STUDIES ON THE CHEMICAL COMPOSITION OF PLANTS ASSOCIATED WITH FLOWER BUD FORMATION*§

Y. ASAMI and H. ITO

*Tokyo Imperial University
Faculty of Agriculture*

*Tokyo Imperial College
of Agriculture*

Since the publication of the work by KRAUS and KRAYBILL,⁽⁵⁾ a great deal of interest has been centered on the study of the relative amounts of carbohydrates and nitrogen in relation to flower bud formation. The general belief that flower bud production is associated with increase in carbohydrate content seems to be supported by the results of various special practices such as ringing and defoliation. However, throughout the recent extensive works, the obtained results are not always the same, and the data which failed to show that the accumulation of carbohydrates favors flower bud formation, have been not rarely reported,⁽¹⁾⁽³⁾⁽⁷⁾ showing that a complete understanding seems to be still very distant.

The studies reported in this paper represent the data obtained with the Japanese pear trees and the short-day plants.

Materials and Methods

EXPERIMENTS WITH JAPANESE PEAR SHOOTS

The vigorously growing shoots of fruit trees are sometimes pruned back in summer for the purpose of getting flower buds on them with a belief that an enough accumulation of carbohydrates would be induced in the pruned shoots through checking shoot growth. The authors,⁽²⁾ however, obtained in their experiment with pear shoots the result that summer pruning induced a rather increase of nitrogen. On the other hand, KAWAGUCHI,⁽⁴⁾ reported in his study with Japanese pear trees that the shoots which had been pruned back in May when they were growing vigorously, generally failed to form flower buds on them, but many of them headed at the end of June or in July when their elongation declined or nearly ended, produced flower buds.

In this study, the effects of early and late summer pruning on the

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chemical composition as related to flower bud production were examined in 1935. The shoots of the variety Chojuro were used. The early heading which would be nearly ineffective for flower bud formation was conducted on May 27, and the late heading which would cause flower bud formation was done on July 4. Samples of each plot were taken for chemical analysis on July 20 when the flower bud differentiation was expected to occur in these shoots.

In Japanese pear trees, the shoots which have grown very vigorously form few flower buds only on their apical portion, while those which have ceased the length growth early form many flower buds on them except on several basal nodes which bear leaf buds. The shoots of these two types were chosen for study in 1936. Early in July, two groups of shoots, long growth and medium growth, were selected. The shoots of long growth were about 150 cm. in length at that time and still growing. Such shoots are found mostly at the center of a horizontal overhead trellis, on which the tree-top of Japanese pear is trained, where the scaffold limbs are bent nearly at right angles. The shoot of medium growth were about 80 cm. in length and had nearly completed length growth at that time. The half of shoots in each group was collected for chemical analysis on July 11, and the other half was remained on tree to examine flower bud formation. The shoots collected for chemical analysis were divided into three portions, top, middle and base, in the group of long growth, and two portions, top and base, in the group of medium growth. The pieces of about 12 cm. long were cutted off from each portion and submitted to analysis.

EXPERIMENTS WITH SHORT-DAY PLANTS

It will be very interesting to examine the effects of day-length on the chemical composition in short-day plants because short-day condition seems to be unfavorable for either carbohydrate accumulation or high carbohydrate-nitrogen ratio. NIGHTINGALE⁽³⁾ reported that carbohydrates accumulate in short-day, flowering salvia, but ARTHUR et al.⁽¹⁾ found no relation between carbohydrate and nitrogen content and flowering in salvia.

In this study, the effects of day-length upon carbohydrate and nitrogen content in relation to flower bud formation with cosmos and chrysanthemum, each of which is a typical short-day plant were examined. The potted plants in short-day plot were brought into a dark room at five o'clock each evening and kept there till eight o'clock in the following morning being exposed to a day-length shortened to 9 hours. To lengthen the photoperiod, 100-watt Mazda electric-light bulbs were suspended 2 feet above the top of plant and arranged at the rate of one bulb for 9 square feet of space. The lights were turned on at five o'clock and off

at ten o'clock each night by the automatic time switch.

Cosmos

Treatments of photoperiod began on July 13, 1935. The first sampling for chemical analysis was made on August 11, when the flower buds began to be formed only in the short-day plot and no sign of flower bud formation was seen in both long-day and control plot. The second sampling was done on August 22, when the flower bud formation was initiated in the control plot, while the plants of long-day plot remained still in vegetative growth.

Chrysanthemum

A Japanese small flowered type was used in 1935. The treatment of photoperiod began on August 13. When the first sampling was made on September 11, the flower buds were formed in both short-day and control plot, while they were not yet found in long-day plot. On October 16, when the second sampling was made, the plants which had been transferred from long-day to short-day plot, formed flower buds, and they were compared with those which remained in long-day plot and formed yet no flower bud.

In 1936, a pink flowered variety *Unaka* was used. Photoperiodic treatment began on July 30, and the samples for chemical analysis were taken on August 13, when the flower bud formation began to occur in short-day plot, but not yet in control plot. Leaves, upper and lower portion of stems were submitted to analysis separately.

METHODS OF CHEMICAL ANALYSIS

The samples were cut with pruning shears as rapidly as possible into sections from one to three mm. long, and preserved in 80 per cent alcohol until the extraction could be begun. For extraction the alcohol was filtered from the sample through a hardened paper. The residue was dried and pulverized to pass a 100-mesh sieve, and was extracted thoroughly with alcohol. The estimation of polysaccharides and insoluble nitrogen was made upon the residue, and sugars and soluble nitrogen were estimated in the extract. The nitrogen was determined by the Kjeldahl method, soluble nitrogen being modified as Ranker's proposition. Nitrate nitrogen was determined by the phenoldisulphonic acid method, amide and ammonia nitrogen were determined by the Van Slyke-Cullen method, and amino nitrogen was determined by the Van Slyke method. The carbohydrates were determined by the Bertland method. Starch was digested with Taka-diastrase, and non-reducing sugars and polysaccharides was hydrolysed with hydrochloric acid as usually.

Results

EXPERIMENTS WITH JAPANESE PEAR SHOOTS

The shoots which had been headed back on May 27, soon developed secondary growth and the flower buds were not generally formed on the primary growth portion. The shoots which had been pruned back on July 4, developed no secondary growth and a few apical buds on the headed portion differentiated into flower bud.

The chemical contents of the late headed shoots and the corresponding portion of early headed and unheaded shoots were shown in Table 1.

TABLE 1.—CHEMICAL COMPOSITION OF CHOJURO PEAR SHOOTS.
EXPRESSED ON PER CENT DRY WEIGHT. SAMPLED ON JULY 20, 1935.

	Upper portion of shoots headed on July 4	Upper portion (primary growth) of shoots headed on May 27	Basal portion of unheaded (control) shoots
Flower bud formation	Flower buds would be formed	Flower buds would not be formed	Flower buds would not be formed
Dry matter (per cent fresh weight)	51.55	45.77	44.53
Soluble solids	30	30	25
Insoluble solids	70	70	75
Soluble nitrogen	0.314	0.188	0.170
Amide and ammonia nitrogen ..	0.0700	0.00532	0.00739
Amino nitrogen	0.140	0.0591	0.047
Insoluble nitrogen	0.305	0.471	0.327
Total nitrogen	0.619	0.659	0.497
Reducing sugars	1.985	1.212	1.623
Non-reducing sugars	2.920	2.370	2.101
Total sugars	4.905	4.485	3.725
Water soluble polysaccharides ..	0.406	0.447	0.392
Starch	0.471	0.482	0.403
Acid-hydrolysable polysaccharides	7.587	9.159	6.736
Total polysaccharides	8.464	10.088	7.531
Total carbohydrates	13.369	14.573	11.256
C-N ratio	21.60	22.11	22.64

It is seen that either early or late summer heading brought about increase in the content of both total nitrogen and carbohydrate fractions. However, as flower bud formation occurred in the late heading plot and not in the early heading plot, when we make comparison of these two heading plots for chemical contents, the most striking feature of difference is the high content of soluble nitrogen in the late heading plot, while

there is no distinct difference in the content of sugars and starch, as well as in the C-N ratio. The high content of soluble nitrogen seems, therefore, favorable for flower bud formation in this case.

In 1936, the shoots of two different growth types were studied. The distribution of flower buds on the shoots of two types was examined on December 7, and is shown in Table 2.

TABLE 2.—DISTRIBUTION OF FLOWER BUDS ON CHOJURO PEAR SHOOTS.
EXAMINED ON DECEMBER 7, 1936.

Shoots of long growth					Shoots of medium growth				
Location of flower buds*	No. of flower buds	No. of nodes	Per cent of flower buds	Length of shoots (cm.)	Location of flower buds*	No. of flower buds	No. of nodes	Per cent of flower buds	Length of shoots (cm.)
No flower bud	0	38	0	180	I - XVI	16	18	88.9	
"	0	34	0	170	I - X	10	16	62.5	
"	0	35	0	180	I - XI	11	17	64.7	
IX, XII, XVI-XX,	8	39	20.5	173	I - VIII	8	16	50.0	
XXII					I - XIV	14	15	93.3	
I - VII	7	31	22.6	170	I - XVI	16	16	100.0	
I - XIII, XV, XVI	15	39	38.4	175	I - XI	11	17	64.7	
I	1	38	2.6	200	I - IX	9	13	69.2	
I - XXI	21	30	70.0	150	I - VIII	8	20	40.0	
I - XXIII	23	30	76.7	132	I - XIV	14	16	87.5	
I - IX, XI, XII,	14	35	40.0	193	I - X	10	20	50.0	
XIV - XVI					I - XVI	16	18	88.9	
I - VII	7	33	21.9	170	I - XVI	16	19	84.2	
IV, IX, XI	3	31	9.7	144	I - XV	15	23	65.2	
No flower bud	0	30	0	144	I - XVI	16	21	76.2	
I - III, V, VII,	8	34	23.5	170					
VIII, X, XII									
Average	7.6	34.1	23.3	168	Average	12.7	17.7	72.4	80

* numbered basipetally

It is shown that on the shoots of long growth, the flower buds were formed only on apical portion and nearly no flower bud was produced on either middle or basal portion, and there were, moreover, in this group the shoots which borne no flower bud at all. On every shoot of medium growth, the flower buds were formed continuously from the apical end to a node lower than middle, remaining only basal portion in barren.

The chemical compositions examined with three portions in the shoots of long growth and two portions in the shoots of medium growth are represented in Table 3.

TABLE 3.—CHEMICAL COMPOSITION OF CHOJURO PEAR SHOOT.
EXPRESSED ON PER CENT DRY WEIGHT. SAMPLED ON JULY 11, 1936.

	Shoots of long growth			Shoots of medium growth	
	Apical portion	Middle portion	Basal portion	Apical portion	Basal portion
Flower bud formation	Flower buds would be formed	Flower buds would not be formed	Flower buds would not be formed	Flower buds would be formed	Flower buds would not be formed
Dry matter (per cent fresh weight)	15	28	37	26	36
Soluble solids	38	16	10	22	11
Insoluble solids ..	62	84	90	78	89
Soluble nitrogen ..	0.240	0.141	0.102	0.389	0.150
Amide nitrogen ..	0.00231	0.00151	0.00126	0.00312	0.00168
Ammonia nitrogen	0.03709	0.02530	0.01568	0.05290	0.01695
Amino nitrogen ..	0.165	0.102	0.068	0.227	0.105
Insoluble nitrogen	1.210	0.625	0.483	0.914	0.541
Total nitrogen	1.450	0.766	0.585	1.303	0.691
Reducing sugars ..	2.048	1.169	0.764	1.017	0.927
Non-reducing sugars ..	4.250	1.618	0.991	2.868	0.927
Total sugars	6.298	2.787	1.755	3.885	1.854
Water soluble polysaccharides ..	0.520	0.410	0.320	0.356	0.313
Starch	0.479	0.619	0.620	0.687	0.610
Acid hydrolysable polysaccharides	4.109	3.116	3.200	3.090	3.200
Total polysaccharides	5.108	4.145	4.140	4.133	4.123
Total carbohydrates	11.406	6.932	5.895	8.018	5.977
C-N ratio	7.860	9.050	10.077	6.153	8.650

With the shoots of long growth, as well as of medium growth, it may be seen that there were evident increase in the content of nitrogen, both soluble and insoluble, and sugars, and decrease in the value of C-N ratio toward the apical end. Though flower bud formation occurred on the apical portion of shoot of long growth, it occurred far more abundantly and constantly on the shoot of medium growth as shown in Table 2, and comparing the apical portion of shoot of long growth and that of medium growth for the contents of nitrogen and carbohydrates, it is the content of soluble nitrogen which is obviously higher in the shoots of medium growth than in those of long growth. Therefore, in this case also, the soluble nitrogen content seems correlated positively with flower bud formation.

EXPERIMENTS WITH SHORT-DAY PLANTS

Cosmos

The results of chemical analysis with cosmos are shown in Table 4.

In the case in which the samples for chemical analysis were taken on August 11, it is shown that the contents of reducing sugars, total sugars and total carbohydrates are the lowest in the short-day plot and the highest in the long-day plot, indicating clearly that short-day condition actually decreased carbohydrate contents. On the contrary to carbohydrates, nitrogen, both soluble and insoluble, is the richest in the short-day plot. As the plants which formed flower buds were those under short days, high content of nitrogen and low content of carbohydrates

TABLE 4.—CHEMICAL COMPOSITION OF COSMOS.
EXPRESSED ON PER CENT DRY WEIGHT. ALL AERIAL PORTION.

Sampling date	August 11			August 22	
Day-length	Natural day (control)	Short day	Long day	Natural day	Long day
Flower bud formation	No flower buds	Flower buds were producing	No flower buds	Flower buds were producing	No flower buds
Green weight of a plant (grams) ..	49.0	38.3	39.0	40.0	37.1
Dry matter (per cent fresh weight)	15.612	9.860	13.156	15.764	16.194
Soluble solids	7.381	3.338	5.067	4.806	4.535
Insoluble solids ..	8.231	6.522	8.089	10.958	11.659
Soluble nitrogen ..	0.5275	1.8708	1.1575	0.6803	0.7682
Nitrate nitrogen ..	0.1320	0.3549	0.1892	0.1452	0.1539
Ammonia and amide nitrogen ..	0.0224	0.0426	0.0319	0.0298	0.0278
Amino nitrogen ..	0.0675	0.0821	0.0745	0.0571	0.0618
Insoluble nitrogen	1.4544	2.6465	1.9205	2.0618	2.0029
Total nitrogen	1.9819	4.5173	3.0780	2.7421	2.7711
Reducing sugars ..	4.2947	1.1157	8.2460	7.6080	8.7138
Non-reducing sugars	0.7692	0.8416	1.6872	1.4265	1.7180
Total sugars	5.0639	1.9570	9.9332	9.0345	10.4318
Starch	2.8396	3.5591	3.4656	4.0576	4.6103
Acid hydrolysable polysaccharides ..	4.7883	4.4008	5.7076	8.3688	8.7323
Total polysacchari- des	7.6279	7.9599	9.1732	12.4264	13.3426
Total carbohydra- tes	12.6918	9.9169	19.1064	21.4609	23.7744
C-N ratio	6.41	2.05	6.21	7.82	8.59

were associated with flower bud formation in this case.

With two plots, natural-day and long-day, of which the samples for chemical analysis were collected on August 22, when flower bud formation was occurring in the plants under natural days but did not occur in those under long days, the contents of nitrogenous fractions showed no distinct difference between two plots, and the carbohydrates were richer, though slightly but consistently, in the long-day plot. Therefore, the low content of carbohydrates was associated with flower bud formation in this case.

Chrysanthemum

With chrysanthemum, the samples for chemical analysis were taken on September 11 and October 16 in 1935, and August 13 in 1936, and the results are shown in Tables 5 and 6.

The results obtained on September 11, 1935 show that all fractions of

TABLE 5.—CHEMICAL COMPOSITION OF CHRYSANTHEMUM.

EXPRESSED ON PER CENT DRY WEIGHT. EXPERIMENT IN 1935.

Sampling date	September 11			October 16	
Day-length	Natural day (control)	Short day	Long day	Transferred from long day to natural day	Long day
Flower bud formation	Flower buds were producing	Flower buds were producing	No flower buds	Flower buds were producing	No flower buds
Green weight of a plant (grams) ..	35.5	26.3	28.8	64.8	56.8
Dry matter (per cent fresh weight)	22.24	19.19	21.62	19.55	19.33
Soluble solids	9.27	8.07	8.93	6.47	6.95
Insoluble solids ..	12.97	11.12	12.69	13.08	12.38
Soluble nitrogen ..	0.6660	0.9951	0.6436	0.5632	0.5067
Insoluble nitrogen	2.0993	2.1528	2.1016	3.0336	2.5436
Total nitrogen	2.7653	3.1479	2.7452	3.5968	3.0503
Reducing sugars ..	2.2950	1.6933	1.7826	1.6896	2.1352
Non-reducing sugars	2.6325	1.8443	2.7086	2.7392	4.7564
Total sugars	4.9275	3.5376	4.4912	4.4288	6.8916
Starch	1.1381	1.1004	1.1987	1.2052	1.1519
Acid hydrolysable polysaccharides..	6.5952	4.8552	6.9450	6.3621	7.1687
Total polysacchari- des	7.7333	5.9556	8.1437	7.5673	8.3206
Total carbohydra- tes	12.6608	9.4932	12.6349	11.9961	15.2122
C-N ratio	4.58	3.01	4.60	3.33	4.98

TABLE 6.—CHEMICAL COMPOSITION OF CHRYSANTHEMUM.

EXPRESSED ON PER CENT DRY WEIGHT.

EXPERIMENT IN 1936. SAMPLED ON AUGUST 13.

Sampled portion	Leaf blade		Stem			
			Upper portion		Lower portion	
Day-length	Natural day	Short day	Natural day	Short day	Natural day	Short day
Flower bud formation	No flower buds	Flower buds were producing	No flower buds	Flower buds were producing	No flower buds	Flower buds were producing
Dry matter (per cent fresh weight)	22.71	13.35	24.80	21.57	34.13	31.78
Soluble solids	3.65	1.74	5.91	4.86	5.49	4.57
Insoluble solids ..	19.06	11.61	18.89	16.71	28.64	27.21
Soluble nitrogen ..	0.1761	0.2996	0.2734	0.3598	0.2151	0.2354
Insoluble nitrogen	3.2057	3.845	0.6996	0.7418	0.4251	0.4579
Total nitrogen	3.3818	4.1447	0.9730	1.1016	0.6402	0.6933
Reducing sugars ..	2.3145	2.6219	2.3184	2.3180	0.9889	0.7868
Non-reducing sugars	1.8575	0.9738	7.6406	7.1858	5.2008	4.6733
Total sugars	4.1720	3.5957	9.9590	9.5038	6.1897	5.4601
Water-soluble polysaccharides..	1.0731	1.0869	0.5524	0.3741	0.6505	0.6272
Starch	3.4281	1.5079	1.3209	0.8957	0.4632	0.2159
Acid hydrolysable polysaccharides..	16.4787	15.6892	12.6585	12.8130	15.7760	15.0710
Total polysaccharides	20.9799	18.2840	14.5318	14.0828	16.8897	15.9141
Total carbohydrates	25.1919	21.8797	24.4908	23.5866	23.0794	21.3742
C-N ratio	7.44	5.28	25.17	21.41	31.47	30.83

carbohydrates were the lowest in content in the short-day plot though there was no consistent difference between the natural-day and the long-day plot, and the nitrogen was the richest in the short-day plot, but the natural-day and the long-day plot were not noticeably different in the nitrogen contents. In this case in which flower bud formation occurred not only in the short-day plot but also in the natural-day plot, any association can not be seen between flower bud formation and chemical contents.

The results obtained on October 16, 1935 show that transferring from the long-day condition to the short-day condition, through which flower bud formation was induced, decreased clearly the contents of carbohydrates and increased, though not greatly, the nitrogen contents. The flower bud formation in this case was, therefore, associated with high content

of nitrogen and low content of carbohydrates.

The results which were obtained on August 13, 1936 and are shown in Table 6, indicate that the contents of carbohydrates were decreased by short days, and that the flower bud formation was correlated also in this case with higher content of nitrogen and lower content of carbohydrates.

From the above mentioned results obtained with the short-day plants, it may be seen that the contents of carbohydrates were decreased by short days, and the flower bud formation was associated with not increase but decrease in the contents of carbohydrates with exception of one case, and it was associated at the same time with increase in nitrogen content, though it was not limited to soluble nitrogen, in 3 cases out of 5 cases examined.

Summary

1. In the results of this study the carbohydrate-nitrogen ratios have not proved of special significance in flower bud formation.

2. In the comparison of chemical composition between early summer headed and late summer headed shoots and also between shoots of long growth and those of medium growth of the Chojuro pear trees, the high content of soluble nitrogen was associated with flower bud formation.

3. The results of the study with short-day plants such as cosmos and chrysanthemum show that the content of carbohydrates was decreased by short days and flower bud formation in these plants was, therefore, associated with decrease in carbohydrates on the contrary to the general belief that the accumulation of carbohydrates favors flower bud production.

4. Within the limits of the data obtained in this study, high content of nitrogen, though not in every case, but on the whole, seems favorable for flower bud formation.

Literature Cited

- (1) ARTHUR, J. M., GUTHRIE, G. D., and NEWELL, J. M.: Some effects of artificial climates on the growth and chemical composition of plants. *Amer. Journ. Bot.* 17: 416-482. 1930.
- (2) ASAMI, Y., and ITO, H.: A preliminary report on the effects of summer pinching upon the carbohydrate and nitrogen contents of the Japanese pear shoots. *Journ. Hort. Assoc. Japan* IV, 2: 59-63. 1933.
- (3) HEINICKE, A. J.: Composition of fruit-bud and spur tissues of Wealthy apples under different condition of nutrition. *Proc. Amer. Soc. Hort. Sci.* 27 (1930): 190-198. 1931.
- (4) KAWAGUCHI, M.: Effects of summer pruning on development of secondary growth and flower bud formation of the Japanese pear shoots (in Japanese). *Agricuture and Horticulture* 4: 563-569. 1929.
- (5) KRAUS, E. J., and KRAYBILL, H. R.: Vegetation and reproduction with special reference to the tomato. *Oregon Agr. Exp. Sta. Bull.* 149. 1918.
- (6) NIGHTINGALE, G. T.: The chemical composition of plants in relation to photoperiodic changes. *Wisconsin Agr. Exp. Sta. Bull.* 74. 1927.
- (7) POTTER, G. F., and PHILLIPS, T. G.: Composition and fruit bud formation in non-bearing spurs of the Baldwin apple. *New Hampshire Agr. Exp. Sta Tech. Bull.* 42. 1930.