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SEASONAL DRIFT IN CARBOHYDRATE CONCENTRATIONS IN GROWING BARLEY

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SEASONAL DRIFT IN CARBOHYDRATE CONCENTRATIONS IN GROWING BARLEY

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INTRODUCTION

Since the potential supply of raw fructose in the form of inulins and fructosans is now known to be enormous, attention has been directed towards possibilities of commercial utilization. If fructose were to become available in large quantities at the same price as sucrose, its distinctive properties should earn for it a permanent place on the carbohydrate market. It is the sweetest and most soluble of all sugars. Its presence in syrups prevents the crystallization of the other sugars present and, in contrast to sucrose which is subject to inversion change, its flavor is permanent. It is also in demand as an ingredient of medicinal preparations.

Economic and technological barriers have prevented the development of a fructose industry in the past. There is, however, reason to believe that the technological difficulties have been largely overcome. At the Iowa State College and at the University of Illinois processes for manufacturing fructose

from the tubers of Jerusalem Artichokes have been in successful pilot scale operation for a number of years.

It should be emphasized that the economic feasibility of a fructose industry in Canada must be left in doubt until sufficient over-all data on yield and a comprehensive survey of sources of raw fructosans become available. It may also be pointed out that the effect of soil and weather conditions on the fructosan accumulation in plants is at present not too well understood. While the occurrence of fructosans and their importance in the general carbohydrate metabolism in plants have received a great deal of attention from a number of biochemists at the Royal Institute of Technology in Great Britain, no attempt has been made to investigate commercial possibilities of using fructosans as raw material for a fructose industry. From the conclusions reached by fructosan chemists, it would appear, on the surface at least, that the accumulation of fructosans in plants is the result of many and probably complex factors.

Nevertheless, certain analytical results obtained in the biochemical study of rye, wheat, and barley indicate some possibility of finding cereal and forage crops suitable for commercial production of fructose. Norman (13) in Great Britain reported in 1936 that the fructosan constituted 34% of the oven dry weight of the above-ground portions of rye grass after about six weeks of growth. Since fructose arising from sucrose was included in his estimate this value

would appear to be much too high. This has been shown in subsequent investigations by others (4). Notwithstanding the failure to confirm Norman's results there remains some possibility of finding relatively high concentrations of fructosans in certain plants grown under conditions which promote the storage of this sugar.

The investigation contained in this report was undertaken as a preliminary survey of the effect of some of the factors which influence the fructose and fructosan content of barley grown under field conditions.

REVIEW OF LITERATURE

A detailed review of the fructosans in monocotyledons can be obtained by referring to Archbold (4). It is stated that the earliest study on this compound was made by Kühnemann (1875), Münstz (1878-1886), and Ludwig and Müller (1873). The discovery of fructosan in cereals resulted from the attempts of agricultural chemists to isolate dextrans as intermediate products between sugar and starch during the development of the grain. So much controversy arose at this time as to the presence or absence of dextrans in monocotyledons that little if any significance was given to the discovery of the fructose polymer. While a number of attempts were made to prepare a pure fructosan from plant extracts, the

methods in use at that time led to isolation of more or less impure substances. This resulted in a variety of descriptions of the compound so that even to this day the nomenclature of these carbohydrates is far from satisfactory.

The more modern work, especially that by Augem (1928), Belval (1924, 1933, 1939), Colin and Chaudin (1933), Challinor et al (4); Norman (1936) (14); Archbold (1938) (3); and Barnell (1938) (10), has confirmed the presence of fructosans in the plants examined by the early workers. It is now well established that the fructosans are usually found as one of the soluble sugars in the cereals and forage crop plants, and that they may form an appreciable part of the total sugar at certain stages during growth.

There still remains a great deal of research to be done on the chemistry of the fructosan molecules, but it is now generally accepted that they yield only fructose on acid or invertase hydrolysis and that their chemical constitution may differ slightly according to the source. Full details of their chemistry properly belong to the field of pure chemistry and may be obtained from the original papers of Hibbert et al and Challinore et al (4), Haworth et al (13), and Reich, W.S. (15).

It has been only in relatively recent years that satisfactory methods for the quantitative estimations of fructosans have been developed and almost without exception all of the work has been done by investigators at the Research

Institute of Plant Physiology, Imperial College of Science and Technology, London. The earlier work was done in France and Germany, and in the literature reviewed no reference to fructosan is reported in any of the work on plant sugars carried out on this continent.

From the available information it can be stated that the amounts of fructosan found in the several plants studied vary within wide limits and are subject to the same marked seasonal changes and environmental conditions that affect the other sugars. In a series of investigations by Colin and Belval (4) on the changes in sugar concentrations in stems and heads of cereals it was observed that, as the spike emerged, fructosans began to accumulate in the stems and the concentration reached a maximum when full growth of the plant was reached. In wheat stems the value reached was 5.08% and at the onset of head formation the heads contained 6 to 8% of the fresh weight. No fructosans were found in the leaves.

Archbold's and Barter's (6) successful isolation of fructosans from barley leaves reopened the question of the significance of fructosans in carbohydrate metabolism and marked the real beginning of detailed study of the role they play. By 1940 Archbold (4) had firmly established that fructosans may be distributed throughout the whole plant.

Earlier workers, notably Colin and Belval (4) supported the view that stored sugars, including fructosans, were stored during the early stages of the plant's growth and

that these reserve stores of sugar were drawn upon when the heads began to develop. Barnell (9) (10), working with wheat and Archbold (3) (5), working with barley, confirmed Colin and Belval's (4) results on the seasonal drift of sugar concentrations. When, however, their results were examined on the basis of quantity per plant, it became clearly evident that the stored sugars were not available in the sense that they can be used as substrates for further growth at a site distant from that at which they originally accumulate. Archbold (3) (5), Archbold and Mukerjee (8), and Archbold and Datta (7) observed that storage of sugar and fructosan was simply a balance of supply over demand and that the sudden onset of the large loss of these sugars from the plant tissues associated with the development of the heads is unrelated. The head is therefore entirely dependent on primary assimilate translocated to it or produced in situ and immediately and irreversibly synthesized.

A consideration of results of the investigations of Archbold et al leads to the conclusion that only conditions which promote the production of primary assimilates by green parts of the plant in excess of immediate growth requirements will result in storage of sugars. It is also to be noted that conditions which promote sugar storage result also in the production of relatively large amounts of fructosan. Losses from the plant after the maximum is reached are related to levels of concentrations reached.

that these passive phases of sugar were taken into the
heads began to develop. Arnold (5) (6), working with wheat
and Arnold (5) (6), working with barley, confirmed this and
Arnold's (4) results on the essentiality of sugar for develop-
ment. When, however, these results were examined on the
basis of quantity per plant, it became almost evident that
the stored sugars were not available for further growth at a rate
that can be used as a substitute for further growth at a rate
from that at which they originally accumulated. Arnold (5)
(6), Arnold and Lister (5), and Arnold and Lister (5)
observed that storage of sugar and protein was largely a
balance of supply over demand and that the stored sugar of the
large loss of these sugars from the plant tissues associated
with the development of the heads is unrelated. The head is
therefore entirely dependent on primary assimilate furnished
to it or produced in situ and immediately and irreversibly
synthesized.

A comparison of results of the investigation of
Arnold et al leads to the conclusion that only material
which promotes the production of primary assimilate in the
parts of the plant in excess of immediate growth requirements
will result in storage of sugars. It is also to be noted
that conditions which promote sugar storage result also in
the production of relatively larger amounts of protein.

Losses from the plant after the harvest is treated are
related to levels of carbohydrate reserves.

It has been observed by Archbold (3) and Russell (17) that mineral deficiencies have rather marked effect on the amounts of sugars stored. An indication of what was observed when barley was grown under conditions of mineral deficiencies (taken from Archbold's and Russell's work) appears in the following tables:

TABLE A

Total sugar and fructosan content of barley plants grown in sand and receiving nitrogen-deficient dressings

	% fresh weight					
	Leaves		Stems		Heads	
	Control	-N	Control	-N	Control	-N
Total sugar	1.52	3.04	2.03	5.76	4.79	4.81
Fructosan	0.13	1.15	0.43	4.03	2.22	2.47

TABLE B

Mean effect of potassium and phosphorus deficiency and of sodium-calcium balance on fructosan concentration in barley

	Potassium			Phosphorus			Sodium/calcium balance	
	Leaves	Stems		Leaves	Stems		Leaves	Stems
High	0.93	2.02	High	0.28	0.86	High Na	0.45	1.01
Medium	0.53	1.19	Low	1.82	1.44	High Ca	0.65	1.29
Low	0.18	0.24						

It was observed in 1960 (IV) and 1961 (IV) that several individuals have shown marked effects on the amount of water consumed. In addition, it was observed that when water was given under conditions of clinical dehydration (from 1960 to 1961) the amount of water consumed was increased in the following manner:

TABLE 1

Total water and electrolyte content of body
fluids given in 1960 and 1961
in 1960-1961 period

1960-1961					
1960		1961		1962	
High	Low	High	Low	High	Low
1.81	0.70	1.75	0.88	1.52	0.75
2.45	0.65	2.02	0.82	1.15	0.75

TABLE 2

Mean values of 1960 and 1961
dehydrated and rehydrated
values on 1960-1961
period

1960-1961			1961-1962			1962-1963		
High	Low	Mean	High	Low	Mean	High	Low	Mean
1.81	0.70	1.25	1.75	0.88	1.31	1.52	0.75	1.13
2.45	0.65	1.55	2.02	0.82	1.42	1.15	0.75	0.95

Gregory (12), in an extensive study of mineral nutrition of plants found that nitrogen deficiency had no consistent effect on reducing sugars but that the total carbohydrate was greatly increased. The effect of phosphorus deficiency resulted in higher levels of free reducing sugars but total sugar was less affected; while potassium deficiency lowers both free reducing sugar and total sugar.

Richards (16) investigating a similar problem, found evidence* supporting Gregory's observations and confirmed the fact that the various mineral treatments affected the ratio of sucrose to reducing sugars. Finally, Russell (17) found ratios of fructosan to other sugars greatly influenced by the various conditions of mineral deficiency, and that in the final analysis the fructosan accumulation was controlled almost wholly by the concentration of other sugars.

On the basis of experiments on mineral deficiencies it becomes clear that fructosans accumulate under all conditions promoting storage of sugars.

The studies on carbohydrate content of plants growing under field conditions is confined almost entirely to the observations Barnell (9) (10) made on wheat. Two wheat varieties were selected and planted in the fall, and harvested

* No consistent differences ascribable to potassium were found.

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the following summer. The percentage of sucrose in the plants was found to some extent to be a function of temperature, the sucrose value increasing with low temperature and falling with moderate temperature. During one cold period sucrose rose from a value of .25% of the fresh weight to a peak, 17 days later, of 1.55%. The low temperatures were associated with more than average sun so that, under frost conditions, the rise in sucrose concentration may be due, to some extent at least, to the rate of production of sucrose by photosynthesis exceeding the rate of utilization in the growth and respiration processes. Temperature conditions resulted in greater fluctuations of sucrose content than did hours of sunshine when results were analyzed statistically. Barnell (10) considered sucrose to be the dominant sugar and, except in the later stages of growth when the highest value for total sugar was observed, glucose exceeded fructose. The values obtained by him are as follows:

Maximum Values of Fructose, Glucose, and Sucrose (% of fresh weight) (9)

Time of head emergence	maximum	Glucose - .50%
Two weeks later	"	Sucrose - 3 to 4%
At same time or a little later	"	Fructose exceeds glucose until harvest.

No significant differences were found in sugar concentrations of the two wheat varieties except that in the later variety the maximum values were reached later. Barnell

finally suggests that the sugar stored is not essential to filling of the grain, and thus supports the conclusions advanced by Archbold and others.

No reference to daily variations of fructosans is reported in the literature reviewed. While the work of Curtis is included in the references of this report it must be understood that no attempt to estimate the fructosans was made by him. Curtis (11) observed that the sugar content of alfalfa is greatly influenced by the time of day at which it is cut. The observed results indicate differences between afternoon and morning cuttings are of the order of 83% or, in some cases, more. These differences were estimated to fall almost entirely on the soluble fractions of the plant materials and would therefore include all the sugars. Curtis further suggests, on the basis of observations made on carbohydrate losses during "curing", that losses of soluble sugars may reach proportions of 50% of the amount known to exist in the green material. Woodward, Tisdale, and Shepherd (20) disagree with Curtis, stating that such high losses cannot be real, since losses due to respiration could not account for such large amounts of sugar. It has already been pointed out, nevertheless, in references to the work of Archbold and others, that losses of sugar from plant tissues have been observed to be large.

It would seem from the foregoing that there is a need for more evidence from experiments with plants to determine

more exactly the magnitude of these changes as related to time factors, soil, and weather effects, and kind of crop concerned.

At present, only the all-over quantitative changes in sugar concentrations appear to be known. Archbold and Datta (7), in their more recent work, have concluded that, before much more can be known of the distribution of the carbohydrate supply for either growth processes or storage, nitrogen metabolism must be considered in relation to carbohydrate synthesis and utilization. This view is further borne out by work of Richards (16) who demonstrated that a remarkably close relationship exists between respiration rate and protein content.

It may be of interest to note that Archbold is now engaged in experiments on the part played by nitrogen in determining the distribution of the available carbohydrate supply.

MATERIALS AND METHODS

Materials

The barley used in these experiments was grown from foundation stock seed of Newal at the University of Alberta. Replicate seedings were made on May 3, May 17, May 25, June 3, and June 22. 1004

Each of the first seedings consisted of one 40-foot row. This material was used in the preliminary testing of methods of analysis. The final planting consisted of 24 rows, 50 feet long and spaced nine inches apart. Plants from this seeding were used for most of the analytical work reported in this paper.

The barley was planted on a field of black loam which had been summerfallowed the previous year. The field is typical of the agricultural soils in the Edmonton area and considered to be very fertile.

The period from June 22 to September 30 was exceptionally wet and very vigorous growth of the barley occurred. Lodging occurred at the end of July after considerable wet weather. The barley was fully headed 57 days after planting, at which time it was approximately 42 inches high. The last collection was made 100 days after planting. The late sowing and abnormally high rainfall contributed to late maturity, so

MATERIALS AND METHODS

Materials

The barley used in these experiments was grown from foundation stock used at Hawaii at the University of Alberta. Replicate seedings were made on May 2, May 15, May 20, June 3, and June 23. Each of the first seedings consisted of one 40-foot row. This material was used in the preliminary testing of methods of analysis. The final planting consisted of 24 rows, 30 feet long and spaced nine inches apart. Plots from this seeding were used for most of the analytical work reported in this paper. The barley was planted on a field of black loam which had been unmanured the previous year. The field is typical of the agricultural soils in the Edmonton area and considered to be very fertile. The period from June 23 to September 30 was exceptionally wet and very vigorous growth of the barley occurred. Lodging occurred at the end of July after considerable wet weather. The barley was fully headed 50 days after planting, at which time it was approximately 44 inches high. The final collection was made 100 days after planting. The late heading and abnormally high rainfall contributed to late maturity, as

that even at the end of 100 days many tillers had not ripened, although the growth period for Newal grown at Edmonton, on the basis of a seven-year average, is 88 to 90 days.

Method of Collection

At weekly intervals, beginning on the eighth day after planting and ending after 100 days of growth, single plants selected at random over the whole plot were cut with shears at ground level until 25 to 150 plants were obtained. To measure the effect of time of collection, one collection was made at 4:30 in the afternoon and another at 8:30 the following morning.

The whole plants were immediately brought to the laboratory where they were cut into half-inch lengths and thoroughly mixed. A forty-gram sample was weighed out and placed in 200 cc. of boiling 80% alcohol. Ten to twenty grams for moisture content determinations were placed in a drying oven kept at 75 to 80°C. The remainder was placed in large, shallow pans and allowed to dry at room temperature. This material, when thoroughly dry, was ground in a Wylie mill and placed in jars until required.

Beginning on August 18, weekly analyses for various carbohydrates were made on the component parts of the plants collected at 4:30 p.m. Heads were separated at the junction with the peduncle, leaves detached at the junction with sheaths

that even at the end of 199 some very different results
obtained, although the growth period for several years at least
long, on the basis of a water-year average, is 10 to 15 years.

Method of Collection

At weekly intervals, collection on the eighth day
after planting and before the first 10 days of growth, plants
plants collected at random over the whole plot were cut with
scissors at ground level until 10 to 150 plants were obtained.
To measure the effect of time of collection, the collection
was made at 4:30 in the afternoon and another at 8:30 the fol-
lowing morning.

The whole plants were immediately brought to the
laboratory where they were cut into leaf-stem samples and
stomach samples. A 100-gram sample was weighed out and
placed in 300 cc. of boiling 95% alcohol. This is usually done
for analysis of carbohydrates and is placed in a boiling
oven kept at 75 to 80°C. The remainder was placed in 100%
alcohol and allowed to dry at room temperature. This
material, when thoroughly dry, was ground in a Wiley mill and
placed in two small bags.

Beginning on August 15, weekly samples for various
carbohydrates were made on the permanent plots of the field
collected at 4:30 p.m. These were weighed and analyzed
with the following, leaves collected on the permanent plots

and sheaths peeled from the stems. After separation--which was done as quickly as possible--the various parts of the plants were cut up. Mixed portions of 5 to 10 grams were weighed out and placed in boiling 80% alcohol.

Notes on height of plants and stage of development, together with notes on weather conditions at the time of collection, were taken throughout the growth period. Detailed records on weather for the entire period appear elsewhere in this report.

Preparation of Material

As a rule a 40-gram sample of the freshly collected and cut material was placed in 200 cc. of boiling 80% alcohol to prevent enzymatic hydrolysis of fructosans and sucrose. Since fructosans are not extracted by alcohol, a water extraction was carried out on the material which was first freed from alcohol. The alcohol was poured off and the plant material washed free of alcohol by shaking with several additions of water. The residual material was transferred to a Waring Blendor, sufficient water added to cover the material, and cutting in the blendor was carried out for approximately five minutes. It was observed that the material was reduced to a very finely divided condition. After transfer to a wide mouth Erlenmeyer, the cut material was shaken in a

and shanks passed from the water. After separation--which
was done as usual--the various parts of the
plants were put up. Small portions of 5 to 10 pieces were
weighed out and placed in bottles for analysis.
Before the plants of flowers and leaves of vegetation,
together with some of the smaller portions of the plant of
collection, were taken throughout the country, which, included
records on water for the entire period of the season in
this report.

Preparation of Material

As a rule a 40-gram sample of the freshly collected
and the material was placed in 100 cc. of boiling 95% alcohol
to prevent any possible possibility of further loss and increase.
Since the material was not extracted of alcohol, it was
extraction was carried out in the alcohol which was first
from the alcohol. The alcohol was removed off and the plant
material was removed from the alcohol to which it was added with
some of water. The residual material was transferred to a
small flask, which was sealed and held in for the material,
and added in the alcohol and sealed for the material.
The material. It was observed that the material was placed
to a very finely divided condition. After transfer to a
small flask, the two material was added to a

mechanical shaker for approximately two hours. The resulting water extract was transferred to a graduated flask to which the residue of the alcoholic extract and washings were added after the alcohol had been removed by distillation under reduced pressure. The residual material was then washed by shaking with small additions of water and decantation of the washings into the flask until the required volume was nearly attained. The liquid was finally made up to volume and preserved by the addition of a little toluene. The extracts obtained from the young material were always deeply colored by the pigments extracted during water and alcohol treatments. Older plants, especially near the end of the growth season, did not give such highly colored extracts.

When analyses were made on the dried materials the same procedures were used, except for the weight of material and final volume of extract.

Residues after alcoholic and water extractions were re-extracted and in no case was there an appreciable amount of total sugar remaining in the residue, and the amount which did remain was of the same order for different samples.

Results of some of such re-extractions are shown in Table C.

TABLE C

Total sugar content in water extracts of barley

<u>Age (days)</u>	<u>1st extraction</u>	<u>2nd extraction</u>
<u>Green plants (% of green weight)</u>		
8	1.22	.03
29	1.46	.03
54	2.83	.04
<u>Dried plants (% of dry weight)</u>		
21	3.76	.16
35	2.12	.15
49	8.38	.15
63	11.29	.15
77	6.32	.09
91	1.31	.13

Removal of alcohol from the alcohol extract and washings presented many difficulties when lack of pressure in water taps made the use of water aspirators unreliable. This was finally satisfactorily overcome by using a vacuum pump on a system consisting of two H_2O condensers, a Claissen flask, and a large $CaCl_2$ trap. Continual use of the pump over periods of a month or more revealed little dilution of oil in the pump. When the vapor of the alcohol and water solution was pumped off at 2 to 3 cm. of mercury, reduction in volume of some 200 to 300 cc. was possible in three hours or less. A fine capillary tube was used to admit small bubbles of air into the solution during progress of distillation in order to prevent frothing and bumping.

The moisture and dry weight determinations were difficult to make accurately because of the rainy conditions that prevailed during periods of collection. Plants collected in the morning were, with few exceptions, either covered with heavy dew or else with rain which had fallen during the night. No attempt was made to dry off excess moisture before sampling, since it was essential that analysis be made on the plants as soon after collection as possible. Any large drops of surplus moisture on the plants were merely shaken off.

Considerable error may arise from this source and, in any future work, some attempt should be made to overcome this difficulty.

Methods of Analysis

A. Reducing Sugars

The modified Harding and Downs copper reduction method was used in all estimations of reducing sugars. Separate estimates of fructose were made after oxidation of the glucose by hypiodate. Both procedures are described fully by Van der Plank (19).

Values for reducing sugars in terms of standard .01 Normal sodium thiosulphate were obtained by using various concentrations of chemically pure fructose and glucose, and

plotting the results on a graph. These values were used to estimate the reducing power of the plant extracts. Considerable testing of the procedure for estimation of sugar was done and the results of such testing appear in Tables D and E.

TABLE D

Copper-reducing power of glucose and fructose in terms of .01 normal sodium thiosulphate

Sugar (mg.)	Glucose (boiling time - 15 min.)		Fructose in presence of .221% KI (boiling time - 10 min.)	
	van der Plank	Observed	van der Plank	Observed
.125	.52	--	--	--
.25	1.06	1.21	.81	.80
.50	2.20	2.30	1.89	1.90
.75	--	3.35	--	3.00
1.00	4.53	4.60	4.08	4.10
1.25	--	5.75	--	5.25
1.50	6.88	6.90	6.41	6.35
1.75	--	8.10	--	7.50
2.00	--	9.25*	--	8.60
2.25	--	10.40*	--	--
2.50	--	11.60*	--	--
2.75	--	12.75*	--	--
3.00	--	13.90*	--	--

* Double volumes of all reagents used.

Plotting the results on a graph. These values were then
 plotted on the graph paper to get the curve. The
 data points of the graph were then used to
 find the values of the curve at various points.

TABLE II

Comparison of the results of the two methods
 for the determination of the rate of reaction

Time (min)	Concentration (M)	Rate of reaction (M/min)	Rate of reaction (M/min)	Rate of reaction (M/min)
0	0.00	0.00	0.00	0.00
10	0.01	0.01	0.01	0.01
20	0.02	0.02	0.02	0.02
30	0.03	0.03	0.03	0.03
40	0.04	0.04	0.04	0.04
50	0.05	0.05	0.05	0.05
60	0.06	0.06	0.06	0.06
70	0.07	0.07	0.07	0.07
80	0.08	0.08	0.08	0.08
90	0.09	0.09	0.09	0.09
100	0.10	0.10	0.10	0.10

* Double values of all numbers are

TABLE E

Recovery of glucose and fructose added to
plant extracts (results expressed as %)

			<u>Recovery</u>	
	<u>Extract + sugar</u>	<u>Extract</u>	<u>Observed</u>	<u>Theoretical</u>
<u>Glucose</u>				
1	1.50	1.14	.36	.40
2	4.18	2.40	1.78	1.88
3	3.87	2.98	.89	.80
4	1.82	.85	.97	.98
<u>Fructose</u>				
1	.76	.36	.40	.40
2	1.58	1.20	.38	.40

Fermentations using the methods described by Yemm (21) were found to be entirely satisfactory and, while corrections for the magnitude of the reducing power due to non-fermentable substances, were not made on all extracts, enough were actually carried out to make this correction possible. Results of fermentation analysis are shown in Table F.

TABLE F
Estimates of non-fermentable substances
in plant extracts

Plant age (days)	On green materials (% green weight)		On dried materials (% dry weight)	
	Charcoal cleared	Uncleared	Charcoal cleared	Uncleared
20	.02	.04	.13	.15
30	.01	.04	-	-
40	.06	.04	.03	.20
50	.05	.06	.01	.24
60	-	-	.01	.42
70	-	-	-	-
80	-	-	.02	.24

Methods for clarification of non-hydrolyzed extracts involved the use of charcoal in the manner suggested by Archbold (1). Results obtained appear to be in agreement with those obtained by Archbold. A few of the observed results are included in Table G.

TABLE 2

Estimates of non-hydrolyzable substances
in plant extracts

Plant (Days)	Chlorophyll Extracted	Chlorophyll Extracted	On green material (% of weight)		On dried material (% of weight)	
			Unhydrolyzed	Hydrolyzed	Unhydrolyzed	Hydrolyzed
30	-	-	90.	12.	12.	12.
32	-	-	90.	-	-	-
40	-	-	90.	90.	90.	90.
50	-	-	90.	10.	10.	10.
60	-	-	-	90.	90.	90.
70	-	-	-	-	-	-
80	-	-	-	90.	90.	90.

Methods for identification of non-hydrolyzable extracts

Involved the use of chromatography in the manner suggested by
Inoué (1). Results obtained appear to be in agreement
with those obtained by Inoué. A few of the results
results are included in Table 2.

TABLE G

Estimates of glucose in water extracts of
barley before and after clarifi-
cation with charcoal

Sample	<u>Before fermentation</u>		<u>After fermentation</u>		<u>Glucose corrected for non-fermentable substances</u>	
	Uncleared	Cleared	Uncleared	Cleared	Uncleared	Cleared
1	1.33	1.21	.14	.04	1.19	1.17
2	1.07	1.02	.16	.09	.91	.93
3	1.48	1.35	.23	.07	1.25	1.28
4	1.01	.89	.19	.03	.82	.86

Amounts of charcoal used were from .4 to .6 g. per 100 ml. of solution containing 4 g. of fresh material per 100 ml.

It should be observed that clarification results in lowered reducing power, owing to non-fermentable substances but, at the same time, results in many instances of increase in value for corrected reducing sugars. It has been suggested by Archbold (2) that reducing substances other than sugars diminish the reducing power of sugars present.

The methods which were used in routine estimations of sugars and which have been referred to, appear to be entirely trustworthy if all the conditions are carefully followed. It has been observed, however, that the following precautions should be emphasized:

1. All reagent solutions used must be accurately and carefully measured.
2. The heating period of 15 minutes must be adhered to under conditions that remain constant from run to run.
3. The "holding period" at 1°C. for two hours in

TABLE 1

RELATIONS OF DIVISION IN ORDER OF
DEGREE OF RELATIONSHIP
RELATIONSHIP WITH DIVISION

RELATIONSHIP WITH DIVISION		RELATIONSHIP WITH DIVISION		RELATIONSHIP WITH DIVISION		RELATIONSHIP WITH DIVISION	
RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION	RELATIONSHIP WITH DIVISION
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00

RELATIONS OF DIVISION IN ORDER OF
DEGREE OF RELATIONSHIP
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RELATIONSHIP WITH DIVISION

one of the steps of hypiodate oxidation of glucose is exceedingly difficult to maintain unless there is available a dependable refrigerator. This troublesome factor was successfully overcome by placing the flasks in ice and water mixtures before placing in the refrigerator.

4. The capacity of the "sugar reagent" to measure reducing power is limited. It was observed that, if the concentration of the sugar in the aliquot was such that reduction nearly equalled the blank, results were invariably unreliable. A difference of at least 1.5 cc. of .01 normal sodium thio-sulphate should obtain between reduced reagent and the blank.

5. Addition of charcoal to extracts must be carefully carried out. Excesses of charcoal were found to remove sugars in rather significant amounts. The amount used should just clear the extracts and no more. The amounts used, therefore, varied with the amount of pigment present in the solutions and less was used with older plants than with younger ones.

6. Neutralization of acidified extracts is very unsatisfactory if end point of neutralization must be made by relying on indicator dyes. The difficulty of observing indicator color change in opaque solutions is great. Some buffer effect was also observed in the hydrolized extracts. The use of a portable glass electrode potentiometer is essential for consistent results.

one of the most of systematic violation of law in
the world is the fact that the law is not
enforced. This is the case in the United States
and in many other countries. The law is not
enforced in the United States in the same way
as it is in other countries.

1. The principle of the law of the land is
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Technique used in the Estimation of Sugars

1. Free reducing sugars were estimated on clarified extracts, using the modified Harding and Downs microcopper reagent. Total sugars were estimated after hydrolysis with N/5 H_2SO_4 , no clarification being necessary.
2. Separate estimations of fructose were made on clarified, non-hydrolyzed and non-clarified hydrolyzed extracts.
3. After corrections in free reducing and total sugars for non-fermentable substances had been made:
 - (a) Free reducing sugar minus free fructose = free glucose.
 - (b) Total reducing sugar minus total fructose = total glucose.
4. The approximate estimate of fructosan was made from the excess of fructose over glucose produced by N/5 acid, plus a correction of 6% glucose occurring in the known fructosan.
5. Estimates of sucrose as the difference between increase on hydrolysis and the fructosan estimate were subject to large errors and therefore not reliable (4).
6. A second means of estimating sucrose is suggested whereby twice the increase in glucose produced on hydrolysis equals sucrose. These values will always be too high owing to the inclusion of glucose from sources other than sucrose. At

best they can only be regarded as approximations (4).

EXPERIMENTAL RESULTS

As a matter of convenience the experimental results obtained in this investigation are divided into four sections:

Section A - The drifts in sugar and dry matter content in growing barley from the eighth day after seeding to the end of the growing season.

Section B - The differences in sugar and dry matter content in growing barley as related to the time of day collections were made.

Section C - The sugar and dry matter content in the stems, sheaths, leaves, and heads of growing barley from the 57th to the 85th day after sowing.

Section D - The losses of sugars from barley plants air-dried at room temperatures.

Seasonal Drift in Sugar and Dry Matter Content

Section A

The results for this section appear in Tables I, II, and III; and Figures 1 to 5.

The plentiful supply of moisture during the season

that they can give no answer to the question (4).

REFERENCES

- As a result of the above the following results
obtained in this investigation are listed below for reference:
Result 1 - The results in cases 1 and 2 are not
identical in general, but they are identical in the case of
the first of the two cases.
Result 2 - The results in cases 3 and 4 are not
identical in general, but they are identical in the case of
the first of the two cases.
Result 3 - The results in cases 5 and 6 are not
identical in general, but they are identical in the case of
the first of the two cases.
Result 4 - The results in cases 7 and 8 are not
identical in general, but they are identical in the case of
the first of the two cases.
Result 5 - The results in cases 9 and 10 are not
identical in general, but they are identical in the case of
the first of the two cases.
Result 6 - The results in cases 11 and 12 are not
identical in general, but they are identical in the case of
the first of the two cases.

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1940

The results of the investigation are given in Table 1, 2, 3,
4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20,
21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36,
37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53,
54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70,
71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86,
87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

resulted in very vigorous growth and before heading many of the plants had already lodged. The leaves and stems were larger than those normally produced and long before heading many of the lower leaves showed yellowing, largely the result of excessive shading owing to lodging. On only four of the 28 collection days was there no rain in the 24 hours preceding, and on many occasions it was raining when samples were taken. The actual moisture content of the material was difficult to obtain. In this section an attempt is made to overcome this difficulty, in part at least, by reporting the results as the average of the afternoon and morning values and omitting the percentages based on green weight in all except a few instances.

Heading was practically complete on the 57th day after sowing. From the 29th day to the 57th day 35 inches of the 48 inches of the season's growth took place. Up until heading the drifts in the concentrations of all sugars were subject to considerable variation. Whereas there was a slow increase in total sugar, the free reducing sugars showed a gradual increase, reaching their maximum content for the season on the 57th day. Despite the great increase in height of plants there was no great increase in the percent dry matter. Many large tillers were produced.

The amounts of free glucose exceeded free fructose throughout the growth season.

Concentration increases in one sugar usually were

associated with increases in another, so that there was evident a gradual upward trend in all of them. This was very noticeable shortly before heading when increases in all sugars were large. Throughout most of the period total fructose exceeded total glucose, the maximum concentrations reached coinciding with those for the free reducing sugars.

The fructose produced by acid hydrolysis, after corrections for the amounts arising from sucrose, appears as fructosan. Except for the rather low values of this sugar obtained on the 36th and 43rd day there was a gradual upward trend until the 57th day, when the maximum concentration was reached. The low values were difficult to explain. The period was marked by large variations in hours of sunshine, temperatures, and amounts of rainfall. It rained almost continuously during July 29, 30, and 31, and there was less than one hour of sunshine recorded. The maximum temperature readings were almost 10°F. less than the July average. The period following was bright and warm.

The fructosans, at their maximum concentration, formed approximately 35% of the total sugar, but the absolute amounts were not large.

Sucrose was the dominant sugar throughout the whole period, reaching its maximum concentration a week or so after the fructosan maximum.

No starch was observed in any of the tissues of the

associated with increased in numbers, as the latter was very
great a general upward trend in all of them. This was very
noticeable especially before reading when interest in all cases
were large. Throughout most of the entire trial period
exceeded total number, the various observations recorded
coinciding with those for the first reading period.
The frequency recorded in each of the trials, after the
reading for the various trials from number, appears as
follows. Except for the first few trials of this series
obtained on the 25th and 26th day there was a general upward
trend until the 27th day, after which the frequency was
reduced. The low values were obtained in the trials. The
period was marked by large variations in terms of number,
frequency, and amount of rainfall. It varied almost con-
tinuously during July 25, 26, and 27, and there was less than
one hour of rainfall recorded. The maximum frequency
readings were around 100. There was the only average. The
total following was 100.0 and more.
The frequency, as well as the amount of rainfall,
formed approximately 100 of the total water, and the frequency
amounts were not large.
Below are the various trials recorded and the
period, showing the various observations made on the other
the 17th day of the trial.
The second trial was observed in part of the frequency of the

plants until head formation, when positive iodine tests were obtained in the head materials.

In the week following heading, the maximum concentrations of all sugars had been reached and, from this date to the end of the season, a sharp decrease in the amounts of all sugars was clearly evident. The presence of fructosans in the plants after the 78th day was doubtful. The drifts in the concentrations of all sugars almost paralleled one another, until at the end of the growth period only small amounts of sugar remained.

For comparative purposes the following observations may be related to periods of growth.

A. From Sowing to Heading

1. The total sugar increased slowly in the early part of the growth cycle. At the same time there was a more rapid increase in dry matter content.

2. There was a gradual increase in the amounts of both free and combined fructose and in glucose.

3. The sucrose level remained fairly constant.

4. All sugars, with the exception of the total sugar and sucrose, reached their maximum concentration at time of heading.

5. This period marked the time of most active growth and, by heading, most structural parts of the plants were formed.

6. Some of the lower leaves were dead by the time heading was complete.

plants used for irrigation, when under long pressure
obtains in the last section.

In the last section of the paper, the various
features of the system are described and, from this data
the end of the season, a first estimate is made of the
amount of water required. The amount of water in
the plants at the end of the season is estimated. The water in
the plantations at the end of the season is estimated and another
estimate is made of the water required for the amount of
water required.

The following are the results of the
work in relation to the water required.

1. From the results

1. The water required for the
first of the season is . . . at the end of the season
water required is . . .
2. There is a . . . increase in the amount of
water required for the first of the season . . .
3. The water required for the first of the season . . .
4. The water required for the first of the season . . .
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9. The water required for the first of the season . . .
10. The water required for the first of the season . . .

B. First week after Heading

1. The maximum concentration of all sugars was reached.

2. Head formation began and was accompanied by a rapid increase in dry matter content.

C. One week after Heading to End of Season

1. The leaves died and ceased to function as centres for assimilation.

2. The dry matter content increased rapidly.

3. The concentrations of all sugars decreased rapidly.

4. Most of the starch in the grain was formed during this period.

On the basis of recent conclusions reached by workers on this problem, the variable trends of all sugars in the early stages of growth are due to the great demands of the actively growing plant for primary assimilates, thus leaving little for purposes of storage. The leaf surfaces which are the most important sources for photosynthate in the early stages were not large enough to do more than supply immediate demands of growth. It is only when the plants become fully developed that demands are satisfied and an excess is produced for condensation to sucrose and fructosan. This condition should normally exist when growth of the stem

1. The first main result of the

1. The first main result of the present paper is the following theorem.

2. Let f be a function defined on the interval $[0, 1]$ and let F be the function defined by

3. The second main result of the present paper is the following theorem.

1. The first main result of the present paper is the following theorem.

2. The second main result of the present paper is the following theorem.

3. The third main result of the present paper is the following theorem.

4. The fourth main result of the present paper is the following theorem.

5. The fifth main result of the present paper is the following theorem.

6. The sixth main result of the present paper is the following theorem.

7. The seventh main result of the present paper is the following theorem.

8. The eighth main result of the present paper is the following theorem.

9. The ninth main result of the present paper is the following theorem.

10. The tenth main result of the present paper is the following theorem.

11. The eleventh main result of the present paper is the following theorem.

12. The twelfth main result of the present paper is the following theorem.

13. The thirteenth main result of the present paper is the following theorem.

14. The fourteenth main result of the present paper is the following theorem.

15. The fifteenth main result of the present paper is the following theorem.

16. The sixteenth main result of the present paper is the following theorem.

17. The seventeenth main result of the present paper is the following theorem.

18. The eighteenth main result of the present paper is the following theorem.

19. The nineteenth main result of the present paper is the following theorem.

20. The twentieth main result of the present paper is the following theorem.

is nearly complete. This is borne out in the observed concentrations of stored sugars found at or near heading. If the view that stored sugar represents a simple balance of demand over supply is accepted, then active and vigorous growth should result in relatively lower concentrations of stored sugars. The results of the present experiments appear to be in agreement with these conclusions, since they do not give the high values observed in plants growing under conditions known to favor sugar storage.

is nearly complete. This is borne out in the observed con-
tractions of the muscles found at or near death. It
the view that the observed contractions are a result of
death, even as it is observed, that active and vigorous
growth should result in relatively lower contractions of
stayed muscles. The results of the present experiments appear
to be in agreement with these observations, since they do not
give the high values observed in plants growing under condi-
tions known to favor rapid growth.

TABLE I
Field notes

Date of collection	Stage of growth	Dry matter (%)	Weather at collection time
June 30	1 leaf	10.9	Cloudy - trace rain
July 1	1 leaf	10.5	Cloudy - rain overnight
July 7	2 leaves	11.1	Cloudy - trace rain
8	2 leaves	10.7	Cloudy - raining
14	3 to 5 leaves	10.2	Fair - warm
15	3 to 5 leaves	11.0	Shower - warm
21	Flag leaf	14.9	Bright - no rain
22	Flag leaf	13.8	Bright - no rain
28	(Some lodging -	17.8	Showery - trace rain
29	(awns showing	14.0	Cloudy - rain overnight
Aug. 4	Head emergence	18.4	Bright - no rain
5	Head emergence	15.3	Bright - rain overnight
11	(Almost headed	21.6	Very cloudy - shower
12	(Almost headed	19.8	Bright - rain overnight
	(badly lodged		
18	Lower leaves)	25.6	Cloudy - cool - damp
19	yellowing)	23.1	Heavily overcast - no rain
25	(Dough stage;end	28.8	Cloudy - shower in p.m.
26	(of max. growth	26.7	Cloudy - heavy dew
Sept. 1	Many lower)	30.3	Heavy clouds - no rain
2	leaves dead)	28.2	Cool - heavy dew
8	(All lower	34.4	Cloudy - cool; trace rain
9	(leaves dead	35.1	Cool - bright
15	Heads ripening	46.3	Cloudy - cold - damp
16	Heads ripening	43.1	Raining - cold
22	(Plants nearly	47.4	Cloudy - cool - no rain
23	(ripe; some	47.0	Cloudy - cool - dew
	(tillers green		
29	Harvest	52.9	Cold - rain - snow
30	Harvest	52.3	Cold - rain and snow

TABLE V
Leaf notes

Date of collection	State of weather	Wind velocity (m/sec)	Number of insects collected at time
June 20	1 leaf	12.4	1000 - 10000
July 1	1 leaf	12.2	1000 - 10000
July 7	2 leaves	11.2	1000 - 10000
8	2 leaves	11.7	1000 - 10000
14	7 to 8 leaves	10.2	1000 - 10000
15	8 to 9 leaves	11.0	1000 - 10000
21	10 to 12 leaves	14.2	1000 - 10000
22	10 to 12 leaves	13.0	1000 - 10000
28	10 to 12 leaves	12.2	1000 - 10000
29	10 to 12 leaves	12.0	1000 - 10000
Aug. 4	10 to 12 leaves	12.2	1000 - 10000
5	10 to 12 leaves	12.2	1000 - 10000
11	10 to 12 leaves	11.0	1000 - 10000
12	10 to 12 leaves	11.2	1000 - 10000
18	10 to 12 leaves	11.2	1000 - 10000
19	10 to 12 leaves	11.2	1000 - 10000
20	10 to 12 leaves	11.2	1000 - 10000
21	10 to 12 leaves	11.2	1000 - 10000
22	10 to 12 leaves	11.2	1000 - 10000
23	10 to 12 leaves	11.2	1000 - 10000
24	10 to 12 leaves	11.2	1000 - 10000
25	10 to 12 leaves	11.2	1000 - 10000
26	10 to 12 leaves	11.2	1000 - 10000
27	10 to 12 leaves	11.2	1000 - 10000
28	10 to 12 leaves	11.2	1000 - 10000
29	10 to 12 leaves	11.2	1000 - 10000
30	10 to 12 leaves	11.2	1000 - 10000
31	10 to 12 leaves	11.2	1000 - 10000
1	10 to 12 leaves	11.2	1000 - 10000
2	10 to 12 leaves	11.2	1000 - 10000
3	10 to 12 leaves	11.2	1000 - 10000
4	10 to 12 leaves	11.2	1000 - 10000
5	10 to 12 leaves	11.2	1000 - 10000
6	10 to 12 leaves	11.2	1000 - 10000
7	10 to 12 leaves	11.2	1000 - 10000
8	10 to 12 leaves	11.2	1000 - 10000
9	10 to 12 leaves	11.2	1000 - 10000
10	10 to 12 leaves	11.2	1000 - 10000
11	10 to 12 leaves	11.2	1000 - 10000
12	10 to 12 leaves	11.2	1000 - 10000
13	10 to 12 leaves	11.2	1000 - 10000
14	10 to 12 leaves	11.2	1000 - 10000
15	10 to 12 leaves	11.2	1000 - 10000
16	10 to 12 leaves	11.2	1000 - 10000
17	10 to 12 leaves	11.2	1000 - 10000
18	10 to 12 leaves	11.2	1000 - 10000
19	10 to 12 leaves	11.2	1000 - 10000
20	10 to 12 leaves	11.2	1000 - 10000
21	10 to 12 leaves	11.2	1000 - 10000
22	10 to 12 leaves	11.2	1000 - 10000
23	10 to 12 leaves	11.2	1000 - 10000
24	10 to 12 leaves	11.2	1000 - 10000
25	10 to 12 leaves	11.2	1000 - 10000
26	10 to 12 leaves	11.2	1000 - 10000
27	10 to 12 leaves	11.2	1000 - 10000
28	10 to 12 leaves	11.2	1000 - 10000
29	10 to 12 leaves	11.2	1000 - 10000
30	10 to 12 leaves	11.2	1000 - 10000
31	10 to 12 leaves	11.2	1000 - 10000

TABLE II

Composition of aerial parts of barley during growth (sugar concentrations expressed as percent green weight)

Collection date	Total sugar	Reducing sugar	Fructosan
June 30	1.08	.31	--
July 7	.85	.36	--
14	1.03	.28	.01
21	1.31	.52	.35
28	1.21	.63	.21
Aug. 4	1.34	.68	.14
11	1.52	.93	.63
18	3.44	1.16	1.20
25	5.22	1.28	1.09
Sept. 1	5.07	1.45	--
8	3.85	1.16	.08
15	2.05	.55	--
22	1.65	.04	--
29	1.06	.04	--

TABLE III

Composition of the aerial parts of barley during growth
(Sugars expressed as percent dry weight)

Date of collection	Age of plants (dys.)	Dry matter % fresh weight	Total sugar	Reducing sugar	Sucrose	Fructosan	Free glucose	Free fructose	Increase after acid hydrolysis	
									Glucose	Fructose
June 30	8	10.7	10.03	2.85	7.88	--	1.73	1.12	3.94	3.24
July 7	15	10.9	7.66	1.80	--	--	1.80	--	--	--
22	22	10.6	9.71	1.62	6.90	.23	1.52	1.10	3.45	3.65
22	29	14.4	9.02	3.51	3.50	2.29	2.75	.76	1.75	3.76
29	36	15.9	7.55	3.96	2.52	1.22	2.92	1.04	1.26	2.33
Aug. 4	43	16.9	7.90	4.03	3.12	.87	2.70	1.33	1.56	2.32
11	50	20.7	7.34	4.51	.20	3.01	2.58	1.93	.10	2.74
18	57	24.3	14.13	4.74	5.04	4.97	3.11	1.63	2.52	6.88
25	64	27.8	18.85	4.60	10.82	3.81	2.99	1.61	5.41	8.85
Sept. 1	71	29.3	17.21	4.95	16.04	--	2.76	2.19	8.02	4.24
8	78	34.8	11.07	3.35	7.50	.26	1.73	1.62	3.75	3.98
15	85	44.7	4.59	1.23	4.54	--	.73	.52	2.27	2.19
22	92	47.2	3.49	.02	3.20	--	.09	--	1.60	1.81
29	99	52.6	2.02	.08	1.64	--	.08	--	.82	1.11

Figure 1

The drifts in sugar and dry matter content in growing barley

Note: Weather data shown are those which prevailed in the day preceding collection.

Dry matter as percent of the green weight.

Figures 2 and 3

Composition of barley during growth.

Sugar concentrations as averages of after-
noon and morning collections

Figure 4

Composition of barley during growth.

Free glucose and free fructose as
averages of afternoon and
morning collections

Figure 5

Sugar concentrations in growing barley
as averages of morning and after-
noon collections

Glucose and fructose as α -D increases
after acid hydrolysis

Section B

The investigation discussed in this section was made in an attempt to estimate the extent of sugar and dry matter changes following periods of darkness. At present there is considerable evidence (8) that losses of stored sugars are not due to the demands of growth but are apparently related to respiration*.

Some striking results were obtained in the preliminary work when sugar concentrations were estimated in plants growing under dull and wet conditions. Collections were made at approximately 1:30 p.m. on three different dates and the data presented in Table IV.

TABLE IV
Sugar concentrations expressed as percent
of green weight

Collection date	Age (dy.)	Total sugar	Reducing sugar	Sucrose	Total glucose	Total fructose
June 9	15	1.22	.39	.10	.44	.78
June 12	18	.44	.15	.02	.14	.30
June 16	22	.26	.06	-	.21	.05

* Losses have been attributed to respiration activities although at present no conclusive evidence has been obtained as to the actual fate of stored sugars (6).

Table 3

The investigation discussed in this section was made in an attempt to determine the extent of oxygen and nitrogen exchange following various treatments. It is known that in certain cases (a) that oxygen and nitrogen exchange may not be as extensive as shown but are significantly reduced in certain cases.

When similar results were obtained in the present study, it was noted that certain treatments in plants exposed under both the two conditions. Diffusion was made at approximately 1:30 p.m. on these different dates and the data presented in Table IV.

TABLE IV

Mean concentration expressed as percent of fresh weight

Concentration (%)	Total Reducible Sugar	Total Sugar	Total Protein	Total Lipid
June 7	1.30	1.30	1.30	1.30
June 12	1.30	1.30	1.30	1.30
June 14	1.30	1.30	1.30	1.30

* Values have been calculated on basis of dry weight of tissue as received. No significant difference was found between the actual and calculated values (6).

The period from June 4th to 9th was exceptionally warm and the hours of sunshine recorded for each day were much higher than the average value for the month. In the following week, 4.17 inches of rain fell and there was no direct sunshine from June 13 to 16. The very sharp and well defined decreases in concentrations of all sugars were clearly related to the prevailing conditions of weather, and it would appear that the low hours of sunlight and low temperatures influence sugar concentrations because losses due to respiration are not replaced by photosynthetic activity.

The remainder of the discussion in this section is concerned with the barley planted on June 22, the data appearing in Table V and Figures 6, 7, and 8.

The dry matter content in the morning collection was, with few exceptions, lower than that of comparable afternoon collections. The largest differences were noted when the plants were young and growing rapidly, but for reasons already considered, the difficulties involved in making moisture determinations made actual estimates of dry matter questionable. A definite relationship between dry matter differences and age was observed to exist. After time of heading, the morning and afternoon differences in dry matter content decreased with increase in age.

Differences in sugar concentration were not clearly evident. There is some reason to suggest that the total sugar values were higher in the afternoon, but the fact that

The period from 10:00 to 11:00 was exceptionally
warm and the hours of darkness extended for some days were
much higher than the average value for the month. In the
following week, 4.17 inches of rain fell and there was no
direct sunshine from 10:00 to 11:00. The very sharp and well
defined depression in concentration of all insects was clearly
related to the prevailing conditions of weather, and it would
appear that the low hours of sunlight and low temperatures
influence insect concentration because of the fact that
insects are not required by parasitoidic activity.
The number of the specimens in this section is
concerned with the data listed on Table 1, the data appear-
ing in Table 1 and figures 4, 5, and 6.
The dry matter content in the various collections
was, with few exceptions, lower than that of comparable in-
sect collections. The largest differences were noted when
the plants were young and growing rapidly, but for plants
already collected, the differences involved in water con-
tent were not so great. The differences were also evident in the
percentage of dry matter. A detailed relationship between dry matter dis-
tribution and age was observed to exist. After the time of collection
the moisture and nitrogen differences in dry matter content
decreased with increase in age.
Differences in water concentration were not clearly
evident. There is some reason to suggest that the total
water values were higher in the afternoon, but the total

TABLE V

Sugar content of barley expressed as percent of dry weight, as related to time of day collections were made

A = afternoon collection
B = collection following morning

Age of plant	Total sugar		Sucrose		Fructose after hydrolysis*		Free glucose		Free fructose	
	A	B	A	B	A	B	A	B	A	B
8	13.76	6.29	11.56	4.20	4.95	1.52	1.65	1.81	1.38	.86
15	7.66	--	--	--	--	--	1.80	--	--	--
22	10.78	8.64	7.24	6.56	4.12	3.18	1.67	1.36	1.37	.82
29	11.07	6.96	2.68	4.34	5.84	1.67	2.95	2.54	.94	.58
36	8.09	7.00	3.02	2.00	2.87	1.79	2.70	3.14	1.01	1.07
43	8.48	7.32	4.14	2.10	2.28	2.35	2.39	3.00	1.74	.92
50	7.31	7.37	1.28	--	3.01	2.47	1.58	3.58	2.08	1.77
57	14.10	14.16	5.54	4.52	6.41	7.35	3.32	2.90	1.60	1.65
64	17.78	19.92	9.32	12.30	8.57	9.13	2.88	3.10	1.67	1.54
71	20.26	14.15	19.66	12.42	4.95	3.54	3.17	2.34	2.31	2.06
78	11.80	10.34	6.88	8.32	4.91	3.05	1.86	1.59	1.69	1.54
85	4.58	4.59	4.96	4.12	1.07	1.13	.55	.89	.49	.52
92	3.04	3.94	1.68	--	--	--	.17	--	--	--
99	2.31	1.70	1.76	1.52	--	--	.13	.02	--	--

* Total increase in fructose after acid hydrolysis.

some of the afternoon values were lower than those for the morning makes acceptance of this open to question. The only real differences were found in the period of one and one-half months immediately after seeding. Near harvest the differences were much smaller and were not consistent.

The free glucose estimations varied so greatly that, with the exception of the first few observations, no consistent differences were noted. The free fructose concentrations, on

TABLE 7

Percent of total sample of 1000
of 1000 selected, as related to time of
day collection was made

A - afternoon collection
B - collection following
morning

Age of plant	Total average		Afternoon		Morning		Total average		Afternoon		Morning	
	1	2	3	4	5	6	7	8	9	10	11	12
1	13.72	0.10	11.62	4.40	1.52	1.42	1.81	1.38	1.30	1.30	1.30	1.30
10	7.08	—	—	—	—	—	—	—	—	—	—	—
20	10.78	0.04	7.74	0.30	0.10	0.10	1.38	1.38	1.38	1.38	1.38	1.38
30	11.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	9.09	7.00	3.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50	8.44	7.32	4.14	2.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
60	7.11	7.37	1.18	—	—	—	—	—	—	—	—	—
70	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
80	17.76	14.02	3.74	10.20	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
90	20.68	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10	14.10
100	11.30	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58	4.58
120	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04
130	2.51	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70

Total increase in fruiting with soil moisture

Some of the afternoon values were lower than those for the morning values respectively of this open question. The only real differences were found in the portion of one and one-half months immediately after reading. They showed the differences were most marked and were not constant. The two groups exhibited rather no growth, with the exception of the first few observations, no significant differences were noted. The two groups continued to grow.

the other hand, showed real differences and, with only one or two exceptions, the afternoon values exceeded those for the morning. The differences in the early stages of growth were much greater than those noted in the periods approaching maturity. Increases in fructose after acid hydrolysis were higher in plants collected in the afternoon, and followed drifts much like those for free fructose. The differences again appeared to be significant. The fructosan values are directly related to fructose increases following hydrolysis so that they too follow much the same concentration changes in relation to the time of day at which collections were made.

The sucrose estimates are at best only approximate and are always too high, since glucose from sources at present undefined is included (4). The data on sucrose showed no real differences, although amounts vary within wide limits.

Great variation in weather conditions occurred throughout the growth period. From evidence obtained on the effect of hours of sunshine and temperature on level of sugar concentrations in plant material investigated in the early part of this work, it would appear that rather large variations must accompany weather changes. If, for example, cloudy conditions prevailed previous to the 4:30 p.m. collection and clear bright weather followed until nightfall, no normal estimate for that day could be expected. The observation for the morning collection on the other hand would be dependent upon the conditions which obtained from dawn to 8:30 a.m. If

storage and formation of sugars is greatly influenced by the hours of sunshine during the period before nightfall and the period preceding 8:30 a.m., the effect of darkness becomes obscured. This difficulty could be overcome in future work by taking the "afternoon" collections at sundown and the morning ones somewhat earlier than 8:30 a.m. As the data appear in this report, little can be known of the effect of the hours of darkness, since some hours of daylight occurred in the interval between afternoon and morning collections. The differences between morning and afternoon collections, nevertheless, did indicate a large daily variation in sugar content.

changes and formation of waves in general. It is the
hours of sunrise during the winter months and the
period preceding 6:30 a.m. the effect of waves is
marked. This effect is marked in the
by being the "strongest" reflection of waves and the
the wave movement will be seen at 6:30 a.m. as the wave
this point, it is seen at the effect of the wave
movement, which some hours of light is the first
of the waves and the moving of the waves. The
between waves and the waves themselves, however, the
indicate a wave which variation is seen.

Figure 6

Dry matter and total sugar content in
growing barley as related to time
of day collections were made

Figure 7

Free glucose and free fructose content of
growing barley as related to time of
day collections were made

Figure 8

Sucrose and total fructose in growing
barley as related to time of day
collections were made

Section C

This portion of the investigation fell considerably short of original expectations. The analysis of the separate parts of the whole plant was undertaken so that an estimation of the level and the time of occurrence of maximum concentrations of sugars could be made. The results obtained indicate that the maxima had either been reached or nearly so in all parts at the time the first analysis was made and, as a consequence, only the "falling phase" of sugar trends was observed. The data are presented in Tables VI and VII.

In all parts of the plant there was an increase in the dry matter content, the larger increases occurring in the stems, leaves, and heads. As the first observations were made at approximately the time of full heading, a good picture of the dry matter increase in the head was obtained. Dry matter changes in sheaths were small. Some doubt may be cast on the results obtained for the leaves, as many of the lower ones, especially in the later periods of growth, had either dropped in the field or were lost in handling. At best the results should be considered only as approximate estimates.

The large increases in the dry matter content of whole plants is closely related to increases of dry matter in the heads. By the time heading was complete it may be assumed that most of the structural parts of the plant had been formed so that changes of dry matter in all parts but the heads were caused by loss of water and tissue degradation, associated with

TABLE VI

Sugar content of stems, sheaths, leaves,
and heads of barley, expressed
as percent of dry weight of plant

Date of collection	age	Stems	Sheaths	Leaves	Heads	Total	Whole plant*
<u>Dry matter as % of fresh weight of whole plant</u>							
Aug. 18	57	--	--	--	--		
25	64	39.3	13.6	18.8	28.4		28.8
Sept. 1	71	37.9	13.1	16.1	32.4		30.3
8	78	35.5	13.6	13.2	37.7		34.4
15	85	35.2	12.6	7.2	45.0		46.3
<u>Total sugar as % dry weight of plant</u>							
Aug. 25	64	9.01	1.86	2.30	4.93	18.10	17.78
Sept. 1	71	8.61	1.80	1.96	4.51	16.88	20.26**
8	78	5.21	2.01	1.55	2.08	10.85	11.80
15	85	1.74	.64	.21	1.31	3.90	4.58
<u>Free glucose as % dry weight of plant</u>							
Aug. 25	64	1.86	.40	.47	.33	3.06	2.88
Sept. 1	71	2.04	.40	.48	.54	3.46	3.17
8	78	1.32	.52	.38	.13	2.35	1.86
15	85	.29	.13	.06	.10	.58	.55
<u>Free fructose as % dry weight of plant</u>							
Aug. 25	64	.86	.18	.23	.22	1.49	1.67
Sept. 1	71	1.53	.28	.32	.21	2.34	2.31
8	78	1.22	.39	.27	.10	1.98	1.69
15	85	.51	.15	.04	.09	.79	.49
<u>Glucose as net increase after hydrolysis as % dry weight of plant</u>							
Aug. 25	64	2.17	.55	.65	1.45	4.82	4.66
Sept. 1	71	2.45	.52	.57	1.49	5.03	9.83**
8	78	.75	.37	.77	.47	2.36	5.20
15	85	.37	.06	.07	.90	1.40	3.03

TABLE II

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE, WYOMING
AS DETERMINED BY THE METHOD OF LIGNITE

DATE OF ANALYSIS: 1937
ANALYST: J. H. HARRIS

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE

ANALYST	DATE	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE

ANALYST	DATE	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE

ANALYST	DATE	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE

ANALYST	DATE	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0

WEIGHT PERCENTAGE OF VARIOUS METALS IN
SOLUBLE FRACTION OF LIGNITE

ANALYST	DATE	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0
J. H. HARRIS	1937	1.0	1.0	1.0	1.0	1.0	1.0

TABLE VI (continued)

Date of collection	Age	Stems	Sheaths	Leaves	Heads	Total	Whole plant*
<u>Fructose as net increase after hydrolysis as % dry weight of plant</u>							
Aug. 25	64	4.11	.73	.96	2.94	8.74	8.57
Sept. 1	71	2.59	.55	.58	2.27	5.99	4.95
8	78	1.92	.75	.13	1.38	4.18	4.91
15	85	.21	.25	.04	.24	.74	1.07
<u>Fructosan as % dry weight of plant</u>							
Aug. 25	64	2.21	.20	.35	1.70	4.46	4.45
Sept. 1	71	.16	.04	.01	.89	1.10	--
8	78	1.33	.44	--	1.04	2.81	1.79
15	85	.21	.21	--	--	.42	--
<u>Sucrose as % dry weight of plant</u>							
Aug. 25	64	4.34	1.10	1.30	2.90	9.64	9.32
Sept. 1	71	4.90	1.03	1.14	2.98	10.05	19.66**
8	78	1.51	.71	1.53	.94	4.69	6.68
15	85	.74	.12	.13	1.79	2.78	4.96
<u>Reducing sugar as % dry weight of plant</u>							
Aug. 25	64	2.72	.58	.70	.55	4.55	4.55
Sept. 1	71	3.57	.67	.81	.75	5.80	5.48
8	78	2.54	.91	.65	.23	4.33	3.55
15	85	.81	.33	.10	.18	1.42	1.04

* Obtained on the whole plants on the corresponding dates of collection.

**The apparent over-estimation of the increase in glucose after hydrolysis gives:

1. Too high value for sucrose.
2. Low value for fructosan.
3. Too high value for total sugar.

TABLE VI (Continued)

NOTE: 1. The values for the first two columns are the values for the first two columns of Table I. 2. The values for the last two columns are the values for the last two columns of Table I.

TABLE VI (Continued)

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE VI (Continued)

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE VI (Continued)

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE VI (Continued)

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NOTE: 1. The values for the first two columns are the values for the first two columns of Table I. 2. The values for the last two columns are the values for the last two columns of Table I.

TABLE VI (Continued)

1. The values for the first two columns are the values for the first two columns of Table I.
2. The values for the last two columns are the values for the last two columns of Table I.
3. The values for the last two columns are the values for the last two columns of Table I.

TABLE VII

Sugar and dry matter content in the stems, sheaths, leaves, and heads of barley

Date of collection	Age of plant	Stems	Sheaths	Leaves	Heads
Dry matter of the part as % of green weight of part					
Aug. 18	57	22.1	24.2	19.2	30.8
25	64	30.0	26.6	24.8	39.6
Sept. 1	71	25.7	24.6	22.9	39.8
8	78	27.4	26.4	28.2	49.0
15	85	32.6	29.6	55.0	53.8
Total sugar as % of dry matter of part					
Aug. 18	57	31.04	17.11	9.74	12.08
25	64	22.93	13.68	12.26	17.37
Sept. 1	71	22.72	13.25	12.18	13.92
8	78	14.67	14.81	11.77	5.51
15	85	4.94	5.04	2.87	2.92
Free glucose as % of dry matter of part					
Aug. 18	57	10.22	3.06	2.60	3.02
25	64	4.73	2.94	2.50	1.16
Sept. 1	71	5.37	2.97	3.01	1.66
8	78	3.72	3.86	2.90	.34
15	85	.83	1.07	.80	.22
Free fructose as % of dry matter of part					
Aug. 18	57	2.04	2.27	--	2.34
25	64	2.20	1.35	1.21	.76
Sept. 1	71	4.05	2.15	2.01	.65
8	78	3.43	2.84	2.06	.27
15	85	1.46	1.22	.58	.19
Glucose as net increase after hydrolysis as % of dry matter of part					
Aug. 18	57	3.13	5.58	--	2.11
25	64	5.53	4.05	3.47	5.10
Sept. 1	71	6.46	3.94	3.54	4.60
8	78	2.12	2.62	5.82	1.25
15	85	1.06	.49	.91	1.99

TABLE VII (continued)

Date of collection	Age of plant	Stems	Sheaths	Leaves	Heads
<u>Fructose as net increase after hydrolysis as % dry matter of part</u>					
Aug. 18	57	15.65	6.20	--	4.61
25	64	10.47	5.34	5.08	10.35
Sept. 1	71	6.84	4.19	3.62	7.01
8	78	5.40	5.49	.99	3.65
15	85	1.59	1.96	.59	.54
<u>Fructosan as % dry matter of part</u>					
Aug. 18	57	14.27	.71	--	2.85
25	64	5.63	1.47	1.84	5.99
Sept. 1	71	.43	.29	.09	2.75
8	78	3.74	3.27	--	2.74
15	85	.61	1.68	--	--
<u>Sucrose as % dry matter of part</u>					
Aug. 18	57	6.16	11.16	--	4.22
25	64	11.06	8.10	6.94	10.20
Sept. 1	71	12.92	7.88	7.08	9.20
8	78	4.24	5.24	11.64	2.50
15	85	2.12	.98	1.82	3.98
<u>Reducing sugar as % dry weight of plant</u>					
Aug. 18	57	12.26	5.33	2.60	5.36
25	64	6.93	4.29	3.71	1.92
Sept. 1	71	9.42	5.12	5.02	2.31
8	78	7.15	6.70	4.96	.61
15	85	2.29	2.59	1.38	.39

senescence.

The most significant results were obtained for the dry matter content of the parts as related to that of whole plants. The distribution of the dry matter of whole plants is briefly summarized in Table VIII.

TABLE VIII

Dry matter in the parts as percent of
dry weight of the whole

Part	57th day after seeding	85th day after seeding
Stems	39.3	35.2
Sheaths	13.6	12.6
Leaves	18.8	7.2
Heads	28.4	45.0

The changes in dry matter in stems, sheaths, and leaves were associated, for the most part, with tissue degradation which occurred during the period of ripening. The increase in the dry matter in the head, on the other hand, was directly related to the accumulation of starch and other materials in the developing grain. At the beginning of the study stems formed the larger portion of total dry matter in the plant, while near the end heads formed 45% of the whole. In all parts, except heads, two factors responsible for dry matter changes were: first, the loss of sugars from the tissues; and second, the changes which are related to dehydration and the transformation that living tissues undergo in

continued.

The most significant results were obtained for the dry matter content of the milk as related to level of intake. The distribution of the dry matter of whole milk is briefly summarized in Table VIII.

TABLE VIII

Dry matter in the milk as percent of dry weight of the whole

Level	Dry matter after separation	Dry matter after separation
Starch	37.8	38.8
Protein	33.8	34.8
Lactose	18.8	19.8
Water	50.4	51.0

The changes in dry matter in whole, separated, and lactated were summarized. The dry matter, with intake being taken which occurred during the period of lactation. The increase in dry matter in the feed, on the other hand, was directly related to the accumulation of starch and other materials in the metabolic stores. At the beginning of the study there was a larger portion of total dry matter in the lactating milk than in the whole milk. In all cases, except water, the changes were significant for dry matter change with time. The dry matter of whole milk was also significant and showed a trend in the same direction as the dry matter of whole milk.

the ripening period. Archbold (5) (7) has found no evidence of breakdown of any tissue during growth for purposes of supplying the developing grain with starch-building materials, so the changes that do occur are associated only with senescence.

It is clearly evident that the change in dry weight is the result of dehydration and death of tissues, at least insofar as the stems, sheaths, and leaves are concerned. More information would have been obtained had the analysis been carried out on a "per plant" basis. The results would have shown the actual quantitative changes in dry matter and sugar content instead of the percentage changes, which indicate relative rather than absolute quantities in each part.

The estimations of the various sugars were made for each part of the plant and for the whole plant. When a consideration is made of the possible sources of error in sampling, and of the errors which result from carrying out so many separate steps in the actual analysis, it is concluded that reasonably good agreement was obtained in all but a few cases. The results for the whole plants collected on September 1st appear questionable.

Most of the sugar was found in the stems and the heads, and this was especially true in the earlier stages of growth. The concentrations of sugars in the stems and heads had reached their maximum levels at or near the time heading was observed to be complete. As nearly as can be determined the maximum sugar levels for sheaths and leaves had been

the nitrogen content. Although (2) was found to be
of importance of the nitrogen content for the purpose of
studying the development of the plant with nitrogen
no the nitrogen that is used for the nitrogen content.

It is clearly evident that the change in the

weight in the range of 10-15% and that of 10-15%
total nitrogen in the leaves, stems, and leaves are connected.

More information would have been obtained had the analysis
been carried out on a "per plant" basis. The results would
have shown the actual percentage changes in dry weight and
weight content of the nitrogen content, which indi-
cate relative rather than absolute changes in each part.

The relationship of the nitrogen content to the
weight of the plant and for the whole plant. When a com-
parison is made of the possible sources of error in sampling

and of the errors which result from sampling and so many
samples taken in the same sample, it is concluded that
reasonably good agreement was obtained in all but a few cases.
The results for the whole plant collected on September 11
appear satisfactory.

Most of the nitrogen found in the leaves and the
stems, and also the nitrogen found in the roots and stems of
growth. The concentrations of nitrogen in the stems and roots
had reached their maximum levels at or near the time of sampling
was observed in the samples. The results for the whole plant
the nitrogen content for the whole plant and leaves and roots

reached earlier.

Throughout the period the total sugars in the stems was about twice that found in the heads, and approximately four times the observed values for leaves and sheaths. The order of the contribution of sugar each part made to the plant was therefore:

Stems, approximately 50%
Heads, approximately 25%
Sheaths and leaves, approximately 25%.

Individual results varied somewhat but the above is a fair approximation.

In the 28-day period there was a marked decline in concentration of the total sugars in both stems and heads, and this decline was closely related to the changes in total sugars estimated for the whole plants. The trends in leaves and sheaths were not so obvious except near the end of the period.

The greater part of the free glucose observed in the plant is contributed by the stems. The amounts found in the other parts were much lower and, on the whole, there was little difference between the concentrations found in various parts. The same relationship exists for free fructose, except that all parts contain somewhat lesser amounts. The lowest concentrations were found in the heads.

The values for glucose and fructose, as increases after hydrolysis, show definite trends, falling steadily from the 57th to the 85th day after seeding. The higher concentra-

tions were again observed to occur in the stems and heads, but there were some differences in the amounts found in the leaves and sheaths.

When reference is made to the sucrose levels in the sheaths and leaves it is apparent that a larger increase in glucose observed in the leaf material would be expected. The fructose differences in leaf and sheath material are less obvious, since the larger amounts of fructosans in sheaths tend to obscure the effect of the increase of fructose from sucrose.

The fructosan concentrations in all parts of the plant varied greatly. There was good evidence that the smallest amounts occurred in the leaves and the greatest in the stems, especially at the time active growth of the stem ceased. The heads contained significant amounts, and when the fructosans in the stem are considered, practically all the fructosans in the plant were accounted for. It is difficult to say just what the general trend was from the few values which were obtained. Generally, the drifts in the whole plant are related to the drifts in the parts. It appears that the maximum concentration reached occurred at the time heading was complete and that, in the period following, the amounts decreased rapidly.

The sucrose concentrations followed trends similar to those for other sugars. The only significant fact observed was that the sucrose formed the highest proportion of

the total sugar in almost all parts of the plant and throughout the period could be considered the dominant sugar.

Of all the sugars considered, the free reducing sugars were subject to the least variation. This fact was noted in other parts of this investigation.

While the period considered is rather short, nevertheless a few general conclusions can be drawn. Up to the time of heading and for a short time after, stem constitutes the larger portion of the dry matter of the whole plant. In the later stages of growth, especially during the ripening period, the heads contain almost half the total dry matter.

In the period following heading, the stems and heads contain almost 75% of the total sugars found in the plants and generally show the most marked changes in both dry matter and sugar content. When the various sugars in the plant are at their maximum the stems contain the highest proportion--as much as 50% of the sugars.

The sheaths and leaves contained less sugar than did the ears , and the variation in concentration as related to the age of the plant did not follow drifts which were as obvious. At no time was there much more than 25% of the total sugar ascribable to leaves and sheaths. This, of course, would not be true in the early periods of the growth cycle. Any changes in sugar concentrations which occurred in either of these parts took place in the latter part of the period under consideration.

All parts of the plant at the end of the 85th day contained relatively small amounts of sugar. Sucrose was the dominant sugar and free fructose was observed to be present in the smallest amounts.

As nearly as can be determined the maximum concentration of sugars was reached in the following time order: leaves, sheaths, stems, and heads. This is, of course, just what would be expected. Concentration trends of all sugars in all parts of the plant were related to the sugar concentrations in the whole plant and appeared to be influenced very markedly by the stage of development of the plant, this being especially true during the latter stages of the plant's growth.

Section D

The data for this section are presented in Figures 9 and 10. All sugar values are expressed as percent of the weight of the material observed after drying for 24 hours in an oven maintained at 55 to 60°C., this low temperature being necessary to avoid fructosan destruction.

A comparison of the seasonal concentration drifts of the total sugar estimated in both green and dried material indicated close agreement. The total sugar values in dried materials were much lower but closely paralleled corresponding values for total sugar in the green materials. The maximum total sugar content after drying of the plants was

11.95%, which was almost 37% lower than the maximum concentration before drying. Larger losses occurred with young plants which had been growing rapidly. With increasing age of the plants losses were not as pronounced. No "average" losses could be estimated but an approximation of from 25 to 45% would include most of the individual values determined.

Concentrations of reducing sugars after drying showed that losses varied with age of plant, the greater differences occurring when young plants were dried. In these, there was a marked reduction in free glucose resulting in the presence of larger amounts of free fructose than of free glucose. In the older material the losses of both of these sugars appeared to be less evident, so that amounts remaining were as high as 80% of the original values.

Very large losses of sucrose were noted and, since this sugar made up the greater portion of the total sugar in the plants before drying, its disappearance during the drying period accounted for most of the sugar lost.

Fructosan losses did not appear to be large, the only obvious differences occurring in the younger plants.

The losses in reducing sugars that actually occurred during drying are difficult to determine as sucrose inversion, which is brought about by enzymatic activity during drying of the plant, would increase the concentration of both glucose and fructose (1). The demands of respiration before death of the

It was also very difficult to find the various companies
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plants, however, reduce the amounts of the latter sugars so that the amounts remaining would depend upon the extent of sucrose inversion and the magnitude of the demands of respiration. The results indicated lowest concentrations of reducing sugars to be associated with the smaller amounts of sucrose originally present. This phenomenon would also account for the relatively higher concentrations of reducing sugars observed in plants that contained large amounts of sucrose before drying.

It was concluded from the observations on sugar losses that occurred during drying of plant material that the most labile sugars were glucose and sucrose, whereas fructose and fructosans were the least affected. The levels of reducing sugars in dry material were related to concentrations of sucrose originally present. The over-all losses in total sugar, due to drying of the plants, was from 25 to 45%.

TABLE IX

Composition of dried barley plants
(Results expressed as % dry weight)

Age of plant	Total sugar	Free reducing sugar	Sucrose	Fructosan	Free glucose	Free fructose
8	4.05	1.22	3.92	--	.34	.88
15	2.55	.93	2.76	--	.04	.89
22	3.44	.83	2.68	--	--	.94
29	4.10	.93	2.08	1.24	.17	.76
36	2.39	.48	1.34	.57	--	.55
43	1.94	.52	.46	1.09	.11	.41
50	5.55	1.66	1.56	2.66	1.02	.64
57	11.03	3.28	6.12	1.86	1.89	1.39
64	11.95	3.80	4.82	3.80	2.22	1.58
71	10.05	3.08	6.36	.70	1.84	1.24
78	7.17	2.58	4.52	.07	1.31	1.27
85	5.21	1.64	2.98	--	.87	.77
92	2.17	.94	--	--	.64	.30
99	.64	.28	--	--	.15	.13

Figure 9

Sugar content in dried barley plants

Results as averages of afternoon
and morning collections

Figure 10

Sugar content of dried barley plants

Free glucose, free fructose, and sucrose
results as averages of afternoon
and morning collections

DISCUSSION AND SUMMARY

Quantitative determinations of sugars in growing barley, with the object of studying seasonal changes and drifts, were carried out. Relationships were found among concentrations of stored sugars, stage of plant development, and growth rate. Weather conditions seemed to be related to rate and extent of sugar accumulation.

When growth rates were high no large accumulations of sugars were observed, although during this particular period most of the vegetative parts of the plants were formed. Sharp increases in all sugar concentrations were noted only when active stem elongation was near completion. Maximum concentrations of all sugars occurred at or near heading. It would seem that in the early periods of the season demands of growth processes utilized most of the available assimilate and that only after full growth was nearly attained was there a surplus of photosynthate produced for purposes of storage.

Sucrose, always the dominant sugar, rose and fell with the other sugars and there appeared to be no evidence that the rise in one was associated with the fall in another. Any changes in ratios were apparently due to a relatively faster increase or decrease of one or the other. Concentrations in all sugars rapidly declined soon after heading until at harvest only small amounts remained.

The conclusions reached by Archbold (5), Archbold and Datta (7), and Archbold and Mukerjee (8) emphasize the point that sugar storage is the result of a simple balance of supply over demand. The observations and results of this investigation support this view.

The seasonal drifts in the concentrations of all sugars, as observed in this work, are in general similar to those reported, but some differences were apparent.

The observed amounts of fructosans were lower, while the estimations of sucrose were higher, except for Barnell's (9) (10) values for wheat. The proportion of fructosans to total sugar at the time the maximum concentrations were noted was 35%, as compared with reported values as high as 60% (4). Free reducing sugar exceeded fructosan concentrations. The presence of fructosans in leaves was not clearly demonstrated.

The drifts of sugar concentrations in each plant component were similar to those observed in whole plants, but had different time relations. As nearly as could be determined the maximum concentrations of sugars occurred in the following time order: leaves, sheaths, stems, and heads. During the period considered, the stems were found to contain approximately 50% of the sugars found in the plants; heads 25%; and sheaths and leaves the remainder. The most apparent decreases in sugars during ripening of the plants occurred in heads and stems, but near the end of the season large losses from all parts were evident.

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Losses of sugars from the stems, sheaths, and leaves were related to senescent changes in these parts. Fructosan concentrations were greatest in the stems and young heads and account for most of the fructosan in the plant. Amounts of fructosans in all parts of the plant were lower than those recently reported by others (4).

The attempts to obtain quantitative evidence with respect to overnight losses in sugars were not very successful, largely because conditions were extremely variable. The few real differences obtained indicated that free fructose and possibly fructosans were affected. The values obtained for the other sugars were so inconsistent that no conclusions were possible. No reference to diurnal changes in fructosan in growing plants was found in the literature, but the results of an investigation on sugar concentration variations in alfalfa as related to time of day, reported by Curtis (11), indicated that large overnight losses were possible. On the average, afternoon cuttings were 83% higher in carbohydrate and 19% higher in dry matter yield than were the morning cuttings.

The dried material contained considerably less sugar than did the corresponding samples of green material. The observed loss of between 25 and 45% was found to fall on the free glucose and the sucrose fractions. Fructosan losses were larger in younger than in older plants, although the all-over decreases noted on drying were less than for sucrose

losses of sugar from the stems, leaves, and leaves
were related to a significant change in sugar content. The
concentrations were greatest in the stems and young leaves and
decreased for most of the tissues in the plant. Amounts of
fructose in all parts of the plant were lower than those
recently reported by Curtis (2).

The effects of certain environmental stresses on
response to waterlogging stress in sugarbeets were not very consistent.
Results because of the large variability. The
total differences between the two tissues and
possibly fructose were not significant. The values obtained for
the other sugar were not significantly different from each other and
possible. In reference to similar changes in fructose in
growing plants was found in the literature, but the results
of an investigation on sugarbeet variations in
plants as related to time of day, reported by Curtis (2),
indicated that large variations found were possible. On the
average, fructose contents were not higher in sugarbeets
and 1% higher in the stems than in the normal
plants.

The effect of certain environmental stresses on
the effect of the environmental stresses of green stress. The
observed loss of sugar in the stems and leaves of the
fructose and the sugarbeets. The results were
were larger in younger than in older plants. The
all-over fructose content of the stems was not significantly

or free glucose. Decreases in reducing sugars were not evident in plants which originally contained high concentrations of sucrose. The possibility of sucrose inversion to free reducing sugars was suggested.

This preliminary survey of some of the quantitative variations in fructosan accumulation in barley indicates that, under normal conditions of growth, there is an increase of fructosan in the whole plant, at least until stem elongation is complete. Subsequently the amount falls as the total sugar declines and the grain ripens. It was evident that the accumulation of fructosans did not occur until conditions which promote sugar storage were present. The ultimate maximum level of fructosan was associated with the concentrations of the other sugars, while the increase with time was due to increasing sugar content. On the basis of these observations and from the conclusions reached by Archbold et al, it became clear that fructosans only accumulate under conditions which promote sugar storage. Furthermore, sufficient evidence has now been obtained to reveal the fact that the accumulation and fate of stored sugar, including fructosans, is not the result of simple, easily understood physiological processes or the result of any one environmental factor, but rather a complex, interrelated combination of all the many factors which modify and determine the normal growth of plants.

Therefore, for the present and in the absence of much more detailed and precise information, it can be stated

or free glucose. Because it is known that some of the
in plants which originally contained high concentrations of
sugars. The possibility of a more extensive study of the
the subject was suggested.

This preliminary survey of some of the possibilities
variations in the amount of sugar in the leaves of
under certain conditions of growth, there is an increase in
the amount in the whole plant, at least until some maximum
is reached. Subsequently the amount falls as the plant
develops and the grain ripens. It was evident that the
relation of the amount of sugar in the leaves to the
amount of sugar in the grain was present. The ultimate maximum level
of sugar was associated with the ripeness of the
other sugar, while the leaves with time was due to the
the sugar content. On the basis of these observations and
from the conclusions reached by Stromberg et al., it became
clear that the amount of sugar in the leaves was not
entirely a function of the amount of sugar in the grain.
has been shown to be true that the amount of
sugar in the leaves is not a function of the amount of
sugar in the grain, but that the amount of sugar in the
leaves is a function of the amount of sugar in the leaves.
of the leaves in any one experimental test. One reason
might be, in addition to the amount of sugar in the leaves,
which might also determine the amount of sugar in the
leaves. For the present and in the future of
most more detailed and precise information, it can be stated

that the possibility of a successful fructose industry using raw fructosans from barley is slight. The only assurance that may be offered is that the actual yield of fructosans from barley grown under normal field conditions will be extremely variable and difficult to predict.

Attempts to breed a high-fructosan barley would be premature in the face of present knowledge of the large and profound effect of the many factors, both environmental and physiological, on fructosan storage.

Some indication of what remains to be done before our knowledge of fructosan formation is complete is revealed in the following quotation taken from Archbold (4): "Only when it can be stated with certainty under which circumstances glucose and fructose are interconvertible in plants, and when some knowledge has been acquired of the mechanisms involved both in such conversions and in polymerization, will real progress in our views on fructosan formation be possible."

In the opinion of the writer, more information and precise results from this study would be obtained if some of the following modifications were adopted:

1. Samples for analysis should be based on a known number of plants and results reported on the quantity of sugar and dry matter per plant.
2. Since the variation in sugar content with time is great, analysis should be made more frequently than once a week.

that the possibility of a secondary transfer is not ruled out. The only evidence that can be offered is that the actual yield of the secondary transfer is not as high as the yield of the primary transfer. This is not a satisfactory explanation, but it is the only one that can be offered at present.

It is not possible to give a definite answer to the question of the effect of the secondary transfer on the yield of the primary transfer. The only evidence that can be offered is that the actual yield of the secondary transfer is not as high as the yield of the primary transfer. This is not a satisfactory explanation, but it is the only one that can be offered at present.

It is not possible to give a definite answer to the question of the effect of the secondary transfer on the yield of the primary transfer. The only evidence that can be offered is that the actual yield of the secondary transfer is not as high as the yield of the primary transfer. This is not a satisfactory explanation, but it is the only one that can be offered at present.

1. The first question is whether the secondary transfer is a significant factor in the yield of the primary transfer. The answer is that it is not a significant factor in the yield of the primary transfer.
2. The second question is whether the secondary transfer is a significant factor in the yield of the secondary transfer. The answer is that it is not a significant factor in the yield of the secondary transfer.

3. Dry matter content and sugar concentrations based on the percentage of green or fresh weight are difficult to estimate with any degree of precision if free water adhering to plants is not rapidly and completely removed. At present no means of removing such water completely are known, but the use of blotters has been suggested.

4. The period selected in this investigation for estimations of "overnight" changes in sugar, water, and dry matter was very unsatisfactory as varying hours of sunlight were included. Plants for the estimations of the effect of daylight should be selected near sun-down. Plants selected for the "morning" collection should be covered the evening previous or collected soon after sunrise.

Finally, the following points should be borne in mind in any future work on the problem of carbohydrate storage in plants:

1. The techniques for analysis of sugar in plants, now generally in use, while greatly improved over those formerly employed, require further refinement. More information as to sources of the glucose that are at present undefined is required before a completely satisfactory technique for estimation of sucrose and fructosan can be devised.

2. The large losses of sugars observed during ripening or drying of plants require explanation. The suggestion that

3. Dry matter content and water concentrations were
on the average of 10% and 90% respectively and did not
vary with any factor of position in the water column.
No change in color, clarity and composition was
observed in the water column and water samples were taken, but the
use of filters was not suggested.

4. The results obtained in this investigation for each
factor of "waterbody" change in water, water, and dry
matter was very satisfactory as the water body of analysis
was limited. Since the water column of the lake of
analysis should be selected near the shore. These results
for the "waterbody" collection should be covered and covering
stations or collection soon after sunrise.

5. Finally, the following points should be noted in

view of any future work on the problem of waterbody
analysis in lakes:

1. The techniques for analysis of water in lakes, as
described in this report, while useful, are not
satisfactory. Further refinement, and improvement in
technique of the kind of water at present mentioned in
this report before a satisfactory technique for water-
body analysis can be devised.

2. The data obtained in water analysis for water
analysis of lakes require explanation. The water body

these and overnight losses are related to respiration has been advanced but is by no means conclusive.

3. Recent observations made by Archbold and Datta (7), Gregory (12), and Richards (16) on carbohydrate storage and utilization indicate that nitrogen compounds are involved. The study of the interrelations of these two groups of compounds appears timely.

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Financial assistance was supplied by the National Research Council, Ottawa.

These and overlap losses are related to registration and
have occurred but is by no means conclusive.

3. Present observations made by Kennedy and Taylor (1957),
Greenough (1957), and Dickson (1957) on vertebrate behavior and
utilization indicate that certain components are involved.
The results of the investigation of these two groups of com-
ponents appear clearly.

REFERENCES

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Financial assistance was supplied by the National
Research Council, Ottawa.

REFERENCES

1. ARCHBOLD, H.K. Ripening processes in the apple and the relation of time of gathering in the chemical changes in cold storage. *Ann. Bot.* 46:407-459. 1932.
2. _____ Physiological studies in plant nutrition: The role of fructosans in the carbohydrate metabolism of the barley plant. Materials used and method of sugar analysis employed. *Ann. Bot. N.S.* 2:183-202. 1938.
3. _____ Physiological studies in plant nutrition: The role of fructosans in the carbohydrate metabolism in the barley plant. *Ann. Bot. N.S.* 2:403-435. 1938.
4. _____ Fructosans in the monocotyledons: A review. *New Phytologist* 39:185-219. 1940.
5. _____ Physiological studies in plant nutrition: Experiments with barley on defoliation and shading of the ear in relation to sugar metabolism. *Ann. Bot. N.S.* 6:487-531. 1942.
6. _____ and BARTER, A.M. A fructose anhydride from the leaves of the barley plant. *Biochem. Jour.* 29: 2689. 1935.
7. _____ and DATTA, C. Sugar metabolism in the barley stem in relation to ear development. *Ann. Bot. N.S.* 8(32):363-384. 1944.
8. _____ and MUKERJEE, B.N. Physiological studies in plant nutrition: Carbohydrate changes in the several organs of the barley plant during growth, with special reference to the development and ripening of the ear. *Ann. Bot. N.S.* 6:1-41. 1942.
9. BARNELL, H.R. Seasonal changes in the carbohydrates of the wheat plant. *New Phytologist* 35:229-266. 1936.
10. _____ Distribution of the carbohydrates between component parts of the wheat plant at various times of the season. *New Phytologist* 37:85-112. 1938.
11. CURTIS, O.T. The food content of forage crops as influenced by the time of day at which they are cut. *Jour. Am. Soc. Agron.* 36:401. 1944.

CONTENTS

1. ASCHOFF, E. C. Algebraic properties of the algebra of
relations of time of feeding in the rabbit
changes in food intake. Ann. Bot. 48:407-423, 1955.
2. The role of transference in the carbohydrate metabolism
of the brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:423-433, 1955.
3. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:433-443, 1955.
4. Transference in the carbohydrate metabolism: a review.
New Phytologist 57:125-133, 1950.
5. Algebraic properties of the algebra of
relations of time of feeding in the rabbit
changes in food intake. Ann. Bot. 48:443-453, 1955.
6. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:453-463, 1955.
7. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:463-473, 1955.
8. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:473-483, 1955.
9. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:483-493, 1955.
10. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:493-503, 1955.
11. The role of transference in the carbohydrate metabolism
in the rabbit brain. Algebraic properties of the algebra of
sugar analysis employed. Ann. Bot. 48:503-513, 1955.

12. GREGORY, F.G. Mineral nutrition of plants. *Ann. Rev. Biochem.* 6:577. 1937.
13. HAWORTH, W.N., HIRST, E.L., and LYNE, R.R. A water-soluble polysaccharide from barley leaves. *Biochem. Jour.* 31:786. 1937.
14. NORMAN, G.A. The composition of forage crops. *Biochem. Jour.* 30:1354-1362. 1936.
15. REICH, W.S. Separation of glucose and fructose. *Biochem. Jour.* 33:1000. 1939.
16. RICHARDS, F.J. Physiological studies in plant nutrition: The relation of respiration rate to the carbohydrate and nitrogen metabolism of the barley leaf as determined by phosphorus and potassium supply. *Ann. Bot. N.S.* 2:491-534. 1938.
17. RUSSELL, R.S. The effect of mineral deficiency on the fructosan metabolism of the barley plant. *Ann. Bot. N.S.* 2:865-882. 1938.
18. SHAFFER, SOMOGYI. Copper-iodometric reagents for sugar determination. *Jour. Biol. Chem.* 100:695. 1933.
19. VAN DER PLANK, J.E. The estimation of sugars in the leaf of the mangold. *Biochem. Jour.* 30:457-483. 1936.
20. WILLARD, C.J. Afternoon vs. morning cutting of alfalfa. (Also notes by WOODWARD, T.E., SHEPHERD, J.B., TYSDALE, W.H. and CURTIS, O.T.). *Jour. Am. Soc. Agron.* 36:937-952. 1944.
21. YEMM, E.W. Methods for determination of carbohydrates in leaves. *Proc. Royal Soc. of London, Series B.* 117:483-504. 1935.

12. GIBSON, F.S. Mineral nutrition of plants. Ann. Rev. 1937. 1:1-15.
13. GIBSON, F.S., and LLOYD, J.S. A water-soluble polyacrylate from polyacrylate. Biochem. Jour. 1937. 31:173-177.
14. GIBSON, F.S. The composition of organic acids. Biochem. Jour. 1937. 31:173-177.
15. GIBSON, F.S. Separation of amino acids and proteins. Biochem. Jour. 1937. 31:173-177.
16. GIBSON, F.S. Physiological studies in plant nutrition: The relation of water-soluble acids to the development and nitrogen metabolism of the plant leaf as determined by phosphorus and potassium analysis. Ann. Bot. 1937. 41:1-15.
17. GIBSON, F.S. The effect of mineral nutrition on the nitrogen metabolism of the plant leaf. Ann. Bot. 1937. 41:1-15.
18. GIBSON, F.S. The effect of mineral nutrition on the nitrogen metabolism of the plant leaf. Ann. Bot. 1937. 41:1-15.
19. GIBSON, F.S. The effect of mineral nutrition on the nitrogen metabolism of the plant leaf. Ann. Bot. 1937. 41:1-15.
20. GIBSON, F.S. The effect of mineral nutrition on the nitrogen metabolism of the plant leaf. Ann. Bot. 1937. 41:1-15.
21. GIBSON, F.S. The effect of mineral nutrition on the nitrogen metabolism of the plant leaf. Ann. Bot. 1937. 41:1-15.