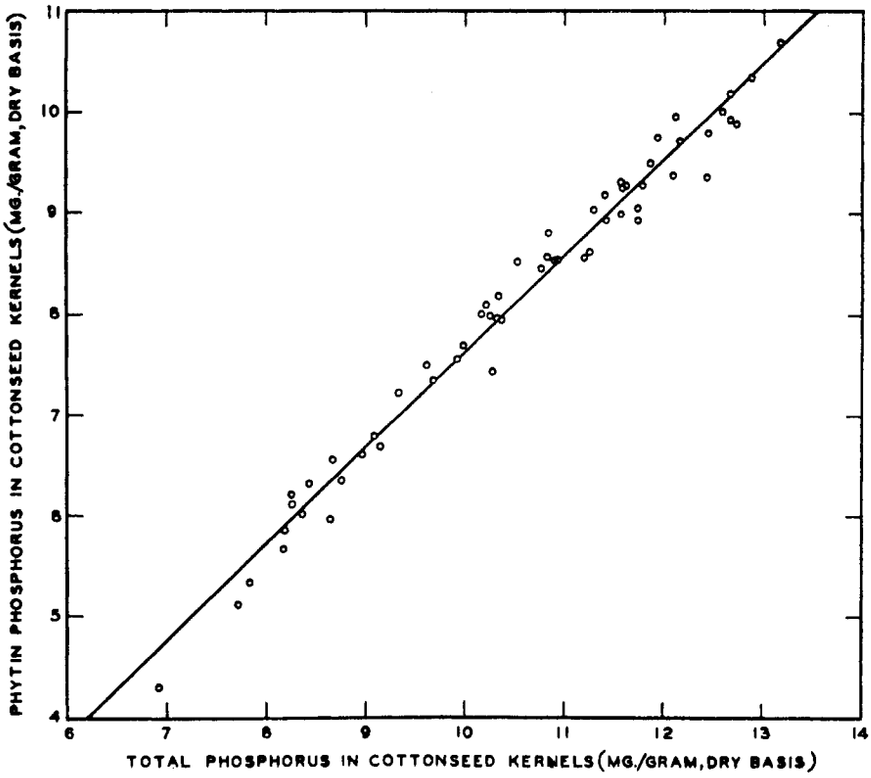

Figure 1. Relation between total phosphorus and phytin phosphorus in cottonseed kernels

Summary

Analytical data are presented for 7 types of phosphorus compounds in 58 samples of cottonseed kernels which were selected from seed of 8 varieties of cotton grown at 13 locations during 3 years so that the influence of varietal and environmental factors could be ascertained.

The 3-year means for total, acid-soluble, phosphatide, inorganic, phytin, nucleic and carbohydrate phosphorus were 10.52, 9.29, 0.70, 0.24, 8.11, 0.53, and 0.91 mg. per gram of moisture-free kernels, respectively. Most of the values for phosphatide phosphorus were about 0.7 mg. per gram and a majority of those for inorganic phosphorus were between 0.2 and 0.3 mg. per gram, whereas the values for most of the other types of phosphorus were more evenly distributed over a wider range. The 3-year means for acid-soluble, phosphatide, inorganic, phytin, nucleic, and carbohydrate phosphorus, expressed as per cent of the total phosphorus, were 88.0, 6.8, 2.3, 76.6, 5.1, and 9.0%, respectively.

Statistical examination of the data indicated that the influence of environmental factors on the values for total, acid-soluble, phosphatide, inorganic, and phytin phosphorus, calculated to either a moisture-free or moisture- and oil-free basis, was highly significant statistically as compared to varietal factors.

The correlation coefficient calculated for the relationship between total phosphorus and phytin phosphorus contents of the moisture-free kernels was +0.989, which was highly significant statistically. The regression coefficient indicates an increase of 0.957 mg. per gram of phytin phosphorus for 1 mg. per gram increase in total phosphorus. Since the standard error of estimate was small (±0.23 mg. per gram) the regression equation for this relationship might prove useful for prediction purposes.

Acknowledgment

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Table III. Amounts of Various Phosphorus Compounds in Cottonseed Kernels Expressed as Percentage of Total Phosphorus

Year, Location, and Variety	Phosphorus Compounds as % of Total Phosphorus					
	Acid-soluble	Phosphatide	Inorganic	Phytin	Nucleic	Carbohydrate
Shafter, Calif. (8 varieties) (1947)						
High	92.1	6.8	2.0	81.6	4.1	10.2
Low	89.3	5.7	1.4	76.3	2.2	7.7
Mean	90.6	6.3	1.7	79.0	3.1	9.0
Acala 1517W (13 locations) (1947)						
High	91.6	8.5	2.7	82.2	7.2	10.6
Low	84.5	6.0	1.6	74.6	2.3	4.2
Mean	88.3	6.8	2.2	78.4	5.0	7.1
Statesville, N. C. (8 varieties) (1948)						
High	85.5	8.6	2.2	73.8	10.2	14.6
Low	81.5	7.9	1.9	66.1	6.1	8.2
Mean	83.8	8.3	2.1	70.2	7.9	11.6
Deltapine 15 (11 locations) (1948)						
High	90.5	9.8	2.9	81.2	7.6	19.5
Low	83.7	6.2	1.5	62.0	3.3	7.7
Mean	88.3	7.2	2.1	75.9	4.5	10.4
Stoneville, Miss. (8 varieties) (1949)						
High	90.2	6.1	2.5	79.9	6.1	10.7
Low	88.1	5.7	1.9	75.2	4.2	6.8
Mean	89.0	5.9	2.1	77.8	5.1	9.1
Mebane (13 locations) (1949)						
High	91.9	7.7	8.9	81.3	6.8	13.8
Low	85.6	5.3	1.8	72.2	2.7	1.4
Mean	88.1	6.4	3.1	77.3	5.5	7.7
3-year-high	92.1	9.8	8.9	82.2	10.2	19.5
3-year-low	81.5	5.3	1.4	62.0	2.2	1.4
3-year-mean	88.0	6.8	2.3	76.6	5.1	9.0