TABLE OF CONTENTS

Vol. 32, No. 1, August 15, 1957

Vol. 32, No. 2, November 15, 1957

Vol. 32, No. 3, February 15, 1958

Vol. 32, No. 4, May 15, 1958

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 1-18

NORTHERN PIKE, ESOX LUCIUS L., POPULATION OF CLEAR LAKE, IOWA[1]

Richard L. Ridenhour
Department of Zoology and Entomology
Iowa State College, Ames

ABSTRACT

Gill nets, fyke nets, wire traps and angling were used to collect 445 pike from 1941 through 1955 in Clear Lake and adjacent Ventura Marsh. Growth in the lake was about the same as in other waters but slower during the second year than in the marsh. Females appeared to grow faster than males during the second year. Condition of pike from the lake and the marsh was nearly identical when the stocked 1953 year class was excluded from the lake estimate. This abundant stocked group remained in poor condition. Angler tag returns, highest during the first year after stocking (9.6 - 33.5 per cent), were used to estimate harvest. Large catches in 1954 and 1955 (2.02 and 0.28 pike per acre, respectively) were probably the result of heavy stocking in 1953. Poor condition and handling possibly contributed to one of two mortalities particularly affecting stocked pike in the lake while high temperature probably was the cause of a mortality in the marsh.

INTRODUCTION

Clear Lake, located in north-central Iowa, is of the shallow eutrophic type (9). With an area of approximately 3600 acres and a maximum depth of approximately 20 feet there is no thermal stratification. The maximum length and width are approximately five and two miles, respectively. Rather extensive stands of *Scirpus* sp. are found along the shores in some areas and during certain years *Potamogeton* spp. are quite abundant in the shallower areas.

The northern pike is one of the principal predatory species of fish in Clear Lake and for this reason is an important factor in the predator-prey relationship of the lake. When over 15,000 fingerling northern pike were stocked into the lake during October, 1953, it appeared to be a particularly appropriate time to initiate study of the northern pike population.

Bailey and Harrison (1) considered the northern pike as "common" in Clear Lake and felt that the natural reproduction of this species was

[1]From Project No. 39 of the Iowa Cooperative Fisheries Research Unit, sponsored by the Iowa State Conservation Commission and the Industrial Science Research Institute of Iowa State College, with the cooperation of the Fish and Wildlife Service, U. S. Department of Interior.

adequate to maintain itself. However, in 1949, a control structure and carp trap was placed between the lake and adjacent Ventura Marsh, a 600-acre marsh area which had been the principal spawning area for northern pike (personal communication from K. M. Madden, Superintendent of Fisheries, Iowa State Conservation Commission).

MATERIALS AND METHODS

Collections of northern pike were made at Clear Lake by the Iowa Cooperative Fisheries Research Unit each year from 1941 to 1943 and from 1947 to 1955. The writer collected specimens in 1954 and 1955, and the earlier collections were by other graduate students in the Research Unit. Several types of gear were used to make these collections (Table 1). Fish were taken from all portions of the lake. Most of the collecting was done during the summer months, but fish were taken as early as April and as late as October.

Scales were taken from a position immediately posterior to the tip of the left pectoral fin. Total (T.L.), fork (F.L.) and standard lengths (S.L.)were measured in most cases and at least total length was always recorded. All lengths were measured to the nearest one-tenth of an inch except for those fish measured in 1941, 1943, 1949 and 1950 which were measured in millimeters. The latter measurements were converted to the nearest one-tenth of an inch. The weight of the fish was measured either in grams or pounds and ounces, but all weights were converted to the nearest one-hundredth of a pound for further computations. Weights were measured on spring platform balances.

Factors for converting one type of length measurement to another, computed from 390 pike, 8.0 - 37.6 inches total length, were as follows:

$$S.L. = 0.91\ F.L. = 0.86\ T.L.$$

The dry mount method (7) was used to prepare all scales in the Clear Lake and Ventura Marsh samples for projection. No indications as to the sex or size of the fish from which the scales were obtained were available at the time of reading. In this manner any bias which this knowledge might have introduced into the determination of age was removed.

The scales of 390 northern pike were examined for age determinations. Since most of the fish collected during the summers of 1954 and 1955 were from the 1953 year class, and, therefore, of a known age, the reading of most of the scales was relatively simple. However, annuli of fish over three years of age were difficult to distinguish and some unavoidable error probably occurred for those larger fish. Two or three readings, in some cases, did not help to clarify the true age of 29 fish. The first reading was accepted for those fish although it was possibly not the best. The scales from one fish were rejected as unusable.

Apparent crowding of circuli followed by a band of widely spaced circuli was considered the best evidence of an annulus. Anastomosis or crossing over of circuli in the posterior-lateral field of the scales was also looked for but it was often not evident. A break or check between circuli following an area of crowded circuli was the easiest and most consistent evidence of an annulus.

The specimens collected in April, May, and some in June failed to reveal an annulus at or near the edge of the scale. An annulus, representing the one to be formed during the year of capture, was considered to be at the edge of the scale, as suggested by Hile (5). Lengths of fish at the time of scale formation were computed by the Lee method (6) using 1.4 inches as the correction factor, a (derived from the body-scale relationship discussed later).

Table 1. Age class composition of northern pike taken by various gear from Clear Lake and Ventura Marsh, Iowa, from 1941 to 1955 and 1953 to 1955, respectively.

Location of Capture	Age Class	Type of Gear: Exp. Gill Nets*	Other Gill Nets	Fyke Net	Seines	Angling	Wire Trap	Found Dead	Total
Clear Lake	0	10			7				17
	I	32			11	1		1	49
	II	37	6	4	3	5			51
	III	43	16		2	5			66
	IV	11	6			1			18
	V	2	3						5
	VI							1	1
	Total	135	31	4	23	12	-	2	207
Ventura Marsh	0	14							14
	I	76		14			2		92
	II	65		7			3	1	76
	Total	155	-	21	-	-	5	1	182
Grand Total		290	31	25	23	12	5	3	389

*With equal lengths of the following mesh sizes, stretch measure: 1.5, 2.0, 2.5, 3.0, and 4.0 inches.

AGE AND GROWTH

A knowledge of the relationship between the body length and the scale radius was required for the determination of growth by the northern pike. An approximation of this relationship was obtained by calculating the regression of body length on scale radius:

$$L = a + bR$$

where

L = total length in inches
R = anterior scale radius X50 in inches
a = a constant

and

b = a constant.

For Clear Lake northern pike, based upon 208 fish:

L = 1.383 inches + 2.278R;
coefficient of correlation, r = 0.857

For Ventura Marsh northern pike, based upon 182 fish:

L = 2.757 inches + 1.969R;
r = 0.524

The difference between these regression coefficients, 2.278 and 1.969 for the lake and marsh respectively, was statistically significant at the 95 per cent level of confidence ($F = 4.33$ with 1 and 386 degrees of freedom). This difference may have been caused by a difference between the growth rates of the fish rather than in the growth of the scales. If the fish in the marsh were larger than those in the lake at the age when the scales began forming and if the scales then grew at the same rate for both the lake and the marsh fish, it would be reasonable to expect such a difference between the body-scale relationships as was computed.

For calculation of growth, the value of a in the regression formula determined from the Clear Lake fish, was used. It was felt that this expression most truly represented the body-scale relationship because most of the growth had probably taken place in Clear Lake proper, except for the 1953 year class.

Although some of the samples were rather small, northerns from each year class from 1936 through 1953 were collected except for the 1937 and 1941 year classes (Fig. 1). The 1953 year class was obviously a particularly abundant one. No northerns from the 1954 and 1955 year classes were found even though special efforts were made for their capture in those years. Growth rates for fish from various year classes were fairly consistent.

The growth of the Clear Lake pike (Table 2) is about average when compared to that reported for other lakes (3). The pike collected from Ventura Marsh (Table 3) apparently grew faster during their second year than those in the lake. The second year increments of the 1953 year class pike collected in Ventura Marsh were significantly larger than those of 1953 year class pike in Clear Lake which were stocked from the marsh when about one year old (Table 4).

The females appear to grow somewhat faster than the males (Table 5). The difference at the first annulus was not statistically significant at the 95 per cent level, but the difference in the second year increments was significant ($F = 5.16$ with 1 and 20 degrees of freedom).

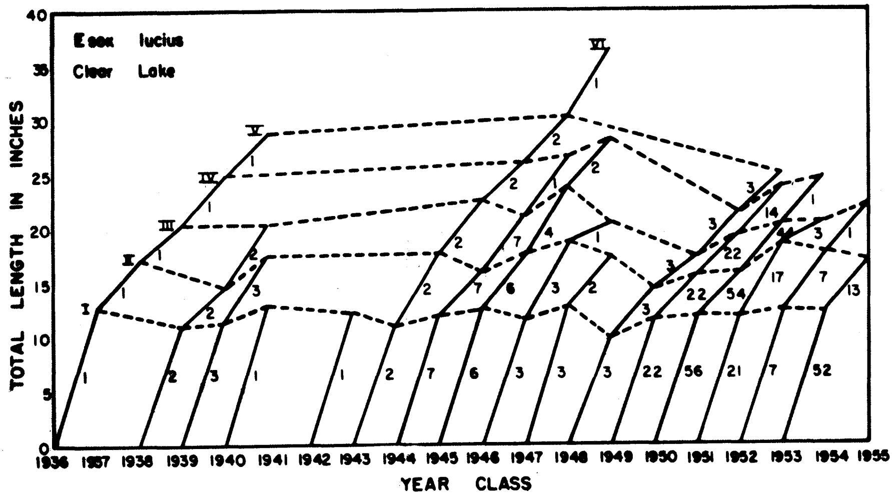


Fig. 1. Growth of Clear Lake northern pike by year classes.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION

It is sometimes desirable to estimate the weight of fish when only their lengths are known. The length-weight relationships for pike from Clear Lake and Ventura Marsh, respectively (Tables 6 and 7) can be expressed as follows:

$$\log W = -2.823 + 3.122 \log L$$

and $\log W = -2.335 + 2.744 \log L$

where $\log W$ = logarithm of weight in tenths of pounds

and $\log L$ = logarithm of total length in inches.

The regression coefficients, 3.122 for the lake and 2.744 for the marsh, were statistically different at the 99 per cent level of confidence (Table 8). This significant difference might be explained by the fact that fish from the marsh were in better shape or heavier for a given length during their first years of life than were fish from the lake which were of the same age. These latter fish were, to a large extent, stocked fish, and were in poor shape probably due to being stocked in large numbers into a strange habitat. The larger fish in the lake were in better shape than the smaller ones which had been stocked.

In many studies the length-weight regression has been fitted to the data averaged by length groups rather than to the individual measurements. For purposes of comparison, a regression was fitted to the means for the Clear Lake northern pike (Table 6):

$$\log W = -2.642 + 2.980 \log L.$$

Table 2. Average growth by age groups of Clear Lake northern pike, 1941-1955

Age Group	Sample Size	1	2	3	4	5	6	Length at Capture Mean	Length at Capture Range
0	17							12.1	8.0 - 15.9
I	48	12.8						15.7	13.1 - 21.5
II	52	12.0	17.5					20.3	15.5 - 25.7
III	66	11.8	16.0	20.4				22.5	17.8 - 27.8
IV	18	12.0	16.5	20.5	24.6			26.0	21.0 - 30.3
V	5	10.3	14.8	18.0	22.0	26.0		27.2	21.4 - 32.3
VI	1	12.7	21.8	27.4	30.8	33.6	36.3	37.6	--
Average Length		12.1	16.6	20.4	24.3	27.3	36.3		
Average Annual Increment		12.1	4.8	4.2	4.0	3.8	2.7		
Summation of Increments		12.1	16.9	21.1	25.1	28.9	31.6		

Table 3. Average growth by age groups of Ventura Marsh northern pike, 1953-1955

Age Group	Sample Size	Annuli 1	Annuli 2	Length at Capture Mean	Length at Capture Range
0	45			11.1	9.5 - 12.7
I	92	12.0		16.0	12.7 - 19.5
II	76	12.2	18.4	19.8	16.0 - 23.3
Average Length		12.1	18.4		
Average Annual Increment		12.1	6.2		
Summation of Increments		12.1	18.3		

Table 4. Analysis of variance of the second year increments by northern pike in Clear Lake and Ventura Marsh of the 1953 year class

	Basic Data			
Group	n	$\bar{x}$	SX	SX^2
Lake	13	4.35	56.5	259.41
Marsh	74	6.26	463.3	3031.63

	Analysis of Variance		
Source of variation	df	SS	MS
Between Areas	1	40.53	40.53
Among Deviates within Areas	85	144.85	1.70
Total	86	185.38	

F = 40.53/1.70 = 23.84

Table 5. Average growth of male and female northern pike of the 1953 year class in Ventura Marsh, 1953-1955

			Annuli		Length at
Age Group	Sex	Sample Size	1	2	Capture
I	M	29	11.8		16.1
	F	46	12.1		16.4
II	M	6	11.0	16.4	17.8
	F	16	12.9	19.6	21.0

Table 6. Mean and calculated weights in pounds and mean condition factors for Clear Lake northern pike, 1941-1955

No.	Mean total length	Weight in Pounds: Actual Range	Weight in Pounds: Actual Mean	Weight in Pounds: Calculated (1)	Weight in Pounds: Calculated (2)	Average Condition C(TL)	Average Condition K(SL)
1	8.0	-	0.10	0.10	0.11	19.5	0.72
2	10.9	0.36-0.38	0.37	0.26	0.28	28.6	1.05
7	11.4	0.25-0.45	0.35	0.30	0.32	23.5	0.86
6	12.4	0.30-0.46	0.42	0.39	0.41	21.8	0.80
8	13.6	0.44-0.52	0.46	0.52	0.54	18.4	0.68
12	14.6	0.40-0.67	0.57	0.65	0.67	18.0	0.66
11	15.3	0.55-0.89	0.67	0.75	0.77	18.7	0.69
6	16.4	0.69-1.06	0.88	0.93	0.95	19.8	0.73
10	17.5	0.77-1.37	1.10	1.14	1.15	20.5	0.75
8	18.4	1.06-1.62	1.36	1.34	1.34	22.0	0.81
18	19.5	1.19-2.19	1.74	1.60	1.59	23.5	0.86
12	20.5	1.56-2.13	1.88	1.87	1.85	21.8	0.80
20	21.4	2.00-3.00	2.38	2.14	2.10	24.4	0.90
15	22.3	2.13-3.00	2.57	2.44	2.37	23.1	0.85
11	23.3	1.94-3.25	2.81	2.79	2.71	22.2	0.82
15	24.5	2.75-4.00	3.28	3.27	3.14	22.4	0.82
6	25.5	3.37-5.13	3.81	3.70	3.54	23.0	0.85
2	26.4	4.13-4.19	4.16	4.12	3.93	22.7	0.84
9	27.5	3.25-5.37	4.46	4.68	4.43	21.5	0.79
3	28.3	4.75-5.50	5.04	5.12	4.83	22.3	0.82
2	29.4	5.13-5.31	5.22	5.77	5.41	20.6	0.76
2	30.2	5.06-6.13	5.60	6.28	5.86	20.4	0.75
1	32.3	-	6.81	7.74	7.16	20.2	0.74
1	37.6	-	9.94	12.44	11.26	18.7	0.69

(1) based on 178 pike: $\log W = -2.823 + 3.122 \log L$
(2) based on the means for each one inch length interval: $\log W = -2.642 + 2.980 \log L$

Condition factors* were computed for the individual fish from Clear Lake and Ventura Marsh and averaged for each one inch interval of total length in Tables 6 and 7 respectively. Since many workers have

*$C = W\,10^5/L^3$, where C = condition factor, W = weight in pounds, and L = total length in inches.

Table 7. Mean and calculated weights in pounds and mean condition factors for Ventura Marsh northern pike, 1953-1955

No.	Mean total length	Weight in Pounds		Calculated Weight (1)	Average Condition	
		Range	Mean		C(TL)	K(SL)(2)
5	9.8	0.20-0.25	0.23	0.24	24.3	0.89
14	10.4	0.24-0.32	0.29	0.29	25.3	0.93
18	11.4	0.30-0.53	0.38	0.37	25.5	0.94
9	12.4	0.39-0.57	0.47	0.46	24.4	0.90
7	13.4	0.27-0.59	0.51	0.57	21.3	0.78
9	14.7	0.66-0.88	0.76	0.74	23.9	0.88
22	15.5	0.74-1.07	0.92	0.85	24.4	0.90
33	16.3	0.62-1.25	1.03	0.98	23.5	0.87
29	17.3	0.98-1.50	1.17	1.15	22.4	0.82
14	18.6	1.25-1.56	1.38	1.41	21.2	0.78
25	19.4	1.25-1.69	1.49	1.58	20.3	0.75
15	20.3	1.44-2.25	1.84	1.79	21.1	0.78
12	21.5	1.44-2.50	2.16	2.10	21.2	0.78
5	22.3	2.31-2.88	2.49	2.32	22.3	0.82
2	23.2	-	3.06	2.58	24.7	0.91

(1) based on individual fish: $\log W = -2.335 + 2.744 \log L$
(2) using $K = C/27.204$ based on Clear Lake northern pike

used the symbol K for the condition factor based upon lengths and weights measured by the metric system, C's were converted to K's by the conversion formula given by Beckman (2), which becomes for these pike:

$$K = \frac{C}{27.204}$$

A comparison of the condition between the northerns from the 1953 year class, which were stocked into the lake from the marsh (mean C = 18.98 for 46 fish), with the condition of the northerns from the same year class remaining in the marsh (mean C = 22.91 for 219 fish) was statistically significant at the 99 per cent level of confidence (F = 47.26 with 1 and 263 degrees of freedom). However, the mean condition factor for all fish which were captured in the lake except the 1953 year class was only slightly different from the mean condition factor for all fish captured in the marsh (mean C = 22.89 for 137 lake fish and 22.93 for 221 marsh fish). These results indicate that stocking a large number of northern pike into Clear Lake had an adverse effect upon the condition of those fish during the first two years after stocking.

The condition of the Clear Lake northern pike was lower than that generally reported for northerns from other areas (3).

Table 8. Analysis of the difference between regression coefficients of the length-weight relationships computed for individual northern pike from Clear Lake and Ventura Marsh, 1941-1955 and 1953-1955, respectively

		Basic Data				
Group	n	S log L	S log L^2	S log W	S log W^2	S (log L)(log W)
Lake	188	242.080	314.133	225.056	293.778	297.337
Marsh	219	263.877	320.046	212.756	223.017	262.108

Analysis of Difference
(X = Log L and Y = Log W)

						Error of Estimate		
Group	df	Sx^2	Sxy	Sy^2	b	df	SS	MS
Lake	187	2.416	7.542	24.363	3.122	186	0.8157	
Marsh	218	2.097	5.755	16.327	2.744	217	0.5352	
					Total	403	1.3509	0.0034
Total	405	4.153	13.297	40.690		404	1.5113	
Difference for testing regression coefficient						1	0.1604	0.1604

F = 0.1604/0.0034 = 47.89

FOOD HABITS

Food of 10 Clear Lake northerns, age group 0 to IV (10.9-27.2 inches total length), was predominantly fish (Table 9). One crayfish was found in an age group II fish. The 1954 hatch of carp was utilized by the northerns in Ventura Marsh through the 1954 and 1955 growing seasons.

Black grubs were fairly common in Ventura Marsh pike and were also found on a few fish captured in the lake. Cestodes were found in the digestive tract of three northerns from Ventura Marsh and one from Clear Lake. A nematode was found in one northern pike from Ventura Marsh.

TAGGING STUDIES

Since 1952, 4,216 northern pike have been tagged in Clear Lake (Table 10). Over one-half of the northerns were tagged as young-of-the-year in Ventura Marsh in September and October, 1953, when experimental gill nets were used and when the same fish were removed by

Table 9. Stomach contents of northern pike collected in Clear Lake and Ventura Marsh, 1941-1955 and 1954-1955, respectively (number of stomachs in samples in parenthesis)

Stomach	Lake (10)		Marsh (121)	
Contents	Frequency	Per cent	Frequency	Per cent
Carp	1	10.0	58	47.9
Bluegill			2	1.7
Bullhead			1	0.8
Fish Remains	4	40.0	38**	31.4
Crayfish	1	10.0		
Plant tuber *			1	0.8
Empty	5	50.0	37	30.6

* probably incidental and not a food item.
** probably carp.

the State Conservation Commission for stocking into Clear Lake. Most of the northerns from Ventura Marsh were released at eight stations around Clear Lake and were found to distribute themselves over much of the lake (4).

Numbered monel metal strap tags were used; mostly size 3 (1 7/16 inches long by 1/8 of an inch wide) but a few size 18 (2 3/4 inches long by 1/4 of an inch wide) were also used. These tags were usually clamped around the premaxillae but a few large tags were placed on the mandibles.

Anglers were depended upon almost entirely for the recovery of tags. The Clear Lake Chamber of Commerce cooperated with the Research Unit by sponsoring a drawing of tag returns for prizes. It is believed that a high percentage of the tagged fish caught by anglers was reported (Table 11).

Most of the spring tagged fish to be reported were caught during the first fishing season following tagging, when an average of 19.2 per cent of the tags were returned as compared to 6.7 and 0.9 per cent during succeeding seasons. The 30.8 per cent return, during the following fishing season, of fish tagged in October, 1953, (not included in Table 11) was slightly lower than the 33.5 per cent return obtained for the fish tagged during the spring of 1954. This difference, though it was not statistically sigbificant, could have been caused by the mortality during the winter to which the fall tagged fish were exposed prior to the fishing season. A marked decrease in the per cent returns was exhibited by the northerns tagged during the spring of 1955 (9.6 per cent). This reduction might be attributed to the mortality occurring in May, 1955, which seemed to have acted particularly upon the fish handled during the spring of 1955 including those tagged at that time.

Table 10. Numbers of northern pike tagged on various dates in Clear Lake and Ventura Marsh, 1952-1955

Year	Clear Lake				Ventura Marsh		Total
	March	April	May	October	September	October	
1952		14	2				16
1953	33	135	35	2,134*	620	526	3,483
1954		167					167
1955		546	4				550
Total							4,216

*an additional 496 northern pike tagged in Ventura Marsh were transferred to Clear Lake.

Most of the tagged fish were caught early in the fishing season which started on May 15 during the years of tagging (Table 12). Untagged northern pike are also caught in larger numbers early in the fishing season. A more gradual return of tags from the group tagged in the fall of 1953 was noticed when they were compared with the returns from the spring-tagged fish and especially with the group tagged in the spring of 1954 which entered the fishery at the same time as the fall-tagged group.

The returns of the northerns tagged during the fall of 1953 were difficult to classify. Some of these fish were tagged in Ventura Marsh and later released into the lake. However, records of the transferred fish are not complete and 89 pike were later reported from the lake when they were supposed to have been still in the marsh and 3 pike were reported from the marsh whey they were supposed to have been in the lake. Ignoring these errors which actually somewhat compensate each other, the tag returns for the fall-tagged fish in the lake and marsh were respectively 30.76 and 1.54 per cent during 1954. The much lower return for the marsh was expected since very little fishing pressure was applied there. Some fishing was done in the marsh during the fall and winter of 1953 resulting in a reported catch of six tagged northerns.

During the summer of 1954, the ratio of tagged to untagged northerns in the angler's catch observed by the Research Unit biologists was 39 to 291. Also during 1954, 988 tags from northerns were returned to the Clear Lake Chamber of Commerce. Therefore, an estimate of the total catch would be:

$$\frac{291 \text{ X } 988}{39} = 7,372 \text{ northern pike.}$$

Errors in this estimate might arise from the fact that all tags probably were not returned when recovered by anglers and the ratio of tagged to untagged northerns was not constant throughout the summer. During the

Table 11. Tag returns by anglers for spring tagged northern pike in Clear Lake, Iowa, 1952-1955

Date tagged	Number tagged	1st Year		2nd Year		3rd Year		Total	
		No.	%	No.	%	No.	%	No.	%
1952	16	3	18.7	1	6.2	1	6.2	5	31.2
1953	203	68	33.5	24	11.8	1	0.5	93	45.8
1954	167	56	33.5	1	0.6			57	34.1
1955	550	53	9.6					53	9.6
Total	936	180	19.2	26	6.7	2	0.9		

first two days of the fishing season, May 15 and 16, 1954, the ratio of tagged to untagged northerns was 23 to 147 while from June 19 to September 1 the ratio was 16 to 144. This difference was probably due to differential mortality acting upon the tagged fish.

From May 15 to September 5, 1955, the ratio of tagged to untagged northerns in the creel census was 17 to 128 and the total angler tag returns for northern pike was 119. A catch estimate based upon these data was as follows:

$$\frac{145 \text{ X } 119}{17} = 1,015 \text{ northern pike.}$$

A differential mortality acting against the tagged northern pike probably occurred this summer which affected the estimate. Even so, the 1955 harvest was noticeably smaller than that in 1954.

The harvest was undoubtedly higher in 1953, 1954, and 1955 than in previous years because of the abundance of the 1952 and 1953 year classes. The particularly high harvest in the early part of the 1954 season was probably the result of the heavy stocking of northerns from the marsh the previous fall.

OBSERVED MORTALITIES

Unusually heavy natural mortalities of northern pike were noted in Clear Lake on two occasions and in Ventura Marsh once. The first mortality occurred during the summer of 1954. The largest numbers of dead northerns appeared along shore in August. Two of the dead northerns which were checked had been tagged and stocked into the lake in October, 1953. Most of the dead fish seemed to be from the stocked 1953 year class as judged by their size. The poor condition and growth exhibited by the 1953 year class in the lake, discussed earlier in this paper, might have been correlated with this mortality though no definite conclusions could be made.

Table 12. Numbers of tagged northern pike caught during each month of the first summer in which the tagged fish were exposed to the fishery

Date tagged	May	June	July	August	September	Total
1952	1	1	1			3
1953						
Spring	45	18	2	2	1	68
Fall	355	205	122	49	23	754
1954	31	8	9	8		56
1955	40	12	1			53
Total	472	244	135	59	24	934
Percentage	50.5	26.1	14.5	6.3	2.6	100.0

Another extensive mortality occurred in May, 1955, and lasted for about four weeks. This mortality seemed to be more severe than the mortality of 1954. Two shoreline checks, made after the mortality had been in progress two weeks, from the State Fish Hatchery to McIntosh Woods State Park, May 13, and in Clausen's Cove, May 14, yielded 42 dead northern pike of which 11 were tagged and 2 possibly had been tagged. An additional 7 dead tagged northerns were reported by various individuals. All the tagged fish found dead had been handled about a month earlier in the carp trap. Since most of the fish handled at the carp trap appeared to be from the stocked 1953 year class which was known to be in poor condition, condition may have been a factor. Handling of northerns at the carp trap in previous years was not known to have resulted in any mortality. Two large females were found egg bound and this was probably the cause of death in these two cases.

Since the counts were made after about one-half of the mortality had occurred, an estimate of the magnitude of the kill could be made. A total of 42 northern pike were found in the two shoreline checks and represented about one-half the dead fish which should have appeared in those areas during the entire period of the mortality. The shoreline represented in the checks was about one-third of the total shoreline. These data provided an estimate of the total mortality during the one month:

$$42 \times 2 \times 3 = 252 \text{ northern pike.}$$

It must be assumed, in conjunction with this estimate, that the dead northern pike were distributed randomly around the entire shoreline. This assumption was probably quite well met since winds observed during the period of the kill were highly variable. An assumption that all dead fish became deposited upon the shoreline must also be made although it was not fulfilled since some of the fish undoubtedly were eaten, sank, or otherwise were kept from reaching or remaining on shore.

Another estimate could be made from the change in the percentage of the angler tag returns for the northern pike tagged during the spring of 1955 and the expected percentage based upon the returns for the previous three years (32.9 per cent). The return obtained during the summer of 1955 was 9.64 per cent which was 23.26 per cent below the expected return. Since all of the tagged fish found dead were handled at the trap during the spring of 1955, it might be assumed that the mortality only affected the handled northern pike (1,260) and an estimate might be based upon those fish:

$$1,260 \times 0.2326 = 293 \text{ northern pike.}$$

This estimate assumes that no factors other than this mortality affected the change in per cent tag returns by anglers and that the mortality affected only the fish handled during the spring of 1955. The first assumption could not be proved one way or the other, but good evidence, as mentioned above, supports the second assumption.

Both of the above estimates must be considered as minimal. In the first case all of the dead fish probably did not drift to shore, and therefore would not have been included in the counts. The second estimate was only an estimate of the kill of northerns handled during the spring of 1955 and did not include any other fish which might have been affected. Of interest was the similarity of the two estimates.

A very noticeable mortality of northern pike in Ventura Marsh started in the latter part of July, 1955. The first signs of distress by the fish in the marsh were observed on July 19 and the last dead northerns were found on August 7.

Temperature readings were taken and oxygen content was determined on July 25, August 1, 7, and 8. The maximum bottom and surface temperatures recorded were 89° and 96°F, respectively, on August 1. Temperatures in an inlet seemed to correspond closely with those in the marsh. The oxygen content was apparently at no time too low for fish survival. During the entire period air temperatures were abnormally high (around 100°F) and there was very little wind.

Two northern pike were captured while still alive though near death and were sent to the Iowa State College Veterinary Diagnostic Laboratory. The only evidence of disorder in these fish was a prominent hemorrhagic enteritis involving the posterior two or three inches of the intestine. Bacteria cultures were negative except for the area of the inflammation where species of Paracolon and Corynebacterium were found (report from Dr. Paul Bennett). The significance of the bacteria or the inflammation was not determined. Specimens taken after the mortality had ended did not show this hemorrhagic condition.

No definite conclusions could be made concerning the cause of this mortality. High temperature probably was a contributing factor that led to the actual death though it might not have been the direct cause. Fish kills also were reported from many other shallow lakes and streams at this time.

Table 13. Numbers of northern pike stocked in Clear Lake and Ventura Marsh*

	Year Stocked				
	1951	1952	1953	1954	1955
Clear Lake					
Fry			50,000	910,500	460,000
Fingerlings	5,822	5,499	18,080		
Adults			100	41	
Ventura Marsh					
Fry			2,250,000	1,220,000	1,700,000
Adults	250	250	250	250	250

*Data supplied by Mr. Ken Madden, Superintendent of Fisheries, Iowa State Conservation Commission.

Too few tags or other marks were found to make any estimate of the magnitude of the mortality. Large numbers of dead northerns probably were missed in the counts since many turtles were present in the marsh and they were observed feeding upon the dead northerns. High temperatures also would have been conducive to rapid decomposition. Two sections of experimental gill net, set within the marsh on August 29, approximately three weeks after the mortality, captured three northerns as compared to 44 and 23 caught by comparable sets made earlier in the summer. The differences in catch might have been due to differences in activity of the fish rather than reduced abundance.

PROPAGATION

Prior to the establishment of the carp trap in 1949, reproduction of Clear Lake northern pike was natural in Ventura Marsh and no definite policy concerning management of northern pike in either the lake or the marsh had been established. Since 1949, brood stock has been placed into the marsh and fingerlings were allowed to pass through the carp trap into the lake in 1951, 1952, and 1953. Various sized northerns obtained from the marsh and the Clear Lake Fish Hatchery were also stocked (Table 13).

The first year that fry were stocked and reared in Ventura Marsh, 1953, 18,080 fingerling northern pike were taken from the marsh and placed into the lake. It was thought that any northerns left in the marsh would be lost by winter kill but this was not the case as that group of northerns was well represented in the marsh until at least July, 1955. No young northerns were found in the marsh in 1954 or 1955. One young-of-the-year northern pike from the 1954 year class was collected in Clear Lake and it was the only evidence of reproduction in Clear Lake from 1952 through 1955.

SUMMARY

1. Gill nets, fyke nets, seines, wire traps, and angling were used to collect 445 northern pike in Clear Lake and Ventura Marsh from 1941 through 1955.

2. The body-scale relationship for 208 Clear Lake northern pike may be expressed as:

$$L = 1.383 \text{ inches} + 2.278R$$

and for 182 Ventura Marsh northern pike as:

$$L = 2.757 \text{ inches} + 1.969R.$$

3. Clear Lake northern pike grew at about the same rate as reported for other waters. Growth in Ventura Marsh was a little faster in the second year than in the lake. Female northern pike apparently grow faster than males, at least during the second year of life.

4. The length-weight relationship of 188 northern pike from Clear Lake may be expressed as:

$$\log W = -2.823 + 3.122 \log L$$

and of 219 northern pike from Ventura Marsh as:

$$\log W = -2.335 + 2.744 \log L.$$

5. Total length may be expressed as 1.16 of the standard length or 1.06 of the fork length.

6. The average _C_ factor for all northern pike collected in Clear Lake except the 1953 year class was 22.89 and for all northern pike collected in Ventura Marsh was 22.93. The condition of the stocked northern pike was significantly less than for the same age group in Ventura Marsh.

7. Carp was the main food item of northern pike in Ventura Marsh.

8. A total of 4,216 northern pike have been tagged in Clear Lake from 1952 through 1955 and 1,153 of those tags had been returned by anglers by August 25, 1955. Returns during the first year after tagging varied from 9.6 to 33.5 per cent.

9. An estimated 7,372 and 1,015 northern pike were caught by anglers in Clear Lake during 1954 and 1955.

10. In August 1954 and May 1955 numbers of dead northern pike, largely the 1953 year class, were found along the shore of Clear Lake. Poor condition and handling might have contributed to the 1955 mortality. A heavy mortality affecting the northern pike of Ventura Marsh in 1955 was attributed mainly to high temperatures.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to the Iowa Cooperative Fisheries Research Unit and the cooperating agencies for the use of their facilities and their financial aid. Appreciation is also expressed to Dr. Kenneth D. Carlander, Department of Zoology and Entomology, and to Charles J. Di Costanzo, who was an aid and companion in the field. Thanks are also extended to James Gilruth and the Clear Lake Chamber of Commerce, to Ken Madden, Muhrl Lindquist, Robert Cooper and the late Jack Stevens, of the State Conservation Commission, and to the anglers who cooperated in reporting tagged fish.

LITERATURE CITED

1. Bailey, Reeve M. and Harry M. Harrison, Jr. 1945. The fishes of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 20:57-77.
2. Beckman, William C. 1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Amer. Fish. Soc. 75(1945):237-256.
3. Carlander, Kenneth D. 1953. Handbook of Freshwater Fishery Biology with the First Supplement. Dubuque, Iowa. Wm. C. Brown Co.
4. _____ and Richard Ridenhour. 1955. Dispersal of stocked northern pike in Clear Lake, Iowa. Progr. Fish-Culturist 17:186-189.
5. Hile, Ralph. 1948. Standardization of methods of expressing lengths and weights of fish. Trans. Amer. Fish. Soc. 75(1945):157-164.
6. Lagler, Karl F. 1952. Freshwater Fishery Biology. Dubuque, Iowa. Wm. C. Brown Co.
7. Lewis, William M. and Kenneth D. Carlander. 1949. A simple method of mounting scales. Progr. Fish-Culturist 11:263.
8. Moen, Tom and Muhrl Lindquist. 1954. The northern pike hatch at the Clear Lake (Iowa) hatchery. Progr. Fish-Culturist 16:89-90.
9. Pearcy, William G. 1952. Some limnological features of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 28:189-207.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 19-34

GROWTH OF BLUEGILL, LEPOMIS MACROCHIRUS, AND PUMPKINSEED, L. GIBBOSUS, OF CLEAR LAKE, IOWA[1]

Charles J. Di Costanzo

Department of Zoology and Entomology
Iowa State College, Ames

Abstract

Age and growth determinations were made from scales of 1,215 bluegill and 336 pumpkinseed collected from 1947-54. Both species grew more rapidly in Clear Lake than in most midwest waters. Male bluegill of age groups II and III were larger than females of corresponding ages. Exceptionally strong year classes of bluegill and pumpkinseed originated in 1951, and very weak year classes in 1949. Strong bluegill year classes occurred in 1946 and 1952. Fluctuations in abundance of both species appear to be closely associated with changes in density of aquatic vegetation. Bluegill weight increased as the 3.45 power of the standard length; that of pumpkinseed, as the 3.19 power.

The Iowa Cooperative Fisheries Unit initiated long-term investigations of fish populations in Clear Lake, Iowa, in 1941. Except for the period 1944-46, data have been collected each summer up to the present date. Particular emphasis has been placed on assessment of age and growth characteristics of the principal fishes, changes in relative abundance, distribution and movements, success of natural reproduction, effect of stocking, estimates of population size, and measurement of environmental factors.

The present paper is concerned with age and growth of the bluegill and pumpkinseed. Of the two, only bluegill are taken in significant numbers by anglers. They comprised approximately 3.3 per cent of the total number of fish caught during the months of July and August, 1953 (Di Costanzo, 1953). Bluegill increased to 12.7 and 16 per cent of the total angler's catch in the summer fishing seasons of 1954 and 1955, respectively (unpublished data). The increased catch in later years was due largely to very unsuccessful year classes in 1951 and 1952.

It is unlikely that either the bluegill or pumpkinseed of Clear Lake will require specific management. However, it is hoped that through

[1]From Project 39 of the Iowa Cooperative Fisheries Research Unit, Sponsored by the Industrial Science Research Institute, Iowa State College and the Iowa State Conservation Commission, in cooperation with the United States Fish and Wildlife Service. The Sport Fishing Institute also provided an annual grant to assist in this project.

long-range analysis of growth trends for all important species, fluctuation in numbers, feeding habits, and related studies something can be learned about the intra- and interspecific and environmental relationships that affect the production of fishes.

Methods and Materials

Age and growth determinations were made for 1215 bluegill and 336 pumpkinseed taken at various locations on the lake from 1947 through 1954. With the exception of fifty bluegill collected on April 10, 1954, most specimens were obtained during the summer months of each year—the latter half of June through August. Samples were taken by a variety of methods which included: experimental gill nets; fyke nets; common sense minnow seines; 30-foot bag seines (1/4-inch bar-mesh bag, 1/2-inch bar-mesh wings); 500-foot seines (1/4-inch bar-mesh); an otter trawl; wire traps; and angling. Each experimental gill net was 125 by 6 feet and consisted of five 25-foot sections of the following mesh sizes: 3/4; 1; 1 1/4; 1 1/2; and 2 inches bar measure.

The scale method was employed in assessing age and growth characteristics. Length measurements (standard, fork, and total) were made to the nearest one-tenth inch for all fish except those in the 1949 collection, which were measured to the nearest millimeter. Weights were obtained to the nearest gram.

Unless specified otherwise all lengths referred to herein are total lengths in inches as measured from the tip of the snout to the compressed lobes of the caudal fin. Factors for converting from total to standard and fork lengths have been computed to permit ready comparison of observations in this paper with those of other studies. The data were originally grouped into 10 millimeter class intervals of standard length and conversion factors determined for each group separately. While the ratios varied somewhat among the different groups, there was no tendency for the ratios to either increase or decrease with change in size for either species.

Hence, for the bluegill in the length range 2 to 10.5 inches conversion factors as determined from 950 fish were as follows:

Standard length = 0.7831 total lengths
Fork length = 0.9558 total lengths
Standard length = 0.8203 fork lengths

Conversion factors for the pumpkinseed were determined from 150 fish ranging in length from 1.5 to 6.5 inches and are as follows:

Standard length = 0.8022 total lengths
Fork length = 0.9572 total lengths
Standard length = 0.8381 fork lengths

For the calculation of past growth the Frazer modification of the direct proportion method was used (see Rounsefell and Everhart, 1953, pp. 323-324). Use of this procedure involves the assumption of a linear relationship between body length and scale radius or diameter. When mean body lengths were plotted against scale radii it became quite obvious that the body-scale relationship for either species could be more precisely expressed by third degree polynomials (Fig. 1). Creaser's (1926) data suggest a somewhat similar sigmoid relationship. Departures from linearity, however, were slight for both species; hence, correction factors (intercept of regression line with body-length axis) for use with the direct proportion technique were obtained by fitting straight lines to the modified data (see below) by the least squares method.

Since the residuals of body lengths on scale radii were not independently distributed, it was thought that the least squares method when applied to all of the data would result in estimates of the body-length intercept that would be too large or too small. This result could be expected whenever the bulk of the data is concentrated on any one part of the sigmoid curve.

Straight lines were fitted to the data for each species in turn by computing the regression of body lengths on scale radius in two ways: first, by treating the measurements on each fish as a pair of observations; and second, by deriving mean body lengths for each scale radius and fitting a straight line to the new set of points. With respect to the pumpkinseed, both methods resulted in correction factors that differed only slightly (1.09 as against 1.16 inches). The mathematical expressions were as follows:

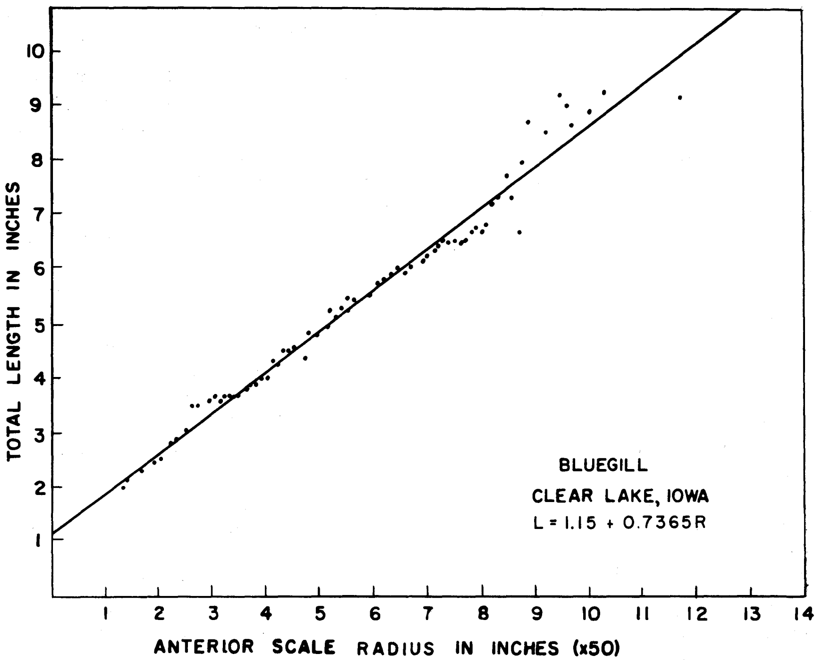
$L = 1.09 + 0.6732R$ (based on individual measurements) .
and $L = 1.16 + 0.6577R$ (based on mean body lengths)
where L = body length
and R = anterior scale radius (x50).

For the bluegill the two procedures resulted in the following relationships:

$L = 1.53 + 0.6795R$ (based on individual measurements)
and $L = 1.15 + 0.7365R$ (based on mean body lengths).

Note that the correction factors in the case of the bluegill differ markedly. Clearly, all scale sizes within the range of the data were not as well represented in the bluegill as in the pumpkinseed data. The bulk of the data, as might be expected, fell within the mid-range of the scale values, where the slope of the sigmoid curve has its lowest value. Consequently, correction factors derived from the regression of mean body length on scale radius were used since this procedure allows the fewer observations at the extremes of the range to carry equal weight.

To facilitate computations, growth of each individual was assessed by means of an alignment chart or nomograph(see Carlander and Smith, 1944).



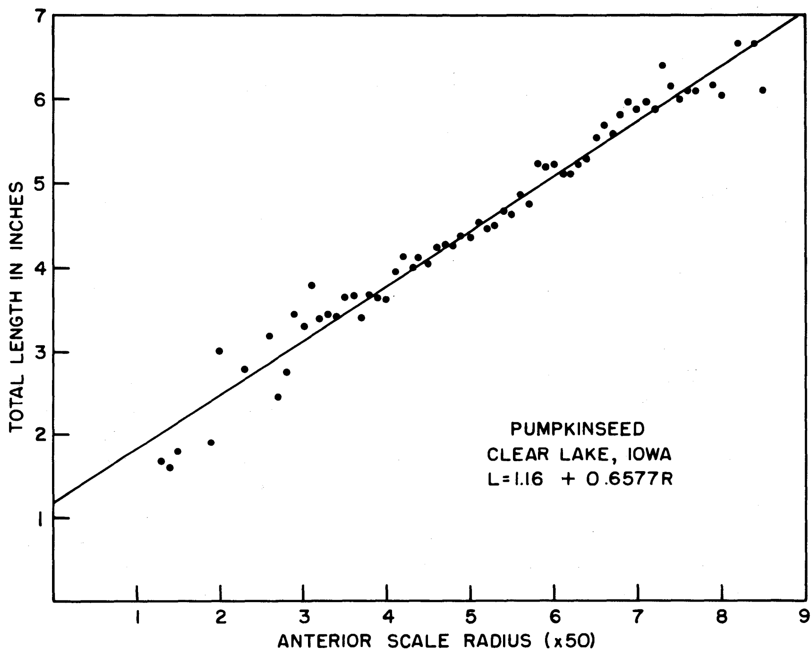


Fig. 1. Body-scale relationships of bluegill and pumpkinseed of Clear Lake, Iowa.

Age and Growth of the Bluegill

Data from all collections, excepting one sample (50 fish) taken in the spring of 1954, were used in calculating average growth of the bluegill (Table 1). Mean total length in inches attained by Clear Lake bluegill from the first to the sixth annulus, as indicated by grand average calculated lengths, are as follows: 2.39; 4.24; 5.60; 6.24; 7.82; 8.17 inches. The average annual increment in length is greatest in the first year of life, while the greatest increment in weight is attained in the fifth year of life.

Table 1. Calculated growth in inches of Clear Lake bluegill by age groups, 1947-1954

Age group	Number examined	Mean total length at annulus 1	2	3	4	5	6	Average length at capture
I	343	2.36						4.08
II	326	2.59	4.54					5.79
III	438	2.30	4.09	5.66				6.30
IV	47	2.13	3.68	5.09	6.08			6.60
V	9	2.35	3.88	5.52	7.00	7.98		8.43
VI	3	2.30	3.87	5.47	6.43	7.33	8.17	8.47

Grand averages, 1166 fish

	1	2	3	4	5	6
Mean total length	2.39	4.24	5.60	6.24	7.82	8.17
Ave. annual increment	2.39	1.83	1.55	1.07	0.96	0.84
Summed increments	2.39	4.22	5.77	6.84	7.84	8.64
Standard length (mm)*	48	84	111	124	156	163
Calculated wt. (gms)**	3.1	21.3	55.6	81.3	189	209
Annual increment in wt.	3.1	18.3	37.2	38.5	85.6	66.5

* Standard length in mm = 19.9 total lengths in inches.

** Log W = -5.3046 + 3.4468 Log L.

Certain apparent inconsistencies in Table 1 should perhaps be pointed out. Note that the average length at capture of age group II fish is greater than average calculated lengths at the third annulus for fish in age groups III to VI. Also, the average length at capture of age group III fish exceeds the calculated averages for the fourth annulus in age groups IV and VI.

These discrepancies may be due in part to differences in growth rate of the various year classes and the disproportionate manner in which

Table 2. Average calculated lengths of Clear Lake bluegill by year classes (number of specimens in parentheses)

Year class	Total length in inches at annulus					
	1	2	3	4	5	6
1942	2.45 (2)	4.15 (2)	6.15 (2)	8.30 (2)	9.40 (2)	
1943	2.50 (6)	4.53 (6)	6.67 (6)	8.42 (6)	6.10 (1)	6.90 (1)
1944	2.34 (6)	4.97 (6)	6.77 (6)	5.35 (2)	6.05 (2)	
1945	2.10 (35)	3.47 (35)	4.60 (31)	5.40 (31)		
1946	2.15 (173)	3.85 (154)	5.24 (151)	6.56 (9)	7.88 (4)	8.70 (1)
1947	2.56 (19)	4.18 (19)	5.80 (10)	7.16 (7)	8.43 (3)	8.90 (1)
1948	2.48 (6)	4.64 (5)	6.97 (3)	7.60 (1)		
1949	--	--	--	--	--	--
1950	2.28 (17)	3.86 (17)	5.20 (11)	6.10 (1)		
1951	2.33 (756)	4.25 (454)	5.85 (277)			
1952	2.89 (193)	4.80 (140)				
1953	3.00 (2)					
Mean total length	2.39 (1215)	4.24 (838)	5.60 (497)	6.24 (59)	7.82 (12)	8.17 (3)

the year classes entered the samples. For example, age group II bluegill consist, for the most part, of the 1951 and 1952 year classes (50 and 43 per cent respectively), both of which have exhibited a relatively faster rate of growth than the bulk of the specimens from which was determined the mean total length at the third annulus (Table 2). Likewise, age group III fish consist primarily of bluegill from the 1951 year class (63 per cent). While the 1951 year class does not show as rapid a rate of growth as the 1952 year class, its advantage in this respect over year classes from which average lengths at the fourth annulus were calculated is sufficient to account, in part, for the slightly higher than expected length at capture of age group III fish.

Quite possibly, also, selective natural or fishing mortality of the faster growing fish could contribute toward the observed discrepancies. Further evidence on this point will be presented elsewhere in this paper.

Unfortunately, most of the specimens taken prior to 1954 were not sexed. However, sex was determined for a sufficient number of the 1951 and 1952 year classes to permit a comparison of the growth of male and female bluegill (Table 3). The variance of calculated lengths at the last annulus was examined in the case of both year classes separately to determine whether mean calculated lengths for male and female bluegill differed significantly. The results indicated significance at the

1 per cent level of probability (for the 1951 year class F = 8.73, with 1 and 237 degrees of freedom; for the 1952 year class F = 11.96, 1 and 93 degrees of freedom.

The data indicate that male bluegill are larger than female bluegill in the third and fourth years of life; but whether this represents a real difference in growth rate between the sexes or is a manifestation of some other factor or factors such as differential mortality rates or distribution of the sexes at time of capture cannot be reliably established. Hubbs and Cooper (1935) pointed out that among centrarchids males usually grow faster than females. Sprugel (1954) found that male bluegill grew more rapidly than females between the first and fourth years of life. Beckman (1949), however, obtained data from several thousand bluegill and was unable to detect any differential growth attributable to sex. Morgan (1951), on the other hand, obtained results that were quite the opposite. He was led to conclude from a study of 300 bluegill that females exhibited the faster growth rate.

A comparison of calculated lengths of bluegill from Ventura Marsh with calculated lengths of bluegill from the main body of the lake failed to reveal any differences in rate of growth that might be attributable to differences in the two environments (Table 4). Ventura Marsh is a shallow body of water, approximately 600 acres in size, adjoining the western end of Clear Lake. The two bodies of water are separated by a combination carp trap and dam. Higher water temperatures are usually attained in Ventura Marsh at an earlier date in spring. Erickson (1952) was able to show that young-of-the-year black crappie grew at a faster rate in the marsh than in Clear Lake proper in 1950. Forney (1955), on the other hand, found that during the summer of 1951 adult black bullhead in Ventura Marsh grew much more slowly than did black bullhead in the lake. He attributed the slower growth to heavy infestations of *Clinostomum complanatum*, which were found on nearly all of the marsh bullhead and on only 1 per cent of the lake bullhead.

Calculated lengths at the various annuli were slightly less for Ventura Marsh bluegill of the 1951 year class than calculated lengths at corresponding annuli for Clear Lake bluegill of the same year class (Table 4). However, the number of specimens from the marsh is small, and it is doubtful that the small differences would be statistically significant if tested. The relatively larger differences with respect to the 1952 year class would be difficult to interpret also because of the small sample size.

Sufficient data were collected in 1947, 1949, and 1952-54 to permit analysis of seasonal growth (Table 5). The data indicate that most of the seasonal growth in length is attained by the end of August and that perhaps little growth occurs thereafter. Age group I fish in 1947 gained 85 per cent of their expected growth by the first week of August. Over a similar period in 1952 and 1953, fish of age group I had acquired nearly 100 per cent of their expected growth. Age group III fish exhibited little or no growth from June through August of 1949. Unfortunately, other age groups were not represented in sufficient number in 1949 to permit a more critical evaluation of the seasonal growth for that year. However, growth studies on the yellow bass of Clear Lake have shown that this species also grew poorly in 1949 (Carlander, Lewis, Ruhr, and

Table 3. Comparison of the growth of male and female bluegill of the 1951 and 1952 year classes

Year class	Sex	Number examined	Average total length at annulus 1	2	3	Total length at capture
1951	Male	133	2.40	4.26	5.93	6.58
	Female	106	2.40	4.19	5.79	6.39
	Difference		0.00	0.07	0.14*	0.19
1952	Male	48	3.03	5.07		6.35
	Female	47	2.88	4.75		5.97
	Difference		0.15	0.32*		0.38

* Differences statistically significant at 0.01 level of probability.

Table 4. Comparison of calculated lengths of bluegill from Clear Lake and Ventura Marsh (both sexes combined)

Year class	Location	Number examined	Calculated length at annulus 1	2	3	Total length at capture
1951	Marsh	20	2.33	4.05	5.80	6.55
	Lake	256	2.38	4.22	5.85	6.48
	Difference		-0.05	-0.07	-0.05	-0.07
1952	Marsh	3	3.23	5.17		6.60
	Lake	137	2.88	4.79		6.04
	Difference		0.35	0.38		0.56

Cleary, 1953). No explanation of the poor growth in that year can be presented at this time.

It should be noted that increments of growth through August for age group I in 1952 and age groups I and II in 1953 exceed 100 per cent of their expected growth. These apparent discrepancies may be attributable to any one of several possible causes, the chief of which appears to be a selective mortality of the faster growing bluegill. Such could arise through the fishing out of larger bluegill by anglers, a higher natural

Table 5. Growth in inches since last annulus and percentage of the average season's growth of Clear Lake bluegill computed at weekly intervals (number of specimens in parenthesis)

Age group	Year	June 13	June 20	June 27	July 4	July 11	July 18	July 25	Aug. 1	Aug. 8	Aug. 15	Aug. 22	Sept. 29
I	1947	--	0.50 29% (2)	0.58 34% (5)	1.00 59% (1)	1.04 61% (6)	1.50 88% (2)	1.50 88% (1)	1.45 85% (2)	--	--	--	--
II	1952	--	--	1.20 63% (1)	1.33 70% (2)	1.50 79% (13)	1.65 87% (44)	1.65 87% (78)	1.76 93% (33)	1.99 105% (76)	2.40 126% (2)	2.06 108% (7)	2.28 120% (15)
I	1953	--	1.20 63% (1)	--	--	1.40 73% (2)	--	1.85 97% (2)	1.90 100% (1)	2.00 104% (2)	2.14 112% (7)	2.10 110% (3)	--
II	1953	0.88 53% (6)	0.78 47% (33)	1.21 82% (14)	0.85 51% (2)	1.06 64% (9)	1.17 70% (7)	1.34 80% (16)	1.61 96% (10)	1.68 100% (6)	1.59 95% (48)	1.91 114% (10)	--
II	1954	--	0.60 (1)	1.00 (2)	1.14 (20)	1.28 (15)	1.14 (14)	1.34 (19)	1.26 (13)	1.32 (23)	1.32 (19)	1.25 (21)	--
III	1954	--	0.40 (1)	0.49 (9)	0.46 (67)	0.58 (66)	0.63 (16)	0.76 (19)	0.74 (16)	0.76 (39)	0.96 (13)	0.73 (10)	--
III	1949	--	0.68 59% (9)	0.63 55% (6)	0.67 58% (4)	0.50 44% (1)	0.79 69% (18)	0.70 61% (12)	0.79 69% (24)	0.74 64% (18)	0.68 59% (9)	0.73 64% (30)	0.34 30% (3)

mortality rate for the faster growing fish, or more likely a combination of the two. Consequently, the percentages of expected growth attained at intervals during the growing season, as presented in Table 5, are undoubtedly overestimates.

A comparison of the growth of bluegill in Clear Lake with the growth data of other waters, as summarized by Carlander (1953), indicated that the growth rate is somewhat higher than has been reported for neighboring states. Within Iowa, the growth rate in Clear Lake is approximately equal to the growth in East and Red Haw Lakes (Lewis 1950) and higher than that reported for the Ike Lake in Marion County (Ruhr 1952).

Length-Weight Relationship

K factors were computed for all bluegill for which standard lengths and weights were available (844 specimens). Equivalent C factors have also been computed and are presented along with other length-weight data in Table 6. It was found that K factors increased with size, varying from 2.23 to approximately 4.90 in the length range 40 to 221 mm. The average K factor was 4.52 and the average standard length 119 mm. The standard length-weight relationship (length in millimeters, weight in grams) of the bluegill may be expressed mathematically as follows:

$$\text{Log } W = -5.3046 + 3.4468 \text{ Log } L.$$

A comparison of calculated weights with empirical weights (Table 6) suggests a reasonably good fit. Application of the t-test to the coefficient of Log L ($t = 8.141$, degrees of freedom = 30) demonstrated that the coefficient was significantly greater than 3.0 (probability level 0.01), indicating that Clear Lake bluegill become relatively more plump as they increase in size.

Fluctuations in Abundance

It was apparent from analysis of the year class composition (Table 2) that 1946, 1951, and 1952 produced strong year classes. The 1946 year class dominated the collections from 1947-50 and was still represented by age group V and VI bluegill in the 1951 and 1952 collections. There can be no question as to the abundance of 1951 bluegill since they so clearly dominated the catches in subsequent years. A strong year class was also produced in 1952. On the other hand, the 1949 year class was not represented in any of the collections and must be described as being very weak or nonexistent. Differences in methods of collection in the various years make interpretation of the relative strength of the remaining year classes difficult, but perhaps it would not be amiss to consider them as being average. The year classes might be classified as follows: strong year classes—1946, 1951, 1952; average year classes—1942-1945, 1947-1948; weak year classes—1949 and 1953.

Table 6. Length-weight relationship and ponderal indices, K and C, of Clear Lake bluegill, 1947-1954

Average standard length (mm)	Number of specimens	Weight in grams Mean	Weight in grams Range	Calculated weight (gm)*	Mean K	Equivalent C**
44	5	2	1-3	2.3	2.23	38.7
53	4	4	4-5	4.4	2.76	47.9
65	2	7	7-8	8.8	2.65	45.9
76	16	17	13-23	15.1	3.97	68.8
86	23	26	14-43	24	4.15	72.0
96	39	37	24-42	34	4.19	72.7
106	117	53	30-70	47	4.41	76.5
116	188	70	47-93	65	4.53	78.5
126	311	93	63-125	86	4.67	81.0
135	114	114	80-150	109	4.68	81.1
146	10	119	119-162	139	3.80	65.8
156	2	193	156-230	179	5.03	87.2
166	6	237	218-252	222	5.22	90.5
177	3	272	242-305	277	4.92	85.3
190	1	310	-	354	4.52	78.3
206	1	482	-	678	5.51	95.6
216	1	482	-	550	4.78	82.9
221	1	440	-	597	4.07	70.6
Total Mean	844				4.52	78.4

*Log W = 5.3046 - 3.4468 Log L

** C = 17.34K

where $K = \frac{W10^5}{L^3}$

W = weight in grams

L = standard length in inches

and where $C = \frac{W' 10^5}{L'^3}$

W' = weight in pounds

L' = total length in inches

and S.L. = 0.7831 T.L.

Food Habits

Feeding habit studies were not regularly conducted in the case of the bluegill. Cursory examinations were made of stomach contents at irregular intervals during July and August of 1949. The contents of twenty-one bluegill stomachs were analyzed. All contained food items of one kind or another. Immature aquatic insects were found in twelve stomachs (tendipedid pupae and larvae, dragon fly nymphs, mayfly nymphs, caddis fly larvae, horsefly larvae, and lepidopterus larvae); terrestrial insects in nine stomachs (several species in the Coleoptera and Hemiptera plus grasshoppers, houseflies, crickets, and wasps); plant remains in nine stomachs (*Chara*, *Najas*, and *Potomogeton*).

Age and Growth of the Pumpkinseed

Average growth of the pumpkinseed was determined from 328 specimens (Table 7). Mean calculated lengths in the first to the third years of life were as follows: 2.24; 4.20; 5.44 inches. The rate of growth of pumpkinseed in Clear Lake is slightly higher than in other waters of the Midwest for which information is available (comparison based on data summarized by Carlander, 1953).

Length-Weight Relationship

Condition factors for the pumpkinseed were found to vary with size of the fish. The K values increased from 4.05 to 4.60 over the length range 55 to 135 mm (Table 8). The average standard length was 98.8 mm and the average K factor 4.32.

The standard length-weight relationship of the pumpkinseed was found to be:

$$\text{Log } W = -4.7404 + 3.1856 \text{ Log } L.$$

The regression coefficient (3.1856) was found to be significantly greater than 3.0 at the 0.01 level of probability ($t = 2.993$ with 133 degrees of freedom). Like the bluegill, Clear Lake pumpkinseed become relatively more plump as they increase in size.

Fluctuations in Abundance

Examination of the year class composition of the collections in the various years 1947-1954 indicated that in general changes in abundance of the pumpkinseed were in close agreement with the fluctuations in number shown by the bluegill (Table 9). The 1951 year class was exceptionally large in the case of both species. While the 1946 pumpkinseed year class was not well represented numerically, it contributed some of the oldest individuals in the collection. This would seem to indicate that a strong year class had originated in 1946. It is probable that 1953

Table 7. Calculated lengths of Clear Lake pumpkinseed by age groups 1947-1954

Age group	Number of specimens	Total length at annulus 1	2	3	Average length at capture
I	196	2.28			3.95
II	113	2.20	4.22		5.42
III	19	2.08	4.06	5.44	5.95

	Grand averages, 328 specimens		
Mean calculated length	2.24	4.20	5.44
Mean annual increment	2.24	2.02	1.38
Summed increments	2.24	4.26	5.64
Standard length in mm*	45.6	85.6	111
Calculated weight in grams**	3.5	26	60
Annual increment in weight	3.5	22.8	36.6

* Standard length in mm = 20.38 total lengths in inches.
** Log W = -4.7404 + 3.1856 Log L.

Table 8. Length-weight relationship of the pumpkinseed, Clear Lake, Iowa, 1947-1952

Average standard length (mm)	Number of specimens	Weight in grams Mean	Range	Calculated weight (gm)*	Mean K	Equivalent C**
54.3	6	6.6	4-9	6.1	4.05	75.5
62.8	6	10.3	8-14	9.7	4.16	77.5
76.1	12	19.3	14-25	17.9	4.35	81.1
86.1	13	23.0	15-30	26.5	3.78	70.5
95.1	35	36.2	26-50	36.4	4.20	78.3
104.5	20	49.6	39-65	49.2	4.34	80.9
116.0	19	73.9	39-91	68.6	4.76	88.7
124.6	21	88.5	60-103	86.3	4.56	85.0
134.5	2	107	106-108	109.8	4.40	82.0
Average 98.8	134				4.32	

* Log W = -4.7404 + 3.1856 Log S.L.
** C = 18.64K

pumpkinseed also warrant classification as a strong year class. Of the remaining year classes only 1949 (represented only by two yearlings) can be definitely described as being weak.

It is interesting to speculate on the probable mechanism or causes for the fluctuation in numbers. Young-of-the-year bluegill and pumpkinseed were always plentiful as indicated by seine hauls made each summer. It seems unlikely then that factors affecting spawning success are the principal causes of variability in year class strength. More likely whatever factors are operating affect survival of young after hatching. The one which seems to us to be the more probable is variation in predation pressure brought about by changes in the distribution and density of submerged aquatic vegetation which undoubtedly provides some degree of protection for young-of-the-year fishes.

During the time that the Unit has been conducting investigations of Clear Lake fish populations some rather marked changed in the abundance of submerged aquatic plants have been noted (Table 10). In some years aquatic plants have been so dense as to seriously curtail boat travel, particularly in the west end of the lake. In other years there is relatively little vegetation and boating is possible on all parts of the lake without the annoyance of fouled propellers. No quantitative measure of the density of aquatic vegetation has been attempted by Unit biologists at the lake. They have, however, attempted to characterize the vegetation by the application of descriptive terms.

The data in Table 10 indicate that fluctuations in number of both the bluegill and pumpkinseed are closely associated with changes in abundance of submerged aquatic vegetation. Further studies are now being conducted to determine what other factors are affecting the survival of young-of-the-year fishes.

Summary

Age and growth determinations were made for 1215 bluegill and 336 pumpkinseed collected from 1947-54. The rate of growth of both species is slightly higher than in most waters of the Midwest for which information is available. Male bluegill of age groups II and III, collected in 1954, were larger than females of corresponding ages. Exceptionally strong year classes of bluegill and pumpkinseed originated in 1951 and very weak year classes in 1949. Strong bluegill year classes occurred in 1947 and 1952. The year 1946 was probably a good year for the pumpkinseed also. Fluctuations in abundance of both species appear to be closely associated with changes in density of submerged aquatic vegetation.

Acknowledgments

Appreciation is expressed to Dr. Kenneth D. Carlander, who supervised the research at Clear Lake and aided in the interpretation of data; to Muhrl Lindquist and the late Jack Stevens, of the Iowa State Conservation Commission, Harold T. Sutcliff, Edward Smith, Richard R. Whitney, and Richard L. Ridenhour, all of whom gave assistance in the field. The author's wife, Doris, prepared most of the scales for study.

Table 9. Growth rate of the pumpkinseed by year classes in Clear Lake, Iowa, 1945-1953

Year class	Average length in inches at each annulus		
	1	2	3
1945	2.30 (7)	4.54 (7)	
1946	2.18 (17)	4.04 (10)	4.30 (2)
1947	2.20 (33)	3.82 (33)	
1948	3.05 (15)	4.40 (1)	
1949	3.70 (2)	--	
1950	2.21 (8)	4.55 (8)	
1951	2.19 (214)	4.34 (68)	5.57 (18)
1952	2.21 (11)	4.10 (5)	
1953	2.08 (21)	--	
Average length	2.24 (328)	4.20 (132)	5.44 (20)

Table 10. Density of submerged aquatic vegetation and strength of bluegill and pumpkinseed year classes, Clear Lake, Iowa, 1946-52 (question mark indicates year class strength unclassified)

Year	Density of vegetation	Strength of year class	
		Bluegill	Pumpkinseed
1946	Dense	Strong	Strong
1947	Sparse	Average	?
1948	Sparse	Average	?
1949	Sparse	Weak	Weak
1950	Sparse	Weak	?
1951	Dense	Strong	Strong
1952	Dense	Strong	?

Literature Cited

Beckman, William C. 1949. The rate of growth and sex ratio for seven Michigan fishes. Trans. Amer. Fish Soc. 76(1946):63-81.

Carlander, Kenneth D. 1953. Handbook of Freshwater Fishery Biology with the First Supplement. Dubuque, Iowa, Wm. C. Brown Co.

_____, W.M. Lewis, C.E. Ruhr, and R.E. Cleary. 1953. Abundance, growth, and condition of yellow bass, Morone interrupta Gill, in Clear Lake, Iowa, 1941 to 1951. Trans. Amer. Fish. Soc. 82(1952): 91-103.

_____ and Lloyd L. Smith, Jr. 1944. Some uses of nomographs in fish growth studies. Copeia 1944:157-162.

Creaser, Charles W. 1926. The structure and growth of the scales of fishes in relation to the interpretation of their life history, with special reference to the sunfish Eupomotus gibbosus. University of Michigan Mus. Zool. Misc. Publ. 17.

Di Costanzo, Charles J. 1953. An analysis of the creel, Clear Lake, Iowa, for the summer of 1953. Paper presented at the 15th Midwest Wildlife Conf., Chicago, December 10, 1953.

Erickson, James G. 1952. Age and growth of the black and white crappies, Pomoxis nigromaculatus (LeSueur) and P. annularis Rafinesque, in Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 26: 491-404.

Forney, John L. 1955. Life history of the black bullhead, Ameirus melas (Rafinesque), of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 30:148-162.

Hubbs, Carl L. and Gerald P. Cooper. 1935. Age and growth of the longeared and green sunfishes in Michigan. Papers Michigan Acad. Sci. Arts and Lett. 20:669-696.

Lewis, William M. 1950. Fisheries investigations on two artificial lakes in southern Iowa. II. Fish population. Iowa State Coll. Jour. Sci. 24:287-324.

Morgan, George D. 1951. The life history of the bluegill sunfish, Lepomis macrochirus, of Buckeye Lake (Ohio). Jour. Sci. Lab., Denison Univ. Bull. 42(4):21-59.

Parsons, John W. 1950. Life history of the yellow perch, Perca flavescens (Mitchill) of Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 25:83-97.

Rounsefell, George A. and W. Harry Everhart, 1953. Fishery Science, its Methods and Applications. John Wiley and Sons, Inc. New York.

Ruhr, C.E. 1952. Fish population of a mining pit lake, Marion County, Iowa. Iowa State Coll. Jour. Sci. 27:55-77.

Sprugel, George, Jr. 1954. Growth of bluegills in a new lake with particular reference to false annuli. Trans. Amer. Fish. Soc. 83(1953):58-75.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 35-37

A NONVISUAL METHOD FOR TRANSPORT NUMBERS IN PURE FUSED SALTS[1]

Frederick R. Duke and James P. Cook

Institute for Atomic Research and Department of Chemistry
Iowa State College, Ames

ABSTRACT

A method for determining pure salt transport numbers not requiring visual observation of the operating transport cell is described. The basis of the method is the change in distribution of the salt in a porous cell with the passage of a direct current, analogous to the Hittorf method in aqueous solution. The method is illustrated by its application to $AgNO_3$.

The measurement of transport numbers in pure fused salt is largely dependent on methods in which visual data must be taken from the operating cell (1). The present report is a description and evaluation of. a cell which avoids this difficulty and which gives some promise of application to high melting salts. The method is based upon the changes in distribution of a fused salt which take place when a direct current is passed through a porous cell of unglazed porcelain containing the fused salt. The method is analogous to the Hittorf method for the determination of transport numbers in aqueous solution in which changes of concentration of the salt are measured with respect to the solvent. In the present work changes in the distribution of the fused salt are measured with respect to the pores of the unglazed porcelain.

EXPERIMENTAL

The cell is composed of a piece of unglazed porcelain about 7 cm in length and 2.5 cm in width. The cell is leached with water to remove any foreign salts which may be present, soaked in a solution of $AgNO_3$ and dried to remove water, leaving behind the salt evenly distributed throughout the pores of the cell. Appropriate electrodes are attached to the ends of the cell which is placed in an electric furnace maintained at the desired temperature above the melting point of the salt. The electrodes are silver wires.

---

[1]Contribution No. 528. Work was performed in the Ames Laboratory of the United States Atomic Energy Commission.

In the determination of transport numbers a current of about five milliamperes is passed through the cell, using an iodine or other suitable coulometer for the measurement of total current. At the conclusion of the run the cell is immediately removed from the furnace and allowed to cool. The size of the cell is measured as accurately as possible and it is divided into two parts, an anode and cathode compartment. After the measurement of the size of the anode and cathode compartments, they are ground in a mortar under water and leached to remove all salt. An alternate method is to extract the salt by means of a Soxhlet extractor. The solutions are then filtered and analyzed by any convenient procedure. The $AgNO_3$ analyses were done by titrating the Ag with standard KCNS (Volhard).

The original concentration of salt in the cell may be found from the difference in weight of the filled and empty cell or by the total salt found by analysis at the conclusion of a run. The latter method was used in the present work.

RESULTS AND DISCUSSION

The calculation involved in determining the transport numbers is illustrated by the following, using silver electrodes and silver nitrate as the electrolyte.

Let $\underline{Z}$ faradays of electricity be passed through the cell. At the cathode $\underline{Z}$ equivalents of silver ion will be deposited as silver. $\underline{Z}\ t^+$ equivalents of silver ion will migrate from anode compartment to cathode compartment. $\underline{Z}\ t^-$ equivalents of nitrate ion will migrate from the cathode compartment to the anode compartment. The changes are expressed in the following equations:

Change of equivalents in cathode =

$-\underline{Z}$ eq. of Ag^+ (deposited) + $\underline{Z}\ t^+$ of eq. of Ag^+
(migrated to cathode compartment) - $Z\ t^-$ eq. of NO_3^-
(left cathode compartment).

Since $t^+ = 1 - t^-$

Change of equivalents in cathode =

$$-Z \text{ eq. of } Ag^+ + \underline{Z} \text{ eq. of } Ag^+ - \underline{Z}\ t^- \text{ eq. of } Ag^+ - \underline{Z}\ t^- \text{ eq. of } NO_3^-$$

$$= -Z\ t^- \text{ eq. of } AgNO_3.$$

Similar equations may be developed for the changes taking place in the anode compartment.

In using this method certain assumptions are necessary. They are: (1) there is no back flow of the salt under the influence of gravity or other forces, (2) the mechanism of conduction in such a cell is the same as in bulk fused salt, and(3) the cell is cut at a point having the original distribution of the salt. This is, of course, analogous to the restrictions on a Hittorf cell for aqueous solutions. These runs were carried out at a temperature approximately 10 degrees above the melting point of the salt. It was found that excessive temperature or excessive current would give rise to very erratic results due to decomposition of the silver nitrate.

The results of seven runs are shown in Table 1.

Table 1. Results of silver nitrate determinations using porous plate cell

Run	Equiv.	Change in cathode	Faradays	t^-	t^+	Comment
1	0.00519	0.00022	0.000945	0.23	0.77	
2	0.00589	0.00017	0.000594	0.29	0.71	
3	0.00326	0.000087	0.000391	0.28	0.72	
4	0.00376	0.00021	0.000489	0.43	0.57	overlap of anode and cathode compartment
5	0.02004	0.00022	0.001357	0.19	0.81	
6	0.00467	0.00053	0.00076	0.70	0.30	no known reason for error in this run
7	0.001383	0.000129	0.00061	0.22	0.78	
	average, omitting 4 and 6			0.23	0.77	

The method appears to have merit, although the precision does not appear to be as favorable as in the case of the moving-bubble cell (1); the precision could probably be improved with practice and with experience in selection of proper cell size and salt proportion.

REFERENCE

1. Duke, F.R. and R.W. Laity. Jour. Phys. Chem. 59:549. 1955.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 39-56

EFFECTS OF NITROGEN FERTILIZER AND OAT DRILL-ROW SPACINGS ON AGRONOMIC AND QUALITY CHARACTERISTICS OF OAT-LEGUME SEEDLINGS[1]

J.G. Wheat, R.E. Atkins, and G.J. Jarvis[2]

Though oats and legumes commonly are seeded together in much of the cornbelt area certain relationships of this companion seeding are not fully established. A considerable amount of conflicting data concerning specific aspects of the small grain-forage crop relationship have been presented. The experiments reported herein were conducted at two Iowa locations which vary widely in inherent soil fertility in an attempt to obtain additional information on this subject.

Pertinent Literature

Agronomists frequently have demonstrated the value of fertilizer applications in maximizing grain yield of the oat crop. Nelson, et al. (14) reported on experiments which showed that many Iowa soils did not have enough available nitrogen to produce a high yielding oat crop. In their tests efficient use of additional nitrogen was made in all years in which oats followed two or more years of nonlegume crops. The use of correct fertilizer applications on some soils gave as much as 20 bushels per acre increase in grain yield of the oats. Similar experiments in Minnesota have been described by MacGregor (10) where the application of nitrogen resulted in marked increases in oat yields. Nelson, et al. (12) listed the order of greatest yield increase attributable to the three main fertilizer elements as nitrogen, phosphorus and potassium. Greatest increases in yield usually were achieved with a complete fertilizer. The application of phosphorus or potassium alone or in combination gave only slight increases if nitrogen was deficient. Other experiments in various areas where oats are produced could be cited to further substantiate the value of fertilizer applications, but those listed will serve as representative examples.

Response of the oat crop to increased fertility has been measured most extensively in terms of grain yield. However, effects of fertilizer applications on a number of other criteria also have been studied. The effect of additional nitrogen on maturity or heading date is varied as reported by different investigators. Gericke (6) and MacGregor (10) generally found a hastening of maturity with the application of nitrogen. Brieba (2), using low to moderate amounts of nitrogen, and MacGregor (10), with heavy applications, observed that maturity was not significantly

[1]Journal paper No. J-3096 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1172.

[2]Research Associate, Associate Professor, and former graduate student in Farm Crops, respectively.

altered. The application by Pendleton (16) of 200 pounds of sodium nitrate per acre resulted in a delayed maturity of the oats. McNeal and Davis (11) working with spring wheat under irrigation in Montana found heading was hastened from one to four days in plots receiving additional nitrogen.

Increased height of oats with the application of nitrogen has been recorded by Gericke (6), Burnett (4) and others. Burnett also observed increased lodging at the higher rates of application. Brieba (2) found that kernel weight was increased progressively as higher nitrogen rates were applied.

Studies relating protein content of the oat grain to nitrogen applications to the soil have been published by MacGregor (10), Gericke (6), and Pendleton (16). All three workers observed increased protein content in the grain as rates of nitrogen application were increased. Results of the papers reviewed thus far indicate that grain yield, straw yield and probably grain quality can be improved with adequate applications of nitrogen.

The effects of nitrogen fertilizer on the companion grass-legume seeding also should be considered. A number of studies have shown a detrimental rather than a beneficial effect on the companion seeding. Pritchett (17) observed that the addition of more than 20 to 30 pounds of nitrogen to oats at seeding time reduced the subsequent stand and hay yields of red clover and of alfalfa-brome seedings. Sweet clover stands and hay yields were affected to a somewhat lesser extent than alfalfa or red clover seedings. He maintained that reduction in stand and hay yield following fertilization of the oat companion crop with nitrogen was due to increased competition which the more vigorous oat plants provided the legume seeding. Competition for light appeared to be the most critical factor, while soil moisture could become limiting under some conditions. Nelson, et al. (13) and Pritchett and Nelson (18) cited 20 pounds of elemental nitrogen per acre as a rate that usually would benefit the oat crop and not reduce hay yields of the companion grass-legume seeding.

The effects of drill-row spacings and drilled versus broadcast seeding of oats have been investigated by several workers. Oats drilled in 7-inch rows were superior in grain yield to broadcast seedings in the experiments of Pritchett and Nelson (18). Blackmon and Snell (1), Pendleton and Dungan (15) and Pritchett and Nelson (18) all observed higher grain yields with 7-inch spacing of drill rows as compared to wider spacings. Results obtained under lower rainfall conditions in Oklahoma by Harper (7) showed an average yield of 34.6 and 34.3 bushels per acre, respectively, for oats grown during a 10-year period at 7- and 14-inch drill-row spacings. Kiesselbach and Lyness (9) state that 7- and 14-inch spaced drill rows of oats yielded essentially alike over an 8-year period, though later data of theirs show an advantage in yield for the 7-inch spacing.

A trend toward better legume stands where wide spacings of oat drill-rows were used is indicated in most studies, but differences in hay yields generally have not been of practical significance. Blackmon and Snell (1) found this to be true in experiments using alfalfa in the companion seeding, while Harper (7) and Kiesselbach and Lyness (9) obtained similar results with sweetclover under dry conditions. Stand establishment and hay yields of the legume were better under 7-inch spaced drill-rows than for broadcast seedings of oats in the experiments of Pritchett (17). He concluded that lessening of the competition between the oat and legume plants through decreased seeding rate of the broadcast oats was not possible when nitrogen applications were made. The thinly sown oats stooled enough more under these conditions to keep competition essentially constant. Smith, et al. (19) and Bula, et al. (3) did not find significant differences in stand establishment for alfalfa-red clover seedings with different sowing rates of the companion oat crop.

The aspect of the problem of competition between oat and legume-grass companion crops that has been studied the least is the effect exerted by different oat varieties. Experiments by Smith, et al. (19), Bula, et al. (3), and Pritchett (17) all showed no differential effects on establishment of the legume or on hay yield attributable to different oat varieties in companion seedings. Collister and Kramer (5), on the other hand, found a reduced stand of legume seedings under Benton and Clinton oats as compared to five other varieties. This difference also was reflected in hay yields.

Experimental Procedure

The experiment was conducted for a period of three years, 1952-1954, at two locations representing major soil types of the state. The area at the Western Iowa Experimental Farm near Castana was chosen as one at which a good response to nitrogen generally occurs, while the experimental site at Ames was considered typical of the more highly productive soils of north central Iowa where oat response to nitrogen fertilizer commonly is less striking. An attempt was made each year to choose areas whose past cropping history indicated they would be deficient in available nitrogen. Prior to seeding, over-all applications of phosphorus fertilizer were made at each experimental area to insure that the soils were not deficient in available phosphorus. At Castana the experiments were conducted on Ida silt loam with 15 to 20 per cent slope, while the experiments at Ames were on relatively level Clarion silt loam.

A split-plot design with four replicates was used for all tests. Whole plots consisted of rates of nitrogen application with 0, 20, 40 and 60 lbs of elemental nitrogen per acre applied as ammonium nitrate (33.5 per cent). Each whole plot was further divided into two subplots, one having oats drilled in rows 7 inches apart and the other with 14-inch drill-row spacings. Within each drill-row spacing six different oat varieties were seeded. The oat varieties grown were Cherokee, Ransom, Clinton, Marion, Shelby, and C.I.5867; the numbered selection is from the cross Santa Fe x Clinton[3] and is similar to the variety Clintafe. The two varieties listed first are early maturing, the second pair are midseason and the last two are late maturing.

Each variety plot was 3.5 by 15 feet in size and consisted either of three fifteen-foot rows spaced 14 inches apart or six rows spaced at 7-inch intervals. Oats were drilled at a 3-bushel-per-acre rate for the 7-inch spaced plots and at 2 bushels per acre for the 14-inch spacings with a funnel-type seeder mounted on a Columbia drill. The center row was harvested for grain yield from the three-row plots and the two center rows were cut from the six-row plots.

A seeding of 8 pounds of alfalfa and 8 pounds of bromegrass per acre was made each year at Ames using a Tysdal seeder. At Castana 10 lbs of alfalfa and 7 lbs of brome per acre were seeded. The fields then were rolled and the nitrogen broadcast on each plot. Seeding was done as early as possible at each location, usually about mid-April. Weather conditions generally were favorable for at least moderately good crop growth during all three seasons. Oat yields were reduced considerably in the 1953 season by heavy infections of both crown and stem rust, with the state average yield being approximately 10 bushels per acre below the average for the preceding 10-year period. Late summer rainfall was limited in 1952 and 1953 and alfalfa stands recorded are somewhat lower than desirable.

Agronomic and quality characteristics for which data were recorded were grain yield, 100-kernel weight, hull percentage, protein per cent of grain, plant height, lodging per cent, heading data, alfalfa stand, and hay yield. Kernel weights were taken on four randomly selected 100-kernel samples for each entry and hull percentages by weight determined using the same samples. Protein determinations were made using the Kjeldahl method for nitrogen on duplicate samples from the bulked replicates of each entry. A conversion factor of 6.25 was used to express the nitrogen determinations as per cent protein. Heading dates were expressed as number of days after May 31 when plots were considered fully headed. Alfalfa stands were taken in the autumn following seeding and were recorded as average number of plants per square foot determined from four 1-foot square quadrates located by predetermined pattern for each entry. Hay yields were recorded to the nearest 0.1 pound (green weight) from a strip 21 inches wide cut lengthwise through each variety plot. Other measurements were made in accordance with procedures in common usage for each character.

Results and Discussion

The experimental areas at Ames and Castana differed considerably in soil type, level of fertility and other environmental factors. In view of these differences and because the response to nitrogen generally was much greater for the experiments at Castana, a combined analysis and summary for the two locations did not seem warranted. Results from each location, therefore, will be presented separately. Summaries of the significant effects attributable to the three variables and the first order interactions among them are given in Tables 1 and 2 for the Ames and Castana experiments, respectively.

Significant differences attributable to the oat varieties tested are shown in Tables 1 and 2 for each character measured on the oat crop itself in all tests, except for hull percentage at Castana in 1953. This was to be expected as the varieties were chosen because they differed considerably in maturity, plant characteristics, yield and other criteria.

Table 1. Summary of significant effects and interactions for agronomic and quality characteristics measured on oat-legume seedings at Ames, Iowa, 1952-1954.[1]

		Primary attributes and interactions					
Character	Year	Nitrogen rates	Drill-row spacings	Oat varieties	N rates x spacings	Var. x N rates	Var. x spacings
Grain yield	1952	*	**	**	NS	NS	NS
	1953	**	**	**	NS	NS	NS
	1954	*	NS	**	NS	NS	NS
Heading date	1952	NS	*	**	NS	NS	NS
	1953	**	NS	**	*	NS	NS
	1954	NS	*	**	*	NS	NS
Plant height	1952	*	NS	**	*	NS	NS
	1953	**	NS	**	**	**	NS
	1954	*	**	**	NS	NS	NS
Hull percentage	1952	**	NS	**	NS	NS	NS
	1953	**	**	**	**	**	NS
	1954	**	*	**	**	NS	NS
100 Kernel wt.	1952	**	**	**	NS	**	**
	1953	**	**	**	**	**	**
	1954	*	NS	**	*	NS	*
Alfalfa stand	1953	NS	NS	NS	NS	*	*
Hay yield	1953	NS	NS	NS	NS	NS	NS

[1] * Differences exceeded 5 per cent level of probability.
** Differences exceeded 1 per cent level of probability.
NS Differences not significant

Further discussion of variety effect on the oat crop itself will be concerned primarily with interactions between oat varieties and either nitrogen rates or drill-row spacings. The effects of oat varieties on alfalfa stand establishment and hay yield will be discussed in the appropriate section.

Grain yield

Differences in grain yield traceable to rates of nitrogen fertilization and to drill-row spacings exceeded either the five or one per cent probability levels for all experiments except for the spacing differences in the 1954 Ames test (Tables 1 and 2). At Ames in 1952 the differences

Table 2. Summary of significant effects and interactions for agronomic and quality characteristics measured on oat-legume seedings at Castana, Iowa, 1952-1954.[1]

Character	Year	Nitrogen rates	Drill-row spacings	Oat varieties	N rates x spacings	Var. x N rates	Var. x spacings
		Primary attributes and interactions					
Grain yield	1952	**	**	**	NS	NS	NS
	1953	**	**	**	NS	NS	**
	1954	*	**	**	NS	NS	NS
Plant height	1952	**	**	**	NS	NS	NS
	1953	**	**	**	**	NS	NS
	1954	**	NS	**	NS	NS	NS
Hull percentage	1952	**	**	**	*	**	NS
	1953	**	NS	NS	*	NS	NS
	1954	**	NS	**	**	**	**
100 Kernel wt.	1952	**	**	**	NS	NS	NS
	1953	**	**	**	NS	*	*
	1954	**	NS	**	NS	NS	NS
Alfalfa stand	1953	NS	NS	NS	NS	NS	NS
	1954	*	**	*	NS	NS	NS
Hay yield	1952	**	NS	NS	NS	NS	NS
	1953	NS	NS	NS	NS	NS	NS
	1954	NS	**	NS	NS	*	NS

[1] * Differences exceeded 5 per cent level of probability.
** Differences exceeded 1 per cent level of probability.
NS Differences not significant.

among the three nitrogen levels for grain yield shown in Table 3 were not significant, but the comparison of plots receiving nitrogen fertilizer with those which did not was significant. An average increase in grain yield of 4.3 bushels for the plots receiving nitrogen was obtained. In 1953 at Ames differences in yield among all nitrogen rates exceeded the one per cent level with an average increase of 9.7 bushels per acre for the plots receiving nitrogen. A significant decrease of 4.3 bushels in grain yield was observed for the average of plots receiving nitrogen in 1954 at Ames. This experiment was nearly 100 per cent lodged, however, and reliability of the grain yields for this test probably is rather poor. An average of the 3-year period at Ames, including the 1954

Table 3. Average yield in bushels per acre of six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 inch	14 inch
Ames	1952	67.4	72.4	71.3	71.4	73.1	68.2
	1953	41.8	48.6	52.9	53.1	52.4	45.9
	1954	57.6	54.9	53.4	51.9	55.8	53.1
	Av.	55.6	58.6	59.2	58.8	60.4	55.7
Castana	1952	22.8	38.5	37.2	44.3	38.6	32.6
	1953	20.5	26.9	33.5	37.3	31.1	28.1
	1954	44.4	52.8	54.9	52.9	51.9	45.5
	Av.	29.2	39.4	41.9	44.8	40.5	35.5

yields, showed an increase of 3.3 bushels per acre for the plots receiving nitrogen. The 20-pound rate of nitrogen in 1952 and the 40-pound application in 1953 at Ames were the rates at which yield increases leveled off and higher rates of nitrogen yielded little or no additional grain.

Grain yields listed in Table 3 for the Castana experiments generally were increased progressively as additional increments of nitrogen were applied. Average increases of 10.2, 12.7, and 15.6 bushels per acre for the plots receiving the 20, 40-, and 60-pound rates of nitrogen, respectively, were obtained. Increases obtained for the three rates of nitrogen in 1954 did not differ significantly and indicated no advantage for the application of more than 20 pounds of nitrogen per acre. For the 1952 and 1953 experiments at Castana, however, it appears that still higher oat yields probably would have been obtained if more than 60 lbs of nitrogen per acre were applied at this location.

Yield differences attributable to the two drill-row spacings also are shown in Table 3 and exceeded the 1 per cent level for all years at both locations, except for the 1954 Ames test (Tables 1 and 2). Higher yields were obtained from oats sown in 7-inch spaced rows in all experiments, the average gain for the 3-year period being 4.7 and 5.0 bushels per acre at Ames and Castana, respectively. Thus the oats grown in the wider spaced rows were able to compensate to a large degree for the smaller plant population per unit area, and total grain yields for the two spacings did not differ greatly. Increased tillering of plants in the wider spaced rows probably was a primary factor contributing to the near equalizing of yields, but actual tiller counts were not taken.

The only significant interaction for grain yield among the three variables was for the relationship between oat varieties and drill-row

Table 4. Average heading dates for six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings at Ames, Iowa, 1952-1954.[1]

	0 lbs		20 lbs		40 lbs		60 lbs	
Year	7 in	14 in	7 in	14 in	7 in	14 in	7 in	14 in
1952	13.9	14.1	14.0	14.0	13.9	14.2	13.8	14.2
1953	18.8	18.2	16.8	17.2	16.1	16.2	15.9	16.2
1954	15.0	15.4	15.2	15.0	15.0	15.2	14.8	15.2
Av.	15.9	15.9	15.3	15.4	15.0	15.2	14.8	15.2

[1]Heading dates expressed as days after May 31.

spacings in the 1953 Ames experiment. An examination of the yield of the different oat varieties at the two spacings in that test showed that Marion oats yielded approximately the same when sown at either spacing, while the other five varieties produced markedly higher yields when sown in 7-inch spaced rows.

Heading date

Dates of heading were recorded only for the experiments at Ames and are shown in Table 4. Heading dates in 1953 were significantly earlier for the plots which received nitrogen with the plots receiving 20, 40, and 60 pounds of nitrogen per acre heading 1.5, 2.4, and 2.5 days earlier, respectively, than the no-nitrogen plots. A trend in this direction was indicated in 1952 and 1954 but the differences did not exceed the 5 per cent level of probability (Table 1). Average heading dates for the 3-year period also show slightly earlier heading for the plots receiving nitrogen, but the entire range was less than one day. Differences in maturity usually are somewhat less than corresponding differences in heading data, hence it appears doubtful if increases in earliness of the magnitude obtained in these experiments would be of practical value at harvest time.

Differences in heading date attributable to drill-row spacings exceeded the 5 per cent level in 1952 and 1954 (Table 1) but are negligible from a practical standpoint. Similarly, the summary presented in Table 1 indicated that both in 1952 and 1954 the interaction of nitrogen rates with drill-row spacings exceeded the 5 per cent level. A tendency for oats in 7-inch spaced rows to head slightly earlier at the higher rates of nitrogen application was suggested but was very small in magnitude.

Plant height

Significant differences in plant height attributable to nitrogen applications were observed in all three seasons at both locations. In the Ames experiments, however, the height increase for the nitrogen treated plots averaged only 1 inch greater than the no-nitrogen plots and actually

Table 5. Average plant height in inches for six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1952	33.6	34.8	35.0	34.6	34.3	34.7
	1953	31.7	33.7	34.5	34.8	33.6	33.8
	1954	42.4	41.7	41.8	41.5	41.4	42.3
	Av.	35.9	36.7	37.1	37.0	36.4	36.9
Castana	1952	21.5	25.6	27.1	28.4	25.0	26.4
	1953	22.2	25.6	27.8	29.0	25.6	26.7
	1954	33.4	35.3	36.1	37.2	35.4	35.6
	Av.	25.7	28.8	30.4	31.6	28.7	29.6

Table 6. Average per cent lodging for six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1952	6	7	12	17	15	6
	1953	12	13	20	26	17	18
	Av.	9	10	16	22	16	12
Castana	1953	4	11	12	11	12	7
	1954	32	32	43	59	41	41
	Av.	18	22	28	35	26	24

showed a slight decrease in height in 1954. Average height increases for the 3-year period at Castana for plots receiving nitrogen were more striking with the 20-, 40-, and 60-pound application rates resulting in average increases of 3.1, 4.7, and 5.9 inches, respectively. Progressive height increases in all three years as nitrogen rates were increased suggests that still taller oat plants might have been produced if higher nitrogen rates were used at the Castana location. It is questionable, however, if this would be desirable as the hazard of severe lodging probably would be increased at higher rates of application.

Table 7. Average hull percentage of six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1952	28.3	28.0	26.6	25.2	27.2	26.9
	1953	31.5	32.2	35.2	32.2	32.0	33.6
	1954	27.6	30.2	28.7	28.3	28.4	29.0
	Av.	29.1	30.1	30.2	28.6	29.2	29.8
Castana	1952	30.2	27.6	25.6	25.4	27.8	26.6
	1953	30.7	30.6	28.7	27.5	29.6	29.2
	1954	32.9	35.3	31.8	35.9	33.9	34.0
	Av.	31.3	31.2	28.7	29.6	30.4	29.9

Oat plants were slightly taller when grown in 14-inch spaced rows as compared with the 7-inch spacings in all experiments. In three of the six tests the differences were statistically significant, although the average difference for all varieties was less than one inch in most experiments.

The interactions between nitrogen rates and drill-row spacings shown in Tables 1 and 2 were significant at Ames in 1952 and 1953 and at Castana in 1953. A trend toward taller plants when the 7-inch spaced rows were grown at the higher levels of nitrogen was evident in the 1953 experiments, but this relationship was not as clear-cut in 1952. Also varieties of oats varied sufficiently in their response to the rates of nitrogen applied at Ames in 1953 to result in a detectable interaction, but pronounced and consistent trends were not evident.

Lodging

Analyses of variance were not calculated for the data on plant lodging because of a considerable number of zero readings in most tests. Application of probability tests to the lodging data thus cannot be made, but differences are shown in Table 6. At Ames in 1954 all plots were nearly 100 per cent lodged, while none of the plots lodged at Castana in 1952. Lodging notes from these two experiments thus were not included in the summary. In both 1952 and 1953 at Ames no increase in lodging for the oats was observed when 20 pounds of nitrogen were applied, but when 40- or 60-pound applications were made lodging scores were approximately double the scores for the no-nitrogen plots; even higher in some cases. The total amount of lodging at the higher nitrogen rates generally would not be considered severe and likely would not cause appreciable yield loss or serious difficulties at harvest.

Table 8. Average gram weight per 100 kernels for six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1952	3.03	3.06	3.10	3.17	3.05	3.12
	1953	2.18	2.22	2.09	2.07	2.16	2.11
	1954	1.95	1.94	1.86	1.81	1.88	1.90
	Av.	2.39	2.41	2.35	2.35	2.36	2.38
Castana	1952	3.02	3.01	3.05	3.14	3.01	3.11
	1953	2.62	2.49	2.47	2.50	2.48	2.57
	1954	1.85	1.90	1.84	1.68	1.82	1.81
	Av.	2.50	2.47	2.45	2.44	2.44	2.50

Lodging at all three nitrogen rates was nearly identical at Castana in 1953 and approximately three times as great as for the plots receiving no nitrogen. Again the highest scores observed were relatively low and would not cause harvesting difficulties. Considerably greater lodging was recorded for the 1954 Castana test, although the plots receiving 20 pounds of nitrogen per acre were equal to the check plots in standability. When 40 and particularly 60 pounds of nitrogen were applied, sizeable increases in amount of lodging were observed. Considerable loss of grain at harvest time undoubtedly would result with oats lodged as severely as were those grown at the higher rates of nitrogen application of this test.

Oats grown in 14-inch spaced rows were lodged considerably less than those sown in 7-inch rows at Ames in 1952. Essentially no difference in lodging was observed in 1953 at the two spacings and the average difference for the 2-year period was negligible. At Castana somewhat greater standability was exhibited by the oats in 14-inch spaced rows in 1953, but in 1954 and for the 2-year period the values obtained for the two spacings were nearly identical.

Hull percentage

Differences in hull percentage due to varying rates of nitrogen application exceeded the 1 per cent level of probability in all experiments, both at Ames and Castana (Tables 1 and 2). Although statistically significant, the differences in hull percentage shown in Table 7 generally were small and varied in direction of change for the different experiments. The average values for the 3-year period at both locations showed no pronounced effect of nitrogen on hull per cent. Similarly, hull percentage values for oatsgrown at 7- and 14-inch spacings did not differ appreciably, though probability tests did indicate statistically significant differences in three of the six tests. Slightly lower hull percentages were observed for oats grown in 7-inch spaced rows in three experiments, while the other three tests showed lower hull percentages for the 14-inch spaced oats. Several statistically significant interactions between nitrogen rates and drill-row spacings, varieties and nitrogen rates and one for varieties and drill-row spacings were obtained for the hull percentage data (Tables 1 and 2). The direction and magnitude of the interactions varied considerably from year to year at the different locations, so that specific discussion of them does not seem warranted.

Weight of 100 kernels

Weight of 100 kernels for oats grown at the varying rates of nitrogen application differed significantly in all experiments and differences attributable to drill-row spacings were significant in four of the six tests (Tables 1 and 2). As was the case with hull percentage, however, the direction of change was quite variable and the differences in kernel weight presented in Table 8 are too small to be of concern from a practical viewpoint.

The variety by nitrogen rate, variety by spacings, and nitrogen rate by spacings interactions for kernel weight were statistically significant in a number of the experiments (Tables 1 and 2). Varied direction for the interactions was evident and all differences were small. Probably the primary conclusion to be made from them is that the oat varieties did not all respond alike to the different nitrogen rates or drill-row spacings, and that the order of response to spacings varied for the different rates of nitrogen application. A tendency for the Ransom variety to produce plumper kernels when grown at the 7-inch spacings was indicated while other varieties generally had higher kernel weights at the 14-inch spacings. Also an indication of a higher level of response in kernel weights for Cherokee and Clinton at the 20-pound nitrogen rate in comparison with other varieties was observed.

Protein content of grain

Preliminary samples were run to standardize techniques prior to making protein determinations but it was not possible to calculate analysis of variance for this criterion as bulked replicated samples were used for the determinations. Protein content was determined for only three of the six oat varieties in each test. Cherokee was selected as representative of the early maturing types, Clinton as a medium maturity oat, and Shelby as a late maturing variety. Mean protein percentages obtained for both the Ames and Castana experiments are given in Table 9. At Ames, protein content of the grain was progressively increased with 20- and 40-pound applications of nitrogen, but further increase was not apparent when 60 pounds per acre was applied. The 20-pound nitrogen rate at Castana did not increase protein content of the grain, but both the 40- and 60-pound applications resulted in proportionate increases in per cent of protein. Mean protein per cent for the Ames tests was almost identical for oats grown at the 7- and 14-inch spacings, while at Castana a slightly higher protein content was indicated for the grain

Table 9. Per cent protein in the grain for three oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

		Nitrogen in pounds per acre				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1952	15.1	15.9	16.3	15.7	15.6	16.0
	1953	12.3	12.8	13.8	14.7	13.5	13.3
	1954	14.8	15.1	15.0	15.2	15.3	14.7
	Av.	14.1	14.6	15.1	15.2	14.8	14.7
Castana	1952	16.2	15.8	16.1	16.6	15.7	16.6
	1953	13.9	13.8	14.6	15.5	14.5	14.4
	1954	11.7	11.7	12.1	12.4	11.9	12.1
	Av.	13.9	13.8	14.3	14.9	14.0	14.4

Table 10. Average number of alfalfa plants per square foot under six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1953-1954.

		Nitrogen in pounds per ac				Drill-row spacings	
Location	Year	0	20	40	60	7 in	14 in
Ames	1953	15.1	15.4	15.2	15.9	15.6	15.3
Castana	1953	8.2	7.1	7.4	6.5	7.2	7.4
	1954	4.2	4.8	4.1	3.3	3.8	4.4
	Av.	6.2	5.9	5.7	4.9	5.5	5.9

from plants grown in rows spaced 14 inches apart. Average protein content for Cherokee grain was 15.6 per cent, with Clinton averaging 14.4 per cent and Shelby lowest in protein content at 13.3 per cent.

Alfalfa stand establishment

The effects of different rates of nitrogen application, varying drill-row spacings, and different oat varieties on the companion alfalfa-brome seeding were measured only on part of the experiments. Fall stand for the alfalfa was not taken at either location in 1952 and the alfalfa stands at Ames in 1954 were a complete failure due to lack of adequate summer moisture.

Table 11. Average number of alfalfa plants per square foot and hay yield in pounds produced under six oat varieties, Ames and Castana, Iowa, 1952-1954.

	Alfalfa plants/sq. ft.			Hay yield in pounds			
	Ames	Castana		Ames	Castana		
Variety	1953	1953	1954	1953	1952	1953	1954
Cherokee	14.5	7.1	4.3	3.4	5.0	2.5	4.3
Clinton	16.7	6.9	4.1	3.6	5.0	2.2	4.4
Marion	15.2	7.3	3.5	3.4	5.0	2.4	4.4
Shelby	15.7	7.5	4.1	3.4	-	-	4.1
C.I. 5867	13.9	7 2	4.3	3.4	-	-	3.9
Ransom	16.4	7.6	4.1	3.5	-	-	4.3

Differences in alfalfa stands attributable to nitrogen rates, drill-row spacings and oat varieties were not significant either at Ames or Castana in 1953 (Tables 1 and 2). Probability values for all three criteria did exceed the 5 per cent level for the Castana test in 1954 but the average stands and range of stands shown in Table 10 were somewhat lower than desirable for good hay production. The trend at Castana was for slightly poorer alfalfa stands where nitrogen was applied, but the reductions were not pronounced. Similarly, the 0.6 plant per acre heavier stand of alfalfa grown under 14-inch drill-rows of oats at Castana in 1954 was statistically significant but it is doubtful if it would be of concern in subsequent hay production. Alfalfa stand differences attributable to growth under different oat varieties were significant only in the 1954 Castana test and then only at the 5 per cent level. A consistent association of better alfalfa stands with maturity classification or growth habit of the companion oat variety is not apparent from the results presented in Table 11.

The interactions for varieties x nitrogen rates and for varieties x spacings for alfalfa standcount in the 1953 experiment at Ames exceeded the 5 per cent level of probability. No consistent trends could be determined for the variety x nitrogen rate interaction, but the variety x spacings interaction apparently was, due to the production of slightly heavier alfalfa stands when Cherokee, Clinton, and Marion were grown in 14-inch drill rows while Shelby, Ransom, and C.I. 5867 had heavier alfalfa stands beneath them when grown in 7-inch spaced rows. Very little if any reliance can be given to these interactions, however, as they exceeded only the 5 per cent probability level and none of the main effects involved in the interactions were significant.

Hay yield

Hay yields were not obtained from the stands established at Ames in

Table 12. Average hay yield in pounds per plot under six oat varieties grown at four rates of nitrogen fertilization and two drill-row spacings, Ames and Castana, Iowa, 1952-1954.

Location	Year	Nitrogen in pounds per acre				Drill-row spacings	
		0	20	40	60	7 in	14 in
Ames	1953	3.4	3.6	3.3	3.4	3.4	3.5
Castana	1952	5.4	5.3	4.7	4.5	5.1	4.8
	1953	2.4	2.5	3.0	1.6	2.6	2.2
	1954	4.7	4.6	3.9	3.9	4.0	4.5
	Av.	4.2	4.1	3.9	3.3	3.9	3.8

1952 and 1954 due to the inadequacy of these stands. At Castana in 1952 and 1953, hay yields were taken only from the plots having Cherokee, Clinton, or Marion as the companion oat variety. Only the differences in hay yield obtained at Castana attributable to nitrogen rates in 1952, drill-row spacings in 1954, and the interaction of varieties x nitrogen rates in 1954 reached the accepted levels of statistical significance (Tables 1 and 2). To facilitate comparisons with stand data hay yields listed in Tables 11 and 12 are in accordance with the year in which the stands were established, i.e., hay yields listed for 1952 actually were harvested in the following 1953 season. Hay yields were progressively decreased in the 1952 Castana test as additional increments of nitrogen were applied, but the most severe decrease was less than 1 pound per plot or approximately 0.3 ton per acre. The significant advantage cited for alfalfa stands under the 14-inch spaced oat rows at Castana in 1954 carried through and was expressed as a 0.5 pound per plot superiority in subsequent hay yields for the plots with 14-inch spaced oat rows over the plots with 7-inch spacing of oat rows. A significant interaction between oat varieties and nitrogen rates was indicated for hay yields from the 1954 Castana experiment, but consistent relationships were not apparent. Hay yields obtained with different oat varieties as the companion crop are shown in Table 11 and were not significant for any of the tests during the 3-year period.

Summary and Conclusions

The effects of four rates of nitrogen application and two drill-row spacings on certain agronomic and quality characteristics of six oat varieties and the companion alfalfa-brome seeding were studied for the 3-year period 1952-1954 at Ames and Castana, Iowa. A split-plot design was used for each experiment with the whole plots consisting of areas receiving either 0, 20, 40, or 60 pounds of nitrogen per acre, and each subplot consisting of oats drilled in rows either 7 or 14 inches apart. Each spacing in turn was divided into six areas each sown to one of six different oat varieties. The oat varieties eveluated were Cherokee, Ransom, Clinton, Marion, Shelby, and C.I. 5867.

Increases in grain yield were obtained when nitrogen fertilizer was applied both at Ames and Castana in all three seasons. Average increase in yield for the plots receiving nitrogen was only 3.3 bushels per acre at Ames, while an average gain of 12.8 bushels was observed at Castana. The additions of 20 and 40 pounds of nitrogen per acre were most effective in amount of yield increase per pound of nitrogen applied at Ames. Results at Castana indicated that rates of greater than 60 pounds of nitrogen per acre might give further increases in grain yield. A reduction in yield of approximately 5 bushels per acre for oats grown in 14-inch drill-rows in comparison with oats in 7-inch rows was obtained for the average of the 3-year period at both Ames and Castana.

Heading dates for the oats on plots receiving nitrogen were hastened slightly for the 3-year period at Ames. Similarly, oats grown in 7-inch spaced drill-rows tended to head slightly earlier than those from 14-inch spaced plots. Neither the average effects of nitrogen nor those for drill-row spacings on heading date were large enough to be of practical significance, as the total range in heading date was less than one full day in both comparisons.

Plant height generally was increased for the oats which received additional nitrogen. Increases were greatest on the nitrogen deficient soils at Castana with plants on the plots receiving 20, 40, and 60 pounds of nitrogen per acre averaging 3.1, 4.7, and 5.9 inches taller, respectively, than oat plants on the check plots. Essentially no difference in height for oats grown in 7- or 14-inch spaced rows was observed at Ames for the 3-year period, while an average increase in height of approximately 1 inch was obtained at the wider spacing at Castana.

Lodging generally was progressively increased at both locations when increased amounts of nitrogen fertilizer was applied to the oats, with lodging scores for plots receiving 60 pounds of nitrogen per acre being approximately double those for the no-nitrogen plots. Average lodging at both locations was slightly less for oats grown in drill-rows spaced 14 inches apart than for oats in 7-inch drill rows. The better standability of oats in the 14-inch spaced rows was very marked for some of the experiments, however, and it appears that growing oats in wide spaced rows may have considerable advantage in some seasons when heavy rates of nitrogen are to be applied.

The effects of varying nitrogen rates and drill-row spacings on hull percentage of the oat crop were highly variable. A consistent or marked effect of these two criteria relative to increased or decreased quality of the grain, as expressed by hull percentage, could not be demonstrated from these experiments. Similarly, the effects on kernel weight were small in magnitude and varied in direction. Additional increments of nitrogen fertilizer and variations in row spacings for oats apparently are more likely to be expressed in increased vegetative growth and total grain production than in improved grain quality as measured by hull percentage and kernel weight.

Protein content of the oat grain usually was increased as higher rates of nitrogen were applied. Differences in protein content of oats grown in 7- and 14-inch spaced drill-rows were negligible. Highest average protein content was exhibited by the Cherokee variety, with Clinton intermediate and Shelby low in per cent of protein in the grain.

Alfalfa stand establishment and hay yields generally were not influenced appreciably by the rates of nitrogen applied to the oats at seeding time, by variations in width between oat drill-rows, or by the different oat varieties grown as companion crop. Specific exceptions to this general trend were observed for some tests, however. Alfalfa stands were somewhat better in plots with 14-inch spaced rows of the oat companion crop than when the oats were grown in 7-inch drill-rows at Castana in 1954. A significant reduction in alfalfa stands at the 60-pound rate of nitrogen application was indicated in the 1954 experiment at Castana. Differences in alfalfa stands attributable to growth under different oat varieties exceeded the 5 per cent level of probability in the 1954 Castana test, but a consistent association of the better alfalfa stands with maturity classification or growth habit of the companion oat variety was not apparent.

Reductions in hay yield on plots receiving 40 and 60 pounds of nitrogen per acre were observed for the experiment established at Castana in 1952, but the most severe decrease was approximately 0.3 ton per acre. For the experiment established at Castana in 1954, subsequent hay yields for plots with 14-inch spaced oat rows were slightly greater than for plots with 7-inch spacing of oat rows. The oat varieties used for companion seeding did not exert a significant differential effect on hay yields in any of the tests.

Literature Cited

1. Blackmon, C. R. and R. S. Snell. 1954. Effect of spacing in winter versus spring grain companion crops and its relation to nitrogen fertilization of the winter type. Agron. Jour. 46:489-491.
2. Brieba, R.S. 1947. Effect of nitrogen supply on nitrogen content and time of maturity of oats and wheat. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa.
3. Bula, R.J., D. Smith, and E.E. Miller. 1954. Measurements of light beneath a small-grain companion crop as related to legume establishment. Bot. Gaz. 115:271-278.
4. Burnett, L.C. 1944. Varietal response of oats to soil nitrogen levels. Proc. Natl. Joint Committee on Nitrogen Utilization.
5. Collister, H.H. and H.H. Kramer. 1952. The effect of oat variety on the stand and development of red clover. Agron. Jour. 44:385.
6. Gericke, W.F. 1922. Studies on the effect of nitrogen applied to oats at different periods of growth. Jour. Amer. Soc. Agron. 14:312-320.
7. Harper, H.J. 1946. Effect of row spacing on the yield of small grain nurse crops. Jour. Amer. Soc. Agron. 38:785-794.
8. Jarvis, G.J. 1953. Differential response of oat varieties to nitrogen fertilization and drill-row spacings. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa.

9. Kiesselbach, T.A. and W.E. Lyness. 1951. Production practices for spring small grains. Nebraska Agric. Exp. Sta. Bull. 406.

10. MacGregor, J.M. 1954. Effect of nitrogen on yield and protein of oats and corn. Minnesota Agric. Exp. Sta. Misc. Rpt. 22.

11. McNeal, F.H. and D.J. Davis. 1954. Effect of nitrogen fertilization on yield, culm number and protein content of certain spring wheat varieties. Agron. Jour. 46:375-378.

12. Nelson, L.B., K. Lawton, and C.A. Black. 1945. Recent investigations of the response of oats to fertilizer in Iowa. Soil Sci. Soc. Amer. Proc. 10:235-239.

13. _____, _____, and W.H. Pierre. 1946. Nitrogen fertilization of oats and its relation to other crops in the rotation. Soil Sci. Soc. Amer. Proc. 11:417-421.

14. _____, H.R. Meldrum, and K. Lawton. 1946. Fertilize the oat crop. Farm Science Rpt. 7:3-6.

15. Pendleton, J.W. and G.H. Dungan. 1953. Effect of different oat spacings on growth and yield of oats and red clover. Agron. Jour. 45:442-444.

16. Pendleton, R.A. 1930. Nitrate fertilizers for oats in Iowa. Jour. Amer. Soc. Agron. 22:663-668.

17. Pritchett, W.L. 1950. Nitrogen fertilization of small grain and its effects on competition with legume-grass companion crop. Unpublished Ph.D. thesis. Iowa State College Library, Ames, Iowa.

18. _____ and L.B. Nelson. 1950. Save that seeding. Iowa Farm Sci. 4:139-140.

19. Smith, D., H.J. Lowe, A.M. Strommen, and G.N. Brooks. 1954. Establishment of legumes as influenced by the rate of sowing the oat companion crop. Agron. Jour. 46:449-451.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 57-61

DAMPING-OFF OF COTTON SEEDLINGS CAUSED BY COLLETOTRICHUM HIBISCI POLL.[1]

H.G. Pulsifer[2]

Summary

Isolates of Colletotrichum hibisci Poll., capable of causing tip blight and other symptoms in kenaf (Hibiscus cannabinus L.) were also capable of damping-off cotton seedlings, causing symptoms of typical damping-off due to Colletotrichum gossypii South. These same isolates of C. hibisci failed to cause any symptoms typical of C. gossypii on cotton bolls and other parts of the mature cotton plant. One instance of limited infection of kenaf seedlings by an isolate of C. gossypii was observed, but in general the isolates of C. gossypii did not infect kenaf at any stage of its development.

Introduction

Kenaf (Hibiscus cannabinus L.), a jute-substitute fiber crop, was introduced into the Western Hemisphere about 1940, according to Haarer (1). Statements by Crandall and Lynn (2) and Pate et al. (3) indicate that the first recorded epiphytotics caused by C. hibisci Poll. on this introduced plant occurred in 1950-51 in Cuba and Florida. Epiphytotic development of C. hibisci on a small experimental planting of kenaf at Ames, Iowa, in 1953 indicated the potential significance of this disease if kenaf were to become a commercial crop.

Close observation and study of the disease and the causal fungus suggested a possible relationship between the anthracnoses of kenaf and cotton; i.e., the causal fungi, C. hibisci and C. gossypii, are similar in form and growth habit, and their hosts, kenaf and cotton, respectively, are both members of the plant family Malvaceae.

The comparisons of C. hibisci with C. gossypii reported here revealed a slight difference between the two fungi in spore size and a distinct difference in growth rate at 32 and 37°C. In cross-inoculation experiments, C. hibisci definitely was capable of inducing damping-off of cotton seedlings.

---

[1]Journal paper No. J-3099 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 110. Taken from a thesis submitted to the graduate faculty, Iowa State College, in partial fulfillment of requirements for the degree, Doctor of Philosophy.

[2]Present address, South Dakota State College, Brookings.

Isolates of C. hibisci and C. gossypii

Two groups of isolates of C. hibisci were used in these experiments. One group was taken from infected kenaf plants grown at Ames, Iowa. A second group was isolated from kenaf seed of the El salvador variety from Florida.

Two isolates of C. gossypii were available for comparison. One was obtained from the New Mexico College of Agriculture and Mechanic Arts through the courtesy of Dr. E. E. Staffeldt. This isolate bore the label "Lehman's No. 16" when received, and is referred to as such below. The other isolate was obtained from a seedling grown from a seed lot of the cotton variety, La. 33, obtained through the courtesy of Dr. D. C. Neal, Pathologist, Agricultural Center, University Station, Baton Rouge, Louisiana, and is referred to as "the Louisiana isolate."

Comparative Spore Size and Temperature-Growth Response

Since there are no marked morphological differences between C. hibisci and C. gossypii, other criteria were adopted for distinguishing the isolates of the two species. The spores of C. hibisci were consistently somewhat smaller than those of C. gossypii, and growth of C. hibisci was markedly less than that of C. gossypii at 32 and 37°C (Table 1).

Table 1. Comparative spore measurements and temperature-growth response among isolates of C. hibisci and C. gossypii.

Isolate	Species	Mean length conidia	Colony diameter (mm) at 32°C	Colony diameter (mm) at 37°C
Lehman's No. 16	C. gossypii	14.3*	38.7**	22.6
Louisiana	C. gossypii	15.0	42.1	25.4
Ames	C. hibisci	10.5	15.4	--
Florida	C. hibisci	11.3	15.2	--

*Average length in microns, 100 conidia, from lima bean agar.
**Mean diameter in mm derived from growth on 8 different Difco agars, after 4 1/2 days.

These differences in spore size and in growth at high temperatures indicate a degree of basic difference between C. hibisci and C. gossypii and were useful in identifying a particular culture taken from diseased host tissue.

Pathogenicity of C. hibisci to Cotton Seedlings

Methods

In the initial test of the pathogenicity of C. hibisci to cotton seedlings, seeds of La. 33 were soaked in a conidial suspension and planted in steamed soil with two other lots of La. 33 which had been soaked in distilled water only. An alfalfa check of 125 seeds was planted in the same batch of steamed soil as a means of determining the possibility of damping-off by organisms other than C. hibisci.

Due to the presence of some C. gossypii in the seed lots of La. 33 used in the above experiment, an attempt was made in the second experiment to free the cotton seed of this pathogen. Two lots of the La. 33 cotton seeds, 125 seeds each, were soaked in full strength Clorox for ten minutes, followed by a two-hour wash in tap water. The other two lots of 125 seeds each were delinted in concentrated sulphuric acid, and then washed for two hours in tap water. After washing, the seed was allowed to dry overnight. The check lots were then submerged in distilled water, while the test lots were submerged in a conidial suspension of C. hibisci. In each case, the seed plus about 50 cc of the respective liquids were placed in the five six-inch pots of soil used for each treatment. In order to keep the spore suspension from sinking down into the soil away from the seeds, a single sheet of filter paper was placed upon the soil surface, and the seed plus the conidial suspension poured over it, whereupon it was covered with soil.

Table 2. Emergence and damping-off of seedlings from cotton seed of the variety La. 33, uninfested and infested with Colletotrichum hibisci. (Data taken 30 days after planting.)

Treatment	Emerged	Damped-off	Failed to emerge
Clorox treated			
Uninfested	112*	0	13
Infested with C. hibisci	22	16	103
Acid delinted			
Uninfested	109	0	16
Infested with C. hibisci	47	45	78

*From five pots of 25 seeds each in all cases.

As damping-off of the cotton seedlings progressed in the experiments cited above, a few damped-off seedlings were taken at random and the causal organism isolated in pure culture. The identity of these isolates was ascertained by means of spore measurements and temperature-growth response tests.

Results

In the initial test of the pathogenicity of C. hibisci to cotton seedlings, only 50 of the 125 seeds of La. 33 which had been soaked in the conidial suspension broke through the soil and the radicle of 42 of these was rotted away before the hypocotyl could assume a vertical position. Eight seedlings survived to grow to somewhat stunted plants at the end of 42 days. The two check lots of 125 La. 33 seeds each, which had been treated with distilled water only, yielded 229 seedling plants, 38 of which damped off during the 42-day period of observation. These damped-off seedlings yielded C. gossypii when tested in the laboratory. An alfalfa check of 125 seeds planted in the same batch of steamed soil showed no damping-off.

In the second experiment, in which special precautions were taken to eliminate C. gossypii from the cotton seed, the damping-off among check plants was successfully avoided, as shown in Table 2. The infested lots in this second experiment were severely damaged by C. hibisci, also as shown in Table 2. Much of the damage was evidenced by a failure of the cotton seedlings to emerge. Of those which did emerge, nearly all damped off during a thirty-day period of observation. The identity of C. hibisci as the causal agent of this damping-off was checked by isolating from eight of the damped-off seedlings taken at random from the treated pots of each treatment. Growth tests and spore measurements of the fungus obtained from these seedlings showed it to be C. hibisci.

Pathogenicity of C. hibisci to Established Cotton Seedlings and Older Plants

In greenhouse experiments, conidial suspensions of C. hibisci were sprayed upon cotton seedlings in stages of development ranging from plants with cotyledons plus one primary leaf up to plants with eight to ten fully expanded leaves. However, in spite of repeated attempts, the only evidence of infection was a spotting of the two or three youngest leaves. When such leaves were placed under agar in Petri dishes, C. hibisci was recovered. Attempts to increase the virulence of these isolates of C. hibisci by repeated inoculation of cotton failed in that the reinoculations produced only the same limited spotting of the youngest cotton leaves.

An attempt to infect cotton with C. hibisci was also made in the field. Three cotton varieties, Coker-100-W, La. 33, and LaDS 5189 were used in the experiment. Each variety had been planted in a block of four eight-foot rows, 20 inches apart, and these blocks were located at random among three similar blocks of kenaf, and three more of okra. The reginned seed of these three cotton varieties had been dusted with Arasan prior to planting.

C. hibisci was in evidence on the kenaf plants by the time they had eight to ten fully expanded leaves, and became progressively more abundant until toward the end of the growing season, it had killed many of them. The three cotton varieties, however, showed no symptoms attributable to C. hibisci, and isolations made from the leaves, stems, petioles, and very young bolls did not yield C. hibisci.

When it appeared, toward the end of the growing season, that a spontaneous spread of C. hibisci would not occur, cotton bolls in various stages of development were injected with a conidial suspension of C. hibisci by means of a hypodermic needle. In spite of abundant rainfall and cool weather, damage to the bolls was limited to internal discoloration of those inoculated, and there was no spread to adjacent uninoculated cotton plants.

Pathogenicity of C. gossypii to Kenaf

Kenaf seedlings appeared not to be susceptible to damping-off by C. gossypii. Out of four successive trials of 125 seeds each, shallow lesions which did not develop extensively were discovered on only two kenaf seedlings. These lesions did yield C. gossypii when isolations were made from them.

Attempts to induce tip blight or other disease symptoms on more mature kenaf plants by inoculation with C. gossypii also failed.

Discussion

Because of the observed differences in pathogenicity, size of conidia, and rate of growth of the available isolates of C. hibisci and C. gossypii, it would appear that the two species are clearly different pathogens.

The readiness with which the isolates of C. hibisci used in these experiments infected the seedlings of Upland cotton, La. 33, indicated that C. hibisci may be a destructive parasite of cotton in the seedling stage. Whether C. hibisci could succeed as the causal agent of boll rot was not determined. A study of this problem at Ames was handicapped by the slow growth of the cotton plant and the late boll formation, as well as by a lack of annual rainfall greater than 40 inches which has been declared essential for the extensive development of boll rot.

To suggest that the superimposition of C. hibisci and C. gossypii in an area where cotton is cultivated would give rise to epiphytotics more virulent to cotton than any heretofore observed requires much further study.

Literature Cited

1. Haarer, A. E. 1952. Jute substitute fibres. Dorchester, England, Wheatland Journals pp. 6-9.
2. Crandall, B. S. and H. D. Lynn. 1954. The resistance of kenaf varieties, hybrids, and relatives to anthracnose. Plant Dis. Reporter 38:311-313.
3. Pate, J. B. et al. 1954. Kenaf in South Florida. The Gard. Jour. New York Bot. Gard. 4:41-41.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 63-69

VARIATION IN MINIMUM TEMPERATURES ON A HALF-MILE SLOPE AND THEIR EFFECT ON PEACH TREES[1]

R.H. Shaw and C.C. Doll[2]

The importance of site selection for orchards and vineyards is well recognized. Grapes are usually planted on south or east slopes to insure sufficient exposure to the sun for proper ripening of the fruit, but for stone fruits a north slope may prove advantageous because of the consequent delay in blooming. The effect of aspect of slope on climatic factors has been discussed by Aikman (1) for a particular area in southern Iowa. According to Geiger (5), different elevations along a slope have different minimum temperatures. In large valleys the lower levels are usually the coldest, the middle of long slopes usually the warmest. Adequate cold air drainage must also be present for good fruit culture, as shown by Aikman and Brackett (2).

Dormant peach fruit buds will normally withstand temperatures of -10° to -15°F (Childers, 3). Once growth has begun in the spring, they are much less hardy. However, variations in the ability of fruit buds to withstand freezing temperatures may be dependent upon many factors. Gardner, et al. (4) summarized the findings in this field by reporting that peach buds showing petal color may withstand temperatures of 20-29°F while those in blossom may withstand temperatures of from 25-30°F. After fruit-set, these minimums vary from 27-30°F.

The peach plantings at the Bluffs Experimental Fruit Farm are located on a 0.47-mile slope of a south and southeast exposure. This study was undertaken to evaluate the differences in minimum temperature which might be found at locations along this slope and the effect of these temperatures on peach trees. The temperatures as measured in the instrument shelter would be higher than those measured closer to the ground. The temperatures in the shelter could also be several degrees warmer than leaf temperatures, as pointed out by Shaw (6).

PROCEDURES

Three stations were located on the hillside; one at the top, one near the bottom, and the other at the Weather Bureau station approximately 44 per cent of the way up the slope (Fig. 1). The bottom station was 1080 air-line feet and 43 vertical feet below the Weather Bureau station on the slope. The top station was 1390 air-line feet and 117 vertical feet above the slope station; and 2470 air-line feet and 160 vertical feet above the bottom station. Standard Weather Bureau shelters were located at

[1]Journal paper No. J-3109 of the Iowa Agricultural Experiment Station, Ames, Iowa. Projects 955 and 1297.

[2]Associate Professor, Agricultural Climatology, Agronomy Department, and Assistant Professor, Horticulture Department, respectively.

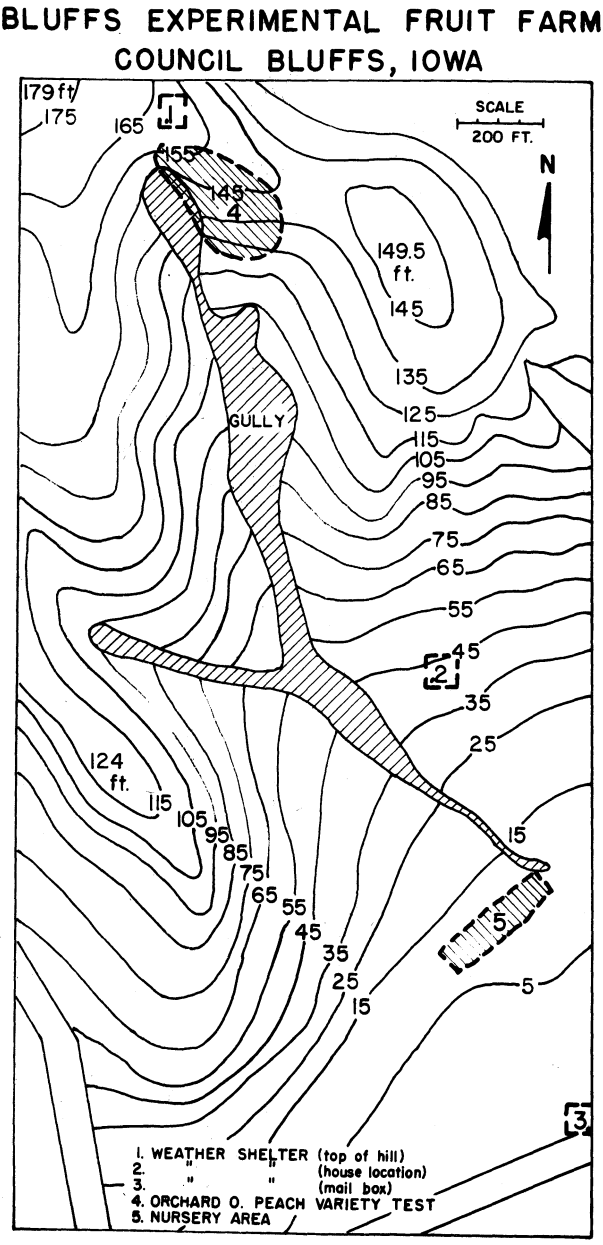


Fig. 1. Topographic Map of **Experimental Area.**

each station. In these shelters were located maximum-minimum thermometers and recording thermographs. The thermometers were read as frequently as was convenient, usually every few days, to provide data to edit the thermograph traces when necessary. The instruments were located at a height of about 4.5 feet above the ground. The period of observation was November 29, 1955 to May 15, 1956.

The peach varieties used in this study were numbered selections from the fruit breeding program of Iowa State College which were being tested for hardiness and quality. Two plantings of these varieties were made in 1948, one on the upper part of the slope (area 4) and the other near the base (area 5) (Fig. 1). Trees in area 4 were on terraces, whereas area 5 was level. Both areas had received the same cultural spray and pruning treatments in 1955. The ground was relatively bare as a result of trashy cultivation the previous season.

Cold damage to fruit buds was determined by sectioning through the buds with a razor blade. Buds were sampled from all areas of the trees. Dates of sampling were February 13 and 17, 1956. The reason for the second date was to increase the number of counts and treatments. Little or no additional damage was evidenced between these dates.

On the morning of April 24, temperatures dropped below freezing throughout the area. Temperatures ranged from 10-25°F on the slope with the lower figure being for the bottom location. This followed a warm period of temperatures up to 82°, which permitted the peach fruit bud to develop as far as 25 per cent of full bloom. All varieties showed pink and/or some bloom. A predominantly cool, cloudy period of 7 days followed these minimums so that the remaining flower development was slow. Full bloom for most varieties occurred between May 2 and May 7.

Counts of blossoms were made on May 2 irrespective of the stage of development or damage. Fruits were counted on the same branches on May 27 and fruit-set determinations were made. This latter date was after the first and second drop periods but prior to the third or June drop.

RESULTS AND DISCUSSION

Temperatures

Daily maximum and minimum temperatures were read from the thermograph traces. Only the minimum temperatures were analyzed for this paper.

As would be expected, the coldest temperatures were recorded at the low elevation station. The coldest temperature of the winter was recorded on the morning of February 3 when the temperatures recorded were: bottom station -20°F, on the slope -13°F, and on the top -9°F. A cold air mass moved into this area on the first; the afternoon of the second was clear with low winds and some light cloudiness during the night. Conditions were ideal for radiation cooling and stratification of the cold air in the valley. The official minimum temperature recorded at the Omaha Airport 6.3 air miles away was -6°F. The distribution of temperatures at the stations up the slope on other cold nights was -16,

Table 1. Comparison of minimum temperatures between three locations at Council Bluffs Fruit Farm, 4.5 feet above the ground, November 29, 1955, to May 15, 1956.

Temperature difference*	Number of occurrences		
	Bottom-Top	Slope-Top	Bottom-Slope
+6, +5	0	1	0
+4, +3	5	3	3
+2, +1	32	40	14
0	37	54	46
-1, -2	23	21	41
-3, -4	13	23	29
-5, -6	19	9	17
-7, -8	13	4	5
-9, -10	4	4	4
-11, -12	6	1	1
-13, -14	4	0	0
-15, -16	2	0	0
-17, -18	1	0	0
-19, -20	1	0	0

*Daily minimum temperature difference measured between locations

-14, -15 on January 19; -12, - 8, 0 on February 4; -11, -2, -6 on January 16; -9, -7, -4 on December 18. The lower elevation was always the coldest. Minimum temperatures reported from the Omaha Airport Weather Station were -8, +3, -3, and -1, respectively, for the same dates.

The differences in minimum temperatures recorded between the three elevations are summarized in Table 1.

Bottom vs Top

The lower location recorded temperatures as much as 20° colder than the top. On April 9, the temperature was 12° at the bottom and 32° on top. There were 14 nights out of 160 when the difference was greater than 10°. One of these nights occurred in December, 3 in January, 4 in February, 1 in March, and 5 in April. These differences could occur during any of these months when the meteorological conditions would give high radiation cooling at night with little mixing of the air from wind. There were 36 nights when the difference was 5° to 10°, and 110 nights when the temperatures were within 4° of each other. On some of these nights the bottom location was warmer, the maximum difference being 4°. On the few nights when the top location was 3-4° cooler, the sky was cloudy and at least moderate winds were blowing.

Slope vs Top

On 14 nights the slope and top were within 4° of each other. The slope was 12° colder on January 4, the largest difference which occurred. The 18 times the slope was 5-10° colder were distributed in all months observations were taken. All of these nights except one were clear all night, or the latter part of the night, and with low wind velocity. On February 2, the slope was 5° warmer than the top. This followed a cloudy windy night.

Bottom vs Slope

On 133 nights the slope and bottom were within 4° of each other. On 27 nights the bottom was 5° or more colder than the slope, with a maximum difference of 11°. Twenty-four of these nights were clear all night or most of the night and with relatively low wind velocities.

Effect on Peach Trees

Fruit Bud Counts

On February 3, the date of the winter minimums, the difference in temperatures between the two peach tree plantings was 11°. This difference is reflected in the percentage of buds surviving the low temperatures, as shown in Table 2. The per cent of live fruit buds in area 4 ranged from 75 to 99 per cent. In the nursery, area 5, these percentages were much smaller, 26 to 50 per cent. Colder temperatures greatly reduced the per cent of live fruit buds; however, the percentage in the nursery area would be sufficient for a crop of peaches if all were to blossom and bear fruit.

Table 2. Per cent of live fruit buds after winter minimums on February 3, 1956.

Date counted	Variety	Per cent of live fruit buds Area 4 (-9°)	Area 5 (-20°)
February 13	A123	96	38
	A126	81	26
	A130	99	33
February 27	A122	81	46
	A124	75	37
	A134	92	50

Fruit Set Determinations

The damage to blossom buds and blossoms by the freeze of April 24 resulted in decreased fruit set on all varieties, but the degree of damage depended somewhat upon the location of the trees, the minimum temperatures, and the stage of development of the blossom bud (Table 3).

Table 3. Per cent of blossoms setting fruit after 10-25° temperatures on April 23, 1956.

Date of full bloom	Variety	Per cent of blossoms setting fruit Area 4 (25°)	Per cent of blossoms setting fruit Area 5 (10°)
May 7, 1956	A123	47	44
May 2, 1956	A126	41	21
May 5, 1956	A130	48	19
May 2, 1956	A134	18	6

Variety A123 showed little difference in fruit set between the two locations and was apparently more resistant to the cold temperatures. Part of this resistance can be attributed to its habit of later blossoming. Variety A134 had a low percentage of fruit set at both locations. Varieties A126 and A130 showed greatly reduced fruit sets of 41 to 21 per cent and 48 to 19 per cent, respectively. The lower temperatures in the nursery area reduced the percentage of blossoms setting fruit, but there was also a large varietal difference.

SUMMARY

Temperature observations were taken at three locations on a slope at the Council Bluffs Fruit Farm. The elevation of the stations from the bottom were, bottom-0 feet, slope-43 feet, top-160 feet. The distance between the bottom and top location was 0.47 mile. The period of observation was November 29, 1955, to May 15, 1956.

The bottom location was as much as 20° colder than the top. On 14 of the 160 nights the difference was greater than 10°. On 110 nights the two locations were within 4° of each other. The bottom location was up to 11° colder than the slope. The cold air collected at the bottom of the slope by air drainage on calm, clear nights.

The per cent of live fruit buds of peaches at two locations was closely related to a freeze on February 3. At one location where a minimum of -9° occurred, the per cent of live fruit buds on several varieties ranged from 75 to 99 per cent. In another area where a minimum of -20° occurred, these ranged from 26 to 50 per cent. A varietal resistance to freezing temperatures was apparent by the number of blossoms setting fruit showing a great varietal difference. At the location which had a minimum of 25° on April 23, fruit set ranged from 48 to 18 per cent; at the other location which had a minimum of 10°, fruit set ranged from 44 to 6 per cent. One variety, which was 2-5 days later in blooming, had the highest per cent of fruit set.

This study again shows the necessity of locating fruit plantings where adequate air drainage is present.

LITERATURE CITED

1. Aikman, J. M. 1941. The effect of aspect of slope on climatic factors. Iowa State Coll. Jour. Sci. 15:161-167.
2. _____ and G. L. Brackett. 1944. Microclimatic differences in minimum temperature and variations in frost injury to hillculture plants. Iowa Acad. Sci. 51:147-156. 1944.
3. Childers, N. F. 1949. Fruit Science. p. 310. Lippincott Pub.
4. Gardner, V. R., F. O. Bradford, and H. D. Hooker. 1952. The fundamentals of fruit production. p. 452. McGraw-Hill.
5. Geiger, R. 1950. The climate near the ground. Harvard University Press.
6. Shaw, R. H. 1954. Leaf and air temperatures under freezing conditions. Plant Physiol. 29:102-104.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 71-88

REPRODUCTION AND GROWTH OF FISHES IN MARION COUNTY, IOWA, FARM PONDS[1]

Robert B. Moorman

Department of Zoology and Entomology
Iowa State College, Ames

During an investigation of the condition of fish populations in Marion County farm ponds, data and scales were collected from many of the fish to give a picture of the growth rate of pond fish in this region. Such information is needed to provide the farmer with a guide as to the sizes of fish which he may expect from his farm. The data also give clues as to the effects of certain features of pond construction and pond management upon the growth of fishes.

Largemouth Black Bass

The largemouth black bass has been widely recognized and utilized as the predatory species in fish combinations for warm-water ponds (4, 24). Bass grow rapidly under favorable conditions with an abundant food supply and they serve as a control on the large numbers of fry produced by other fishes. An indication that even young-of-the-year bass may be active predators was obtained at Pond 6 on July 15, 1950, where both young white crappies and young black bullheads were found in the distended stomachs of young-of-the-year bass.

During the investigation, varying numbers of bass were collected from 19 ponds. Collections were made primarily with seine, but in some cases by treatment of the pond with rotenone or by trapping and angling. Since bass were not readily taken by seine, most of the ponds are represented by small numbers of bass and by unequal size and age distribution of those collected. As a result, the data from all of the ponds have been combined for most of the study.

Age and growth

Length-weight. The length-weight relationship was determined for 257 bass varying in length from 3.5 inches to 17.5 inches. Fish less than 3.5 inches in total length were not included in the computation because it was felt that the 500 gram capacity balance used was not

[1]From Project 37 of Iowa Cooperative Fisheries Research Unit sponsored by the Iowa State Conservation Commission and the Industrial Science Research Institute of Iowa State College with the cooperation of the U.S. Fish and Wildlife Service. Part of a thesis filed in partial fulfillment of requirements for the degree Ph.D. The entire thesis "Fish populations in some Iowa farm ponds in relation to past history and management," submitted in 1953, is on file in the College Library.

completely reliable at the smaller weights. The length-weight equation in logarithmic form for the bass is:

$$\text{Log } W = -1.450 + 3.136 \text{ Log } L$$

where W = the weight in hundredths of pounds
and L = the total length in inches.

As indicated by the formula, individual bass increased in weight somewhat more rapidly than the cube of the total length. Because of the relatively few fish ten inches and larger involved in the computations, the formula will probably give estimated weights with less accuracy in that size range than in the smaller sizes.

Condition factors. The condition factors or ponderal indices, as a measure of relative plumpness, were computed for the 257 bass included in the length-weight determination (Table 1). There is a general tendency for larger condition factors and therefore greater plumpness to be associated with the larger fish, as would be expected since the weight increased more rapidly than the length cubed. The largest fish listed did not have the largest condition factor however. The largest condition factor determined for any individual bass, 82.5, was for an Age Group III fish measuring 12.2 inches, and the lowest factor, 27.3, was for an Age I fish measuring 3.8 inches from the heavy population of yearling bass in Pond 25.

Comparison of these condition factors with those of bass from other areas indicates that the bass in the present study were in relatively poor condition (10). Bennett (7) sets the following standards for condition factor, C, for the largemouth black bass: poor 35-45; average 46-55: good 56-85. The low mean condition factor of 43.3 may indicate a shortage of food or unavailability of food under a situation such as muddy water.

Growth. In the study of growth it was assumed that the generally accepted scale method (11, 26) was valid for bass from farm ponds. Evidence that supports this assumption is as follows:

1. There is correlation between the size of the fish and its age, both from individual ponds and from ponds as a whole.

2. A dominant year-class observed as young-of-the-year in 1949 in Pond 25 could be followed in 1950 and 1951 and had gained an annulus each year (Table 2).

3. In those ponds where the bass were of known age, there was complete agreement between the number of annuli and the known age. In Ponds 13, 33, 43, 51, and 59 the bass captured were of known age under conditions such that there was little likelihood of confusing them with bass of younger ages.

Since about one-third of the bass from which scales were collected came from Pond 25, a pond which was classed as being overcrowded with bass, the growth data for this pond (Table 3) are given separately from that for the other ponds (Table 4). In Pond 25 the 1949 class

Table 1. Total length, weight, and condition of largemouth black bass, 19 farm ponds, Marion County, Iowa, 1950 and 1951.

Mean total length, inches	No. of fish	Mean weight, pounds	Mean condition C (T.L.)**	Estimated weight*, pounds
3.8	18	0.021	39.7	0.023
4.0	19	0.030	41.5	0.027
4.7	78	0.040	40.0	0.045
5.1	40	0.057	41.7	0.059
5.7	13	0.069	40.5	0.083
6.1	13	0.103	44.2	0.103
6.7	5	0.149	49.4	0.138
7.2	2	0.180	48.1	0.173
7.6	6	0.193	43.4	0.205
8.2	13	0.267	47.9	0.260
8.6	8	0.293	46.1	0.302
9.1	5	0.342	44.7	0.361
9.5	1	0.494	57.8	0.413
10.4	1	0.540	41.1	0.549
10.9	1	0.625	48.3	0.636
11.0	4	0.677	50.5	0.654
11.6	7	0.822	52.2	0.773
12.2	5	0.980	53.7	0.906
12.6	3	0.939	47.3	1.00
13.1	1	1.25	55.6	1.13
13.6	7	1.08	51.8	1.27
14.0	2	1.64	60.4	1.39
14.6	2	1.75	56.8	1.59
15.2	2	1.55	43.7	1.80
17.5	1	2.56	47.9	2.80
Total	257		Mean 43.3	

*Log W = -1.450 + 3.136 Log L

** $C = \frac{W \times 1000}{L^3}$ where W = weight in hundredths of a pound and L = total length in inches.

Table 2. Observed total lengths of 1949 year-class of largemouth black bass, Pond 25, during a three year period.

Date of capture	Number of fish	Mean total length in inches	Age in years
June 28, 1949	17	2.3	0
July 12, 1949	25	2.9	0
June 15, 1950	15	4.0	I
July 20, 1950	119	4.9	I
July 10-11, 1951	13	8.3	II

showed very slow growth, but the older bass grew very rapidly after they were large enough to eat the middle-sized bluegills and bass.

When compared with rates of growth reported for other bodies of water it is seen that the bass from Iowa ponds other than Pond 25 show above average growth (10). The fish at Onized Lake, Illinois, as reported by Bennett (5) were under heavy fishing pressure by anglers and apparently were at less than the full carrying capacity of the lake, and were thus able to make large gains in growth. Somewhat the same explanation may be possible for the rapid growth in Iowa farm ponds, since many of the ponds were young in years and may not have been at full carrying capacity.

Table 3. Calculated and measured total lengths of 44 largemouth black bass from Pond No. 25, Marion County, Iowa.

Year collected	Age class	Number of fish	Average calculated length in inches at annulus 1	2	3	4	Length at capture
1950	I	29	3.4				4.7
	III	4	4.2	8.1	13.0		13.1
	IV	1	4.2	8.7	10.8	13.5	14.0
1951	II	10	2.9	5.7			8.4
Mean total length, inches			3.4	6.6	12.5	13.5	
Annual increments			3.4	3.2	4.3	2.7	
Sum of increments			3.4	6.6	11.0	13.7	

Table 4. Calculated and measured total lengths of 93 largemouth black bass from 18 farm ponds, Marion County, Iowa, 1950 and 1951.

Age class	Number of fish	Average calculated length in inches at annulus 1	2	3	4	5	Length at capture
I	62	5.5					7.5
II	7	4.1	9.0				10.0
III	13	5.3	9.6	12.8			13.5
IV	9	4.6	8.7	11.7	13.3		13.8
V	2	3.8	8.4	10.2	12.7	14.3	15.2
Mean total length, inches		5.2	9.1	12.2	13.2	14.3	
Annual increments		5.2	4.4	3.0	1.8	1.6	
Sum of increments		5.2	9.6	12.6	14.4	16.0	

Reproduction

Swingle and Smith (25) have reported the minimum weight of bass for spawning to be five to six ounces. On the basis of the Iowa pond data, such bass would be approximately nine inches in total length. On the average, this size is reached sometime during the third summer of life and probably near the end of the growing season. The minimum spawning size is therefore probably reached too late for the spawning period that year, and such bass would first reproduce as three year old fish (in their fourth year of life). Our data show that in the newly stocked ponds, the bass customarily spawn as two year old fish. In 17 newly stocked ponds where bass were known to have survived and where inspections were made in subsequent years, successful spawning occurred in each during the second spring following stocking. These bass were all stocked as fingerlings in the fall. Bennett (6) found bass from Fork Lake, Illinois, sexually mature at two years of age. Dugan (12), in six experimental farm ponds in West Virginia, found bass reproducing the second summer after stocking in three ponds, the year after stocking in one pond, and reproducing for the first time during the third year after stocking in two ponds. Both of the last-mentioned ponds had existing populations of other species of fish at the time of stocking, so that the delayed spawning may have been an end result of competition for food and space.

The onset of spawning by largemouth black bass apparently follows the spring rise in water temperatures to 70°F (22). Spawning periods reported for the bass include: April-June for Alabama (25); May for Fork Lake, Illinois (6); prior to May 28-June 18 for Deep Lake, Michigan (9). Because spawning dates were never specifically investigated for the Iowa ponds, little information is available other than that the year's hatch of young bass was usually present in the ponds by late June.

After the first reproduction of bass occurred in a pond, reproduction generally occurred each year thereafter, except where the fish were decimated by winterkill or other causes. Data on 17 ponds, for years following a season of successful spawning of both species stocked, show only three instances where bass did not spawn annually and for which there is no clear explanation. In Pond 18 both bass and bluegills reproduced in 1948 and in 1951, but the bass did not do so in the two intervening years, 1949 and 1950. In Pond 27 both species reproduced in 1947 and 1949, but the bass did not reproduce in 1948. Pond 25 showed a similar pattern, with bass reproducing in 1949 and 1951 but not in 1950. Bass populations in Iowa ponds are apparently more successful in spawning than are those in Indiana ponds, for which Krumholz (16) reported successful spawning only one year in every two on the average.

Bluegill

The bluegill serves the role of forage fish in farm ponds. It grows to a larger size than many of the other sunfishes and spawns intermittently throughout the summer months, thereby providing a succession of food for the bass with which it is customarily stocked (24).

Collections of bluegills were made from 19 ponds at the same time and in the same manner as the collections of bass. The data have been combined briefly to furnish a generalized picture of Iowa ponds followed by data from individual ponds.

Age and growth

Length-weight. The length-weight relationship was determined for 1435 bluegills varying in length from 3.5 inches to 8.6 inches. The lower size limit was chosen somewhat arbitrarily to reduce weighing errors with the balance used, and the upper limit denotes maximum size of the bluegills captured. The length-weight equation in logarithmic form for the bluegill is:

$$\text{Log } W = -1.360 + 3.282 \text{ Log } L$$

where W = the weight in hundredths of pounds
and L = the total length in inches.

As indicated by the formula the weight of bluegills increased somewhat more rapidly than the cube of the length (Table 5). On the average, bluegills reach a weight of one-fourth pound at a length of approximately 7.0 inches, and a weight of one-half pound at 8.5 inches. A weight of one-fourth pound corresponds to what Bennett, Thompson, and Parr (8) have defined as "desirable size" for bluegill, representing the minimum size for table use.

Condition factors. Condition factors or ponderal indices were computed for the 1435 bluegills over 3.5 inches (Table 5). As is to be expected from the length-weight formula, relative plumpness tends to increase with an increase in length. The range for condition factors for

Table 5. Total length, weight, and condition of bluegills, 19 farm ponds, Marion County, Iowa, 1950 and 1951.

Mean total length, inches	Number of fish	Mean weight, pounds	Mean condition C (T.L.)	Estimated weight, pounds *
3.7	238	0.033	66.2	0.032
4.2	198	0.049	65.7	0.049
4.7	217	0.069	65.8	0.070
5.2	219	0.095	68.4	0.099
5.7	229	0.134	71.5	0.132
6.2	192	0.172	74.5	0.174
6.7	87	0.225	75.6	0.225
7.2	50	0.282	76.6	0.285
7.9	45	0.366	78.0	0.386
8.2	22	0.423	78.7	0.436
8.6	4	0.539	86.2	0.510
Total	1435	Mean	69.7	

*Log W = -1.360 + 3.282 Log L

individual bluegills is from a low of 36.2 for a 4.0 inch fish from Pond 5 to a high of 104.5 for a 3.9 inch fish from Pond 18. The mean condition factor of all of the bluegills is 69.7, which, on the basis of the standards suggested by Bennett (6), is intermediate between poor and average plumpness. Bennett demonstrates that the average condition of a population of bluegills fluctuates seasonally, with a characteristic high level of condition in May and a low one in November. To compare condition factors for several populations it is therefore necessary, not only that they be for similar length ranges, but that the collections of data be for similar seasons of the year. Since most of the fish listed in Table 6 were collected from mid-June to August, the seasonal differences are probably not great.

Growth. Data on growth of bluegills in Marion County farm ponds are based on the study of scales taken from 567 fish from 12 of the ponds during 1950 and 1951. Assessment of age and calculation of total length for various years of growth was by the methods outlined in the discussion of the largemouth black bass. The ponds are separated into groups for presentation and discussion of the data (Table 7).

The first group are those ponds having a succession of age classes of both bass and bluegills and judged to be in balance according to the definition of Swingle (23). The ponds most productive of fishing are in this group, but also included are two where fishing pressure was almost nonexistent. Growth in this group of ponds was generally good, with total lengths at successive annuli of 1.7, 4.1, 6.1, and 7.0 inches. Bluegills in all the ponds were relatively young; only Pond 6 contained any bluegills 4 years of age or older.

Pond 2, stocked 5 and 6 years prior to sampling, was treated with rotenone, and all fish other than young of the current year were collected. White crappies and black bullheads were present in addition to bass and bluegills, and the crappies were apparently more nearly dominant than were the bluegills. The presence of brush and rock "shelters" in the pond may have favored the crappies, and the competition of the crappies and bullheads combined held bluegills growth to less than the mean for other balanced ponds. Bluegills 5.5 inches or more long made up 80 per cent of all the bluegills over one year of age.

Pond 6, stocked in 1944, was sampled in both 1950 and 1951, by seining and angling. It contained bass, bluegills, white crappies, and black bullheads. While bass appeared to dominate the pond, the crappies were numerous and successful in reproducing annually. By size and weight they appeared more successful than the bluegills, although the bluegills were more abundant. Rates of growth of the bluegills for the two years of collection varied, with the 1950 collection showing the more rapid growth. Bluegills of age classes I and II predominated in numbers both years, the samples showing few three-year-old fish. Bluegills 5.5 inches long and longer made up 14 to 17 per cent of all bluegills in the samples. Population estimates for bluegills varied from approximately 1500 in 1950 to 1500-2500 fish in 1951. Pond 6 was 0.7 acre in area.

Pond 12 contained bass, bluegills, and golden shiners, with the golden shiners few in number and of small size and probably of a single recent age class. Probably the bass consumed the annual production of young golden shiners each year. Fishing for bluegills was uncontrolled at this pond and heavier than that at almost any other pond. Bluegills after their first year grew at a more rapid rate than the means for all ponds in the table. Fifty per cent of all the bluegills over one year of age were 5.5 inches or longer.

Pond 33 contained bass, bluegills, and black bullheads. The bullheads appeared more numerous than the bluegills and all of them were more than 7 inches long. Young bullheads produced in 1950 had vanished by 1951 and were presumed eaten by the bass. The water in the pond was always roily with mud attributed to the bullheads. The original stocking of bass displayed poor growth, being only 10 to 12 inches long at four years of age. The growth rate of bluegills was only slightly better than that of the unbalanced ponds, and only 11 per cent of the bluegills were 5.5 inches long or better.

The bluegills in Pond 45 showed a more rapid growth rate than those in any other pond. Total lengths at various annuli calculated from the 1950 collection of bluegills were 3.4 inches, 6.2 inches, and 7.3 inches for the first three years of life. The growth rate determined from the 1951 collection was similarly rapid. For several years prior to 1946 this pond reportedly produced bluegills up to 11 inches long, but the present collections included no bluegills over 8.5 inches. Growth of bass was also rapid, with fish of Age Group III being 13.5 to 15.0 inches

Table 6. Comparison of condition factors for bluegills from various midwestern localities.

Authority	Locality	Range in total length (inches)	Range in subgroup mean C's	Mean C
Beckman, (3)	Michigan lakes	1.4-10.0	56-75	-
Present study	Iowa farm ponds	3.5-8.6	65.8-86.2	69.7
Lewis, (18)	Iowa, Red Haw Lake	2.2-10.6	-	70.4*
Lewis, (18)	Iowa, East Lake	2.5-8.5	-	69.4*
Ruhr, (20)	Iowa, Ike Lake	3.0-8.4	61.0-91.9	64.1
Hennemuth, (15)	Iowa, Lake Ahquabi	3.0-7.0	67.2-75.8	69.9

*Data converted from K(S. L.) to C(T. L.) by use of formula

$C = 36.1\ r^3 K_m$

where r = ratio of standard length to total length for the population concerned

and K_m = coefficient of condition in the metric system.

long. Populations of both bass and bluegills were heavy, with estimates of 800 to 1200 fish for the 0.3 acre pond. Bluegills over 5.5 inches made up 23 per cent and 54 per cent of the 1950 and 1951 collections, respectively.

Pond 51 is included with the balanced populations on the basis of successful reproduction of both bass and bluegills, although one year was missing from the sequence for both species. The pond was in its fourth summer when collections of fish were made, and the original stocking of bass and bluegills had reached 15.4 inches and 6.7 inches total length, respectively. Growth of bluegills generally was near the mean for all the balanced populations. Fish over 5.5 inches long made up 43 per cent of the bluegills captured in 1950.

Pond 57 was continuously muddy with fine suspended clay. Populations of both bass and bluegills seemed low and the rate of growth for bluegills was somewhat less than the mean for all balanced ponds. Forty-seven per cent of the bluegills were 5.5 inches or more long.

The ponds grouped as having unbalanced populations are those having a history of interrupted sequence of bass and bluegill reproduction, although both species may have been present in the pond as adults or subadults. The fish populations in these ponds are judged to have been unsatisfactory for sustained production of harvestable fish. None of these ponds were fished to any extent, although one of them contained harvestable size bluegills. The rate of growth of bluegills in these ponds was noticeably slower than in the balanced ponds. The means for total length at successive annuli are 1.2, 3.0, 5.0, and 5.8 inches. Four-year-old bluegills were present in fair numbers in two of the four ponds listed in Table 7 as having unbalanced populations.

In Pond 14, successful reproduction of bass and bluegills occurred in the same year only once in the first seven years after stocking. Additional bass were stocked two years after the first stocking and these reproduced for the first time in their fourth summer. Two of the 15 bass in the second stocking were removed in 1949 and may have left few bass to serve as predators, as bullfrog tadpoles were abundant in the pond the following year. Bluegills reproduced four years in the last five of record, and the oldest fish had attained a length of only 5.4 inches by the end of their fourth year of life. The 1950 bluegill population over 3.5 inches long was estimated at 886 fish for the half-acre pond. Black bullheads were present in the pond but seemed few in number and, so far as is known, did not reproduce in either 1950 or 1951.

Bluegills in Pond 18 showed the best growth of any unbalanced pond, with the original stocking of bluegills reaching 6.8 inches at the end of their fourth year. The young bluegills produced the summer following stocking also showed relatively good growth, while bluegills of the next two-year classes showed poor growth. The water was constantly muddy with suspended fine clay and was relatively cold in temperature (68°F at one meter depth in mid-day on August 28, 1951). Bass of the original stocking reproduced the second summer, and then skipped two years before producing young again. The bluegills reproduced every year, 1946-1951. In 1950, 47 per cent of the bluegills were 5.5 inches long or longer, all of them members of the year-classes of the original stocking and the year following. In 1950, the population of bluegills 3.5 inches and longer was estimated at 123 fish. The first young bass produced in the pond were seven to nine inches long in their third summer, indicating rather poor growth.

Data for Pond 30 indicate that winterkill must have occurred with some regularity. Three years after the original stocking of bass, bluegills, and bullheads, a second stocking of bass was made, but was apparently not entirely needed to populate the pond, since a very heavy crop of young bass was produced the following year. The fourth winter after the second stocking, winterkill occurred and a third stocking was made to replenish the bass. Bluegills reproduced successfully in all but one of the five years of record. Bullheads were abundant in 1949 and 1950 and a total of 80 pounds were removed by seine in those two years in attempts to bring the population under control. Bluegills of the 1947 year class predominated in the 1950 collection of fish, with individuals 5.5 inches or longer making up 41 per cent of all those collected. Growth was rapid for the first two years of life and slow for the third, an indication that probably two growing seasons were necessary to bring the depleted population to carrying capacity following winterkill. Population estimates were, in 1947, 682 bluegills and 253 bullheads and, in 1950, 81 to 172 bluegills and 49 to 78 bullheads. The pond area was 0.3 acre.

The data for Pond 43 present a somewhat special case in that the collection of fish in 1950 revealed only one fish more than one year old. No bluegill was over 5.5 inches in total length although the pond had been stocked for four years. The pond was continually muddy with fine clay, and black bullheads outnumbered the bluegills in the 1949 seining at a ratio of eight to one. The original stocking of bass reproduced for the first time as three year old fish.

Table 7. Growth summaries for bluegills in Marion County farm ponds.

Pond number	Number of fish	Average calculated length at each annulus in inches			
		1	2	3	4
Balanced population					
2	29	1.8	3.7	5.2	
6 (1950)	51	1.4	4.1	6.6	
6 (1951)	68	1.0	3.0	5.2	7.0
12	29	1.6	4.8	7.1	
33	33	1.1	3.7	6.2	
45 (1950)	48	3.4	6.2	7.3	
45 (1951)	51	3.3	6.1	7.5	
51	33	1.6	4.1	6.1	
57	32	1.0	3.9	5.9	
Combined	374	1.7	4.1	6.1	7.0
Overcrowded with bass					
25	40	1.5	4.4	6.1	7.1
Unbalanced population					
14	46	0.9	2.6	4.3	5.4
18	42	1.1	3.2	5.7	6.8
30	43	1.7	3.3	4.8	
43	22	1.5	3.8		
Combined	153	1.2	3.0	5.0	5.8

Growth data for Pond 25 are listed separately as an example of bluegill growth in a pond over-populated with bass. In 1947 the pond was judged as becoming over-populated with bass, and in 1949 a large hatch of bass occurred that dominated the pond for that and the following two years. Bluegills reproduced successfully in small numbers each year except 1950. They probably were successful the following year, 1951, only because winterkill had reduced the number of bass in the pond, lessening the pressure by predators. Seining showed few bluegills in the pond in any one year and such bluegills were usually large in size. Growth was rapid, particularly in the last two years of study, with the length means at successive annuli being 1.5, 4.4, 6.1, and 7.1 inches. The largest bluegill collected in any of the ponds studied, 8.6 inches, was from this pond.

Growth rates for bluegills in the present study rank well by comparison with other bodies of water (10). Growth in the balanced ponds and in Pond 25 is equal to that of other Iowa impoundments (15, 18, 20) and is generally superior to that of the other midwestern lakes listed.

Reproduction

Bluegills have been reported as spawning at one year of age if, at that time, they weighed one-half ounce or more (25). Bluegills of that weight in Iowa farm ponds would be approximately 3.5 inches in total length. So far as is known this minimum size was reached and bluegill reproduction occurred in all newly stocked ponds the summer following stocking. The minimum size was not normally reached by yearling bluegills in other ponds where the stocking was several years old.

The time of spawning by bluegills has been reported as ranging from May to August for midwestern lakes (7, 19). In the Iowa ponds young bluegills could usually be collected with a minnow seine by late June or early July. In four instances, however, (Ponds 6, 14, 30, and 43), young could not be located in early summer but were found readily by an August inspection (Ponds 6, 14, 43) or fish of a corresponding age class turned up in collections the following year (Pond 30). Water temperatures less than 80°F (22) or overcrowding (25) may be responsible for late spawning of bluegills. The latest known hatching of bluegills was in Pond 43 in 1951, where abundant bluegills three-fourths inches long were found October 11th. On the basis of development stages given by Morgan (19) these bluegills would be at least four weeks old, with a probable hatching date of September 13 or slightly earlier. Of course, it is possible that growth for the season had already ceased or slowed down considerably, in which case the hatch was somewhat earlier.

After bluegills reproduced for the first time in a pond, they generally reproduced successfully each year, except where prevented by winterkill or other cause. In Pond 25 the failure of bluegill reproduction was probably due to the heavy population of bass. Failure in Pond 30 for the year 1948 and Pond 51 for 1951 followed possible winterkill conditions. Cause of the failure in Pond 6 for 1951 is unknown but may possibly have been caused by human interference as an intensive trapping program using wire traps was carried on throughout the month of August. As implied under the discussion on delayed spawning, and as suggested by Ball and Tait (2), low temperatures may also be involved in failures to spawn. In some northern waters (1, 16) bluegills may not spawn at all in certain years.

White Crappie

In farm fish ponds the white crappie has a role intermediate between a predator and a forage fish (24). Bennett (4) regards the white crappie as well suited to artificial lakes, where it reproduces very successfully, but where its numbers must be reduced at intervals to prevent stunting.

Records show that white crappies were part of the original stocking in seven of the 60 ponds. When first inspected during the present study, two of these ponds no longer contained any crappies and one additional pond contained crappies apparently stocked supplementarily. One of

Table 8. Total length, weight, and condition of white crappies, Pond 2 and Pond 6, Marion County, Iowa, 1950.

Mean total length in inches	Number of fish	Mean weight, pounds	Mean condition C (T.L.)	Estimated weight, pounds *
Pond 2				
3.8	2	0.023	41.9	0.025
4.2	6	0.038	51.3	0.035
4.7	18	0.051	49.1	0.050
5.1	11	0.065	48.9	0.065
7.2	2	0.193	51.7	0.196
7.8	2	0.251	53.0	0.253
8.2	4	0.301	54.5	0.298
8.6	3	0.340	53.4	0.345
9.1	1	0.403	53.6	0.415
10.4	1	0.782	69.5	0.638
10.6	1	0.608	51.1	0.676
11.2	1	0.756	53.8	0.808
Pond 6				
5.8	1	0.079	40.5	0.079
6.9	2	0.131	39.8	0.137
7.3	39	0.170	43.7	0.164
7.7	59	0.203	44.5	0.194
8.1	4	0.218	41.0	0.227

*Pond 2: $\text{Log } W = -1.458 + 3.208 \text{ Log } L$
Pond 6: $\text{Log } L = -1.528 + 3.177 \text{ Log } L$.

these, Pond 23, was no longer suitable for fish and another, Pond 7, contained such an unbalanced population that it was deemed valueless for study and was never again visited. All four of the remaining ponds contained reproducing populations of crappies, and Ponds 2 and 6, where collections were made, showed crappies reproducing almost annually.

Age and growth

Length-weight and condition. The length-weight relationships for crappies taken from Ponds 2 and 6 in 1950 were calculated separately and the following formulae in logarithmic form obtained:

(1) Pond 2: $\text{Log } W = -1.458 + 3.208 \text{ Log } L$
(2) Pond 6: $\text{Log } W = -1.528 + 3.177 \text{ Log } L$

where W = the weight in hundredths of pounds
and L = the total length in inches.

As indicated by the formulae, the weight of white crappies in both ponds increased more rapidly than the cube of the length. The Pond 2 crappies weigh noticeably more for their length than do Pond 6 crappies (Table 8). The condition factors, C, also indicate greater relative plumpness for the Pond 2 fish. Since the collections of crappies from both ponds were made in early August of the same year (1950) there is little likelihood that seasonal fluctuations in condition could be responsible for the observed differences, as was demonstrated for coefficient of condition, K, for white crappies from Lake Decatur, Illinois (14). The crappies from the two ponds were intermediate in plumpness when compared with crappies from a northern Iowa natural lake (13) and three southern Iowa impounded lakes (15, 18).

Growth. The growth of crappies in Pond 2 and Pond 6 ranks relatively poor when compared with the growth rates for other midwestern waters (10). It apparently takes about three growing seasons to produce a six-inch crappie, a minimum desirable or harvestable size.

Reproduction

White crappies apparently stocked as yearlings from a nearby stream reproduced the year following in Pond 2. In Pond 6 where they were stocked as fingerlings, crappies first reproduced as two year olds. Spawning occurred every year in Pond 2 but was intermittent in Pond 6, with no visible reproduction in 1948 and 1949.

Black Bullhead

The bullhead has long been used in stocking ponds and artificial lakes because it reproduces successfully and is easily caught by inexperienced fishermen with simple tackle. Its feeding habits on muddy bottoms have brought it general accusations of being the cause of roiliness in the waters of shallow lakes and ponds. Furthermore, bullheads usually become overcrowded and stunted when bass predation is not adequate.

Age and growth

Length-weight and condition. Black bullheads occurred in fair numbers in some ponds in association with bass and bluegills. Length-weight data for 244 bullheads from seven ponds were combined (Table 9). Minimum desirable size for bullheads is about six inches, at which time they weigh approximately one-tenth pound. The condition factors, C, show a slight tendency toward increase in value with an increase in length of the fish.

Growth. No attempt was made to determine age of the bullheads by analysis of the growth rings on the vertebrae as done by Lewis (17) for the bullhead or on the spines as done by Sneed (21). Size classes of bullheads present in any one pond normally covered such a short range that there seemed to be only a single age class present. Therefore approximate ages of the fish could not be secured from length frequencies.

Table 9. Total length, weight, and condition of black bullheads, seven farm ponds, Marion County, Iowa, 1950 and 1951.

Mean total length in inches	Number of fish	Mean weight, pounds	Mean condition C (T.L.)	Estimated weight, pounds *
3.5	1	0.024	56.0	0.021
4.3	2	0.039	49.8	0.038
4.5	3	0.041	45.3	0.044
5.7	2	0.089	49.1	0.091
6.3	13	0.115	43.8	0.124
6.7	47	0.136	44.2	0.150
7.3	51	0.181	47.6	0.194
7.7	78	0.217	47.7	0.229
8.1	32	0.268	49.7	0.267
8.6	9	0.326	50.6	0.320
9.0	3	0.398	53.9	0.369
9.6	2	0.470	53.0	0.450
10.4	1	0.626	55.7	0.575
Combined	244		51.6	

*Log W = -1.3518 + 3.0596 Log L.

In Pond 27 after a severe winterkill in 1949-1950 eliminated most of the other fish, bullheads were able to spawn successfully for the first time in several years. By late June of the following year these fish were all approximately five inches long.

SUMMARY

1. The bass in the present study were in relatively poor condition compared with bass from other areas, but grew more rapidly than those from other Iowa impoundments and better than the average of those from some midwestern lakes. The length-weight relationship of the largemouth bass was best described by the equation:

$$\text{Log } W = -1.450 + 3.136 \text{ Log } L$$

which indicates that the weight of an individual bass increased somewhat more rapidly than the cube of the total length. They reached minimum spawning size during their third summer and probably spawned for the first time the following spring. Bass in newly stocked ponds grew more rapidly and usually spawned as two-year olds. There was successful spawning each year in most ponds.

2. The bluegills from the farm ponds were poor to average in relative plumpness. The length-weight relationship of the bluegill was best described by the formula:

$$\text{Log } W = -1.360 + 3.282 \text{ Log } L$$

which indicates that the bluegills increased in weight somewhat more rapidly than the cube of the total length. Growth of bluegills in ponds having balanced populations was generally good, total lengths at successive annuli being 1.7, 4.1, 6.1, and 7.0 inches. Growth in ponds not displaying balanced populations was noticeably slower. In new ponds bluegills usually reached spawning size at one year of age, but growth in established ponds was slower, and bluegills probably did not spawn until two years old. In the Iowa ponds the time of spawning was shown to vary widely and in some cases there was no apparent hatch of bluegills until August.

3. White crappies seemed to reproduce almost annually in Iowa farm ponds. The weight of crappies increased slightly more rapidly than did the cube of the length. Crappies from two of the ponds were intermediate in plumpness when compared with those reported in other Iowa studies. Growth of the crappie was rather slow in the ponds studied, three growing seasons being necessary to produce a fish of harvestable size. Black bullheads in most ponds were represented by only a single age group.

Acknowledgments

The author is grateful to the farmers who permitted work in their ponds and to the technical personnel of the Marion County Soil Conservation District. Particular thanks are due Mr. Harlan J. Chandler of the S.C.S. whose enthusiastic cooperation and aid in the field made the work so enjoyable. Dr. Kenneth D. Carlander supervised the research and preparation of reports. Thanks are also extended C.E. Ruhr, Paul Osborn, and John Lawrence for their aid in the field.

Literature Cited

1. Ball, Robert C. 1952. Farm-pond management in Michigan. Trans. 17th North Amer. Wildlife Conf. 221-225.
2. _____ and Howard D. Tait. 1952. Production of bass and bluegills in Michigan ponds. Michigan Agric. Exp. Sta. Tech. Bull. 231.
3. Beckman, W.C. 1948. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Amer. Fish. Soc. 75:237-256.

4. Bennett, George W. 1943. Management of small artificial lakes. Illinois Nat. Hist. Survey Bull. 22:357-376.
5. _____. 1945. Overfishing in a small artificial lake. Onized Lake near Alton, Illinois. Illinois. Nat. Hist. Survey Bull. 22:373-406.
6. _____. 1948. Review of "Fish ponds for the farm" by Frank C. Edminister. Jour. Wildl. Mgmt. 12:215-217.
7. _____. 1948. The bass-bluegill combination in a small artificial lake. Illinois Nat. Hist. Survey Bull. 24:377-412.
8. _____, David H. Thompson, and Sam Parr. 1940. Lake Management reports. 4. A second year of fisheries investigations at Fork Lake, 1939. Illinois Nat. Hist. Survey Biol. Notes 14.
9. Carbine, W.F. 1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th North Amer. Wildl. Conf. 275-287.
10. Carlander, Kenneth D. 1953. Handbook of freshwater fishery biology with the first supplement. Wm. C. Brown Co., Dubuque, Iowa.
11. Creaser, Charles W. 1926. The structure and growth of the scales of fishes in relation to the interpretation of their life history, with special reference to the sunfish (Eupomotis gibbosus). Univ. Michigan Mus. Zool. Misc. Publ. 17.
12. Dugan, R. Franklin. 1951. Fish production records on some West Virginia farm ponds. Trans. 16th North Amer. Wildl. Conf. 403-421.
13. Erickson, James G. 1952. Age and growth of the black and white crappies, Pomoxis nigro-maculatus (LeSueur) and P. annularis Rafinesque, in Clear Lake, Iowa. Iowa State Coll. Jour. Sci. 26:491-505.
14. Hansen, Donald F. 1951. Biology of the white crappie in Illinois. Illinois Nat. Hist. Survey Bull. 25:211-266.
15. Hennemuth, R.C. 1955. Growth of crappies, bluegill, and warmouth in Lake Ahquabi. Iowa State Coll. Jour. Sci. 30(1):119-137.
16. Krumholz, Louis A. 1951. Further remarks on the minnow seine method of sampling fish ponds. Jour. Wildl. Mgmt. 15:110-112.
17. Lewis, William M. 1949. The use of vertebrae as indicators of the age of the northern black bullhead Ameiurus m. melas (Rafinesque). Iowa State Coll. Jour. Sci. 23:209-218.
18. _____. 1950. Fisheries investigations on two artificial lakes in southern Iowa. II. Fish populations. Iowa State Coll. Jour. Sci. 24:287-324.
19. Morgan, George D. 1951. The life history of the bluegill sunfish, Lepomis macrochirus, of Buckeye Lake (Ohio). Denison Univ. Bull. Jour. Sci. Lab. 42(4):21-59.
20. Ruhr, C.E. 1952. Fish population of a mining pit lake, Marion County, Iowa. Iowa State Coll. Jour. Sci. 27:55-77.
21. Sneed, Kermit E. 1950. A method for calculating the growth of channel catfish, Ictalurus lacustris punctatus. Trans. Amer. Fish Soc. 80:174-183.
22. Swingle, H.S. 1949. Some recent developments in pond management. Trans. 14th North Amer. Wildl. Conf. 295-310.

23. _____. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Alabama Agric. Exp. Sta. Bull. 274.

24. _____ and E.V. Smith. 1940. Experiments on the stocking of fish ponds. Trans. 5th North Amer. Wildl. Conf. 267-276.

25. _____ and _____. 1943. Factors affecting the reproduction of bluegill bream and largemouth black bass in ponds. Alabama Agric. Exp. Sta. Bull. 87

26. Van Oosten, John. 1929. Life history of the lake herring (Leucichthys artedi LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U. S. Bur. Fish. 44:265-428.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 89-93

THE ROLE OF CHLORIDE ION IN THE FERRIC-STANNOUS REACTION
A Reinterpretation Based on New Equilibrium Data[1]

Frederick R. Duke and Norman C. Peterson

Institute for Atomic Research and Department of Chemistry
Iowa State College, Ames

The equilibrium constants for the association of stannous ion with chloride ion in perchloric acid solutions of ionic strength 2.0 M were determined by Duke and Courtney (1). Subsequently Vanderzee and Rhodes (2) determined the equilibrium constants at an ion strength 3.0 and at several temperatures. A remark in their paper as to an alternative interpretation of the data of Duke and Courtney (1) has prompted a reinvestigation of the interpretation of the influence of chloride ion on the rate of the ferric-stannous reaction, which was investigated by Duke and Pinkerton (3).

As was pointed out in that paper, the rate-determining step is probably a one electron transfer between chloride complexes of tin and iron. Accordingly, it is of interest to correlate the second order rate constants (first order in total Fe(III) and first order in total Sn(II)), at fixed chloride concentrations, with the concentration of free chloride ion in solution. The dependence of the second order rate constant, k_2, upon free chloride ion concentration, C, should be of the form

$$k_2 f(C) = dC^n + eC^{n+1} + fC^{n+2} + \ldots \qquad (1)$$

where the function f(C) as given by Duke and Pinkerton is

$$f(C) = (1 + B_1{}^f C + B_2{}^f C^2 + B_3{}^f C^3)(1 + B_1{}^s C + B_2{}^s C^2 + B_3{}^s C^3) \qquad (2)$$

where the constants $B_1{}^f$, $B_2{}^f$, $B_3{}^f$ are the concentration constants for the equilibria

$$Fe^{+3} + Cl^- = FeCl^{+2} \qquad (3)$$
$$Fe^{+3} + 2Cl^- = FeCl_2{}^+ \qquad (4)$$
$$Fe^{+3} + 3Cl^- = FeCl_3, \qquad (5)$$

and the constants $B_1{}^s$, $B_2{}^s$, $B_3{}^s$ are the concentration constants for the corresponding reactions of stannous ion,

$$Sn^{+2} + Cl^- = SnCl \qquad (6)$$
$$Sn^{+2} + 2Cl^- = SnCl_2 \qquad (7)$$
$$Sn^{+2} + 3Cl^- = SnCl_3{}^- \qquad (8)$$

[1]Contribution No. 527. Work was performed in the Ames Laboratory of the U.S. Atomic Energy Commission.

The values of the constants B_1^f, B_2^f, B_3^f are 3.8, 4.84, and 0.198 as taken from Duke and Pinkerton's paper. The constants B_1^s, B_2^s, B_3^s according to Vanderzee and Rhodes (2) are 11.6, 52, and 33, all at ionic strength 2.0. Both the rate constants and the function f(C) are sensitive to errors in the chloride ion concentration, making a correction necessary for the metal complexes. The chloride ion concentration was calculated from the total Sn(II) and Fe(III) concentration (initial values) as follows. The total chloride ion concentration, C_t, is the sum of several terms.

$$C_t = (Cl^-)+(SnCl^+)+2(SnCl_2)+3(SnCl_3^-)+(FeCl^{++})+2(FeCl_2^+)+3(FeCl_3). \tag{9}$$

Writing Eq. (9) in terms of total tin, t_s, total iron, t_f, and denoting the chloride ion concentration by C, we have

$$C_t = C+t_s\frac{B_1^sC+2B_2^sC^2+3B_3^sC^3}{1+B_1^sC+B_2^sC^2+B_3^sC^3}+t_f\frac{B_1^fC+2B_2^fC^2+3B_3^fC^3}{1+B_1^fC+B_2^fC^2+B_3^fC^3}. \tag{10}$$

Eq. (10) may be solved for C numerically by successive approximation. This is accomplished by rewriting the equation in the form

$$C = \frac{C_t}{1+t_sR_s+t_fR_f},$$

where

$$R = \frac{B_1^s+2B_2^sC+3B_3^sC^2}{1+B_1^sC+B_2^sC^2+B_3^sC^3}$$

and

$$R_f = \frac{B_1^f+2B_2^fC+3B_3^fC^2}{1+B_1^fC+B_2^fC^2+B_3^fC^3}$$

and the two terms in the denominator containing C may be regarded as correction terms.

All the data of Duke and Pinkerton on the ferric-stannous reaction in the presence or chloride ion are summarized in Table 1. The chloride ion concentrations were calculated by successive approximations as outlined above, starting with C_t as the first approximation. The evaluation of the order in chloride ion was done graphically. From Eq. (1) it may be seen that a graph of log $K_2f(C)$ vs. log C should be a line with slope n, or might be a curve with several linear portions. The data in Table 1 are graphically presented in Fig. 1. The line has a slope of 4.0, which indicates that the reaction is fourth order with respect to chloride ion. The data at the three highest chloride concentrations, if the deviation is significant, indicate a fifth order term. No other terms are necessary to interpret any of the data.

Although the kinetic order in chloride ion does not enable us to assign uniquely the reactivity to individual complex ions, it is interesting to note that the reactivity is consistent with that observed in other reac-

Table 1

Table No. in Duke and Pinkerton (3)	T_c	T_s	T_f	C	l-mole^{-1} min.$^{-1}$ k_2	f(C)	$Q = k_2 f(C)$ Q
I	0.136	0.00875	0.101	0.0961	1.96	3.64	7.14
	0.136	0.00875	0.0812	0.1005	2.14	3.86	8.26
	0.136	0.00875	0.0609	0.106	2.42	4.13	10.0
	0.136	0.00875	0.0406	0.112	2.28	4.47	11.2
	0.136	0.00875	0.0203	0.120	2.32	4.90	11.4
II	0.217	0.00875	0.101	0.158	7.27	7.33	53.2
	0.163	0.00875	0.101	0.116	3.07	4.65	14.3
	0.136	0.00875	0.101	0.0962	1.90	3.68	6.99
	0.108	0.00875	0.101	0.0759	0.982	2.89	2.84
	0.0813	0.00875	0.101	0.0565	0.377	2.25	0.849
	0.0542	0.00875	0.101	0.0373	0.109	1.72	0.1875
III	0.125	0.121	0.0188	0.0560	0.329	2.22	0.730
	0.125	0.0809	0.0188	0.0682	0.567	2.60	1.47
	0.125	0.0607	0.0188	0.0745	0.0756	2.84	2.17
	0.125	0.0405	0.0188	0.0872	0.954	3.32	3.16
	0.125	0.0202	0.0188	0.1012	1.374	3.90	5.36
IV	0.251	0.0809	0.0188	0.155	5.36	7.12	38.2
	0.201	0.0809	0.0188	0.118	2.62	4.77	12.5
	0.151	0.0809	0.0188	0.0851	0.998	3.25	3.22
	0.125	0.0809	0.0188	0.0688	0.567	2.52	1.43
	0.100	0.0809	0.0188	0.0535	0.267	2.16	0.576
	0.0752	0.0809	0.0188	0.0397	0.0940	1.79	0.168
V	0.111	0.00180	0.00360	0.108	2.50	4.40	11.0
	0.270	0.00185	0.00370	0.265	24.1	20.4	492
	0.359	0.00175	0.00351	0.354	44.2	40.0	1770
	0.476	0.00163	0.00326	0.470	80.9	85.1	6880

tions if it is assumed that the reactive reductant is $SnCl_3^-$. Silverman and Dodson (4) have found comparable reactivities for the two iron complexes in the radioactive exchange of ferric and ferrous ion in solution, and $SnCl_3^-$ appears to be the only reductant involved in the reduction of methyl orange in stannous chloride solutions (5).

In agreement with this assumption, the ratio of reactivities (at 20°C) of the iron complexes $FeCl_2^+$ and $FeCl^{+2}$ towards Fe^{++} is 1.8:1 calculated from Silverman and Dodson's data (4), and a maximum of 2.3:1 towards $SnCl_3^-$ calculated from Duke and Pinkerton's data (3). It would be interesting to investigate the relative rates of reduction of the ferric complexes in other systems to see if this behavior is general.

The observed fourth order dependence over most of the concentration range is in agreement with the suggestion of Weiss (6), made without detailed equilibrium data, that the reactants are Fe^{+3} and $SnCl_4^{-2}$.

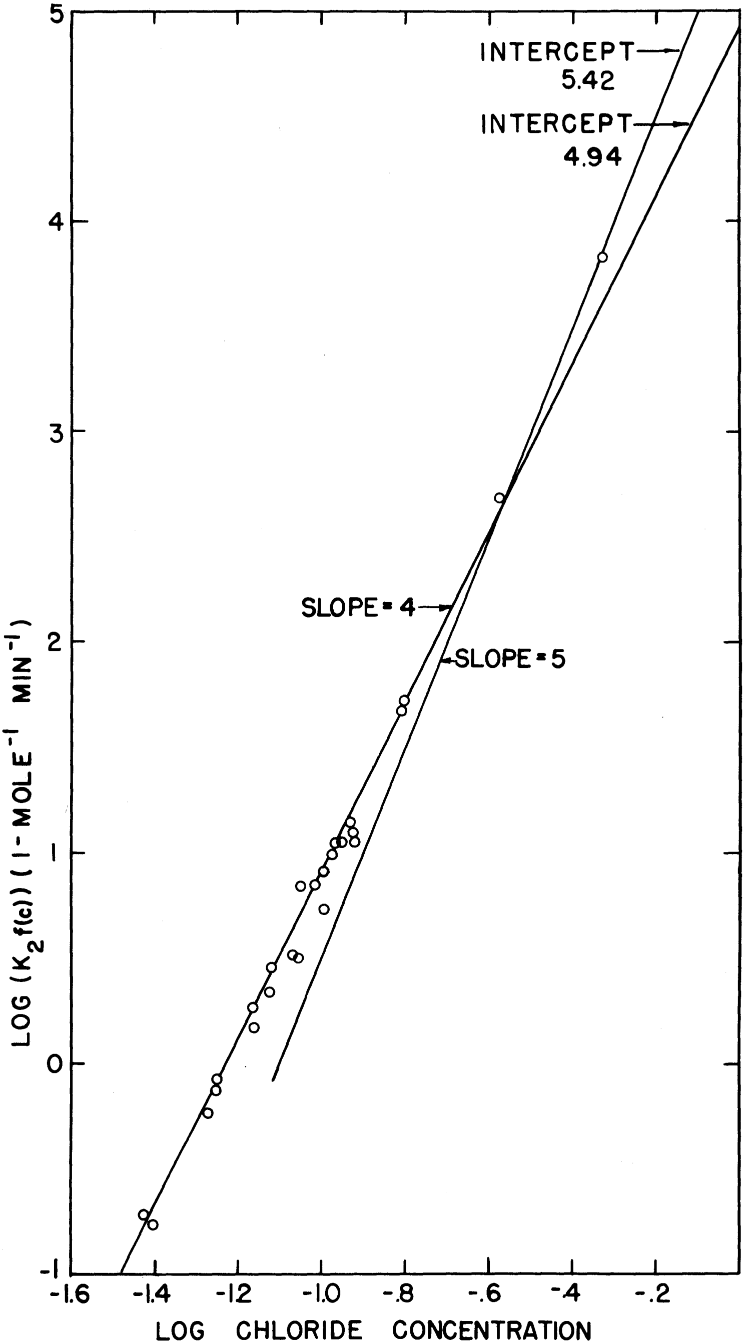


FIG.1 RATE AS FUNCTION OF CHLORIDE ION CONCENTRATION.

In summary, we have re-examined all the data of Duke and Pinkerton on the chloride catalyzed ferric-stannous reaction and find that the rates agree better with the expression

$$k_2f(C) = 8.7 \times 10^4 C^4 + 26 \times 10^4 C^5$$

than with the one found in the original paper,

$$k_2f(C) = 1.2 \times 10^3 C^3 + 72 \times 10^3 C^4 + 27 \times 10^4 C^6.$$

REFERENCES

1. Duke, F.R. and W.G. Courtney. 1950. Iowa State Coll. Jour. Sci. 24:397.
2. Vanderzee, C.E. and D.E. Rhodes. 1952. Jour. Amer. Chem. Soc. 74:3552.
3. Duke, F.R. and R.C. Pinkerton. 1951. Jour. Amer. Chem. Soc. 73:3045.
4. Silverman, J. and R.W. Dodson. 1952. Jour. Phys. Chem. 56:846.
5. Peterson, N.C. 1956. Thesis, Iowa State College.
6. Weiss, J. 1944. Jour. Chem. Soc. 309.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 95-104

THE EFFECT OF THE SHAPE OF THE SOIL SURFACE PROFILE ON SOIL TEMPERATURE AND MOISTURE[1]

Robert H. Shaw[2] and Wesley F. Buchele[3]

Agricultural practices are designed to obtain maximum efficiency in crop production. Tillage practices designed to increase surface and internal drainage of the soil have resulted in changing the temperature of the surface soil in the spring. In certain problem areas where shaping of the surface profile has been carried out, a change in soil temperature has resulted.

As early as 1733, Tull (13) recognized the higher temperature of a ridged soil as compared to a flat field. Wollny (14) found the south side of a 15° hill was 1.5°F warmer than the north side. King (8) studied the higher temperature of land sloping toward the south and found that an 18° slope was 3.1°F warmer at the one-foot depth than the equivalent depth on the north slope, 2.8°F warmer at the two-foot depth, and 2.8°F warmer at the three-foot depth. Keen (7) obtained the soil temperature of a "small heap of clay soil that had been in position for several years", with a slope in each direction of approximately 8 per cent. He found that when compared with the north slope, the south slope was found to be 8.4°C warmer at a depth of one and one-half inches and 5.4°C warmer at a depth of three inches. He also observed a difference in moisture content and its effect on the timeliness of cultivation.

Shreve (12) recorded measurements in the region of the desert laboratory, Tucson, Arizona, on the north and south slopes of an artificial hill two years after construction. The hill was made of alluvial clay and was 10 feet high with a 30° slope. The temperature measurements were made at the three-inch depth after the moisture content had become the same. In April and May, the weekly average maximum showed the southern slope to be 5 to 7°C warmer than the northern slope.

Soil temperature (10) is one of the most important factors governing the germination of all seeds. Germination, emergence, and early growth of plants are intimately related to soil temperature. The effects of soil temperature are probably more critical during the periods of germination and early seedling development than during any other stage of vegetative growth. Unfavorable soil temperatures at seeding time lowers the rate of germination and emergence which results in a poor stand; as a consequence a reduced yield may be harvested because of the lowered plant population, and possible delayed maturity.

Root growth responds to soil temperature changes. For corn, Dickson (4) found the largest root system, irrespective of the age of the plant,

---

[1]Journal paper No. J-2884 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No's 996 and 787.

[2]Associate Professor Agricultural Climatology, Agronomy Department.

[3]Agric. Engr. (Agent) USDA, ARS, AERB, TMLS, and Assistant Professor, Agricultural Engineering Department.

developed at soil temperatures of about 24°C, with good growth in the 20-28°C range. Below 20° or above 28°C there was a definite reduction of root growth. The heaviest and longest tops developed at a soil temperature of 24°C during the earlier stages of growth, but the optimum soil temperature for later growth increased to 28°C.

Percolation rates are also affected by soil temperature. Bouyouces (1) found that percolation of water through soils increased with temperature up to 30°C, then dropped off. Pillsbury (9) working with Indio loam found a similar increase in the percolation rate with increased temperature but did not record a decrease with temperatures over 30°C.

With soil temperatures exerting these effects on soil properties and plant growth, a change in the soil surface profile may have considerable effect on plant development. Because the soil is often cold or wet in the spring, ridge planting seems to have possibilities for Iowa. Planting the corn on the ridge might give more rapid emergence in the spring. In order to determine the soil temperature relationship across the ridge profile, this study was undertaken.

METHODS

Temperature observations were taken across the ridge and furrow profile with laboratory mercurial thermometers. Although not designed for soil temperature work the error in using these thermometers (5) is relatively small. In undisturbed soil it was first necessary to drive a dowel pin into the soil almost to the desired depth, then insert the thermometer in this hole, forcing the bulb into the compact soil. In disturbed loose soil the thermometer could be inserted directly to the desired depth. Observations were recorded on top of the ridge, bottom of the furrow, and on each slope at depths of 1, 3, and 6 inches from the soil surface. In Fig. 1 the pattern of thermometers across an idealized profile is shown.

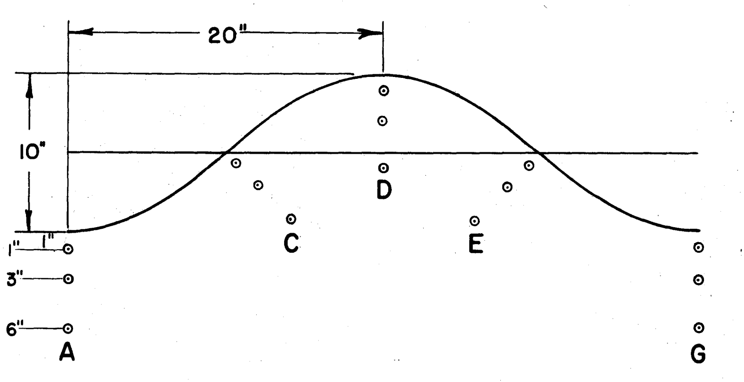


Fig. 1. Location of thermometers in an idealized ridge-furrow profile.

RESULTS AND DISCUSSION

The ridge, furrow, and slopes receive different amounts of radiation during the day.

The radiation (I_h) received per unit area of horizontal soil surface is proportional to the cosine of the angle of incidence (θ_h). The angle of incidence (θ_h) is the included angle between the sun rays and a perpendicular to the horizontal surface. Thus the smaller the included angle, the greater the quantity of radiation impinging upon the unit horizontal area.

(1) $$I_h = I \cos \theta_h$$

then

(2) $$I = \frac{I_h}{\cos \theta_h}$$

where

I = the intensity of the direct solar radiation on a surface perpendicular to the sun rays. Does not include diffuse radiation.

I_h = the intensity of the direct solar radiation on any horizontal surface.

θ_h = the angle of incidence between the sun rays and a perpendicular to the horizontal surface.

The intensity of the direct solar radiation on any surface other than horizontal may be determined by the following equation:

(3) $$I_i = I \cos \theta$$

where

I_i = the intensity of direct radiation on the sloping surface.

θ = the included angle between the sun rays and a perpendicular to the sloping soil surface at any given time.

Substituting I from equation (2) in equation (3),

$$I_i = \frac{I_h \cos \theta}{\cos \theta_h}$$

Dale (3) found that θ is a very small angle for surfaces which approach the angle of 45° and the cos θ approaches the value of one. Thus the south side of ridges running in an east-west direction receives the maximum amount of radiation, which is approximately equal to (I).

Assuming a north-south theoretical ridge as shown in Fig. 1, it is possible to compute the period during which some portion of the furrow is shaded, by using curves calculated by Ives (6). Using these data for May 6, the closest comparable date available from his data, some portion of the furrow is shaded prior to approximately 9 a.m. and after about 3 p.m. Sunrise at this time of the year is around 5 a.m. and sunset 7:20 p.m. During the rest of the day the ridge and furrow would be expected to receive the same amount of radiation. There would be little difference in amounts of radiation falling on the ridge and furrow in east-west ridges. The slopes would, however, receive much different amounts of radiation. The results of these differences in radiation received should be shown in soil temperatures. The differences found will depend upon the time of day readings are taken. The diurnal range of temperature decreases with increasing depth, while the time of occurrence of a maximum or minimum temperature becomes later with increasing depth. According to Shaw (11), measurements taken from 6 to 8 a.m. at the depths used in this series of observations reflect conditions near the minimum temperature epoch, while observations taken from 2 to 5 p.m. reflect conditions near the maximum temperature epoch. Although incoming radiation is being received until sunset, the net radiation balance in the late afternoon is negative; i.e., more is being lost than received and the soil surface is cooling.

Data for six different times of observation are shown in Figs. 2 and 3. These represent the average of three replications. The largest differences between locations were usually found around the maximum temperature time. The differences in temperature between the ridge and the furrow are summarized in Table 1. All figures in the table show the ridge to be warmer than the furrow.

Table 1. Temperature difference in degrees Fahrenheit between the ridge and the furrow. (Ridge-Furrow)

	Time					
Depth	4:30 pm Apr. 29	7:00 am Apr. 30	3:15 pm Apr. 30	7:30 am May 1	2:30 pm May 1	3:00 pm June 5
1"	7.7	0.9	6.8	0.8	7.0	1.0
3"	8.9	1.3	5.0	0.1	5.2	5.5
6"	2.3	2.7	3.2	1.9	3.2	3.1

On two different days observations were taken several times each day. Observations for the 3-inch depth are summarized in Fig. 4. During these two periods of observation the ridge was always warmer than the furrow, with the greatest difference, about 5°F, occurring in the afternoon. For several hours during the middle of the day the slopes were warmer than the ridge or furrow. The east slope reached its maximum temperature around noon, while the west slope reached a maximum temperature just prior to 4 p.m. On July 6 the east slope had a higher maximum than the west. This was accounted for by greater cloudiness in the afternoon.

There are several physical factors which contribute to the ridge

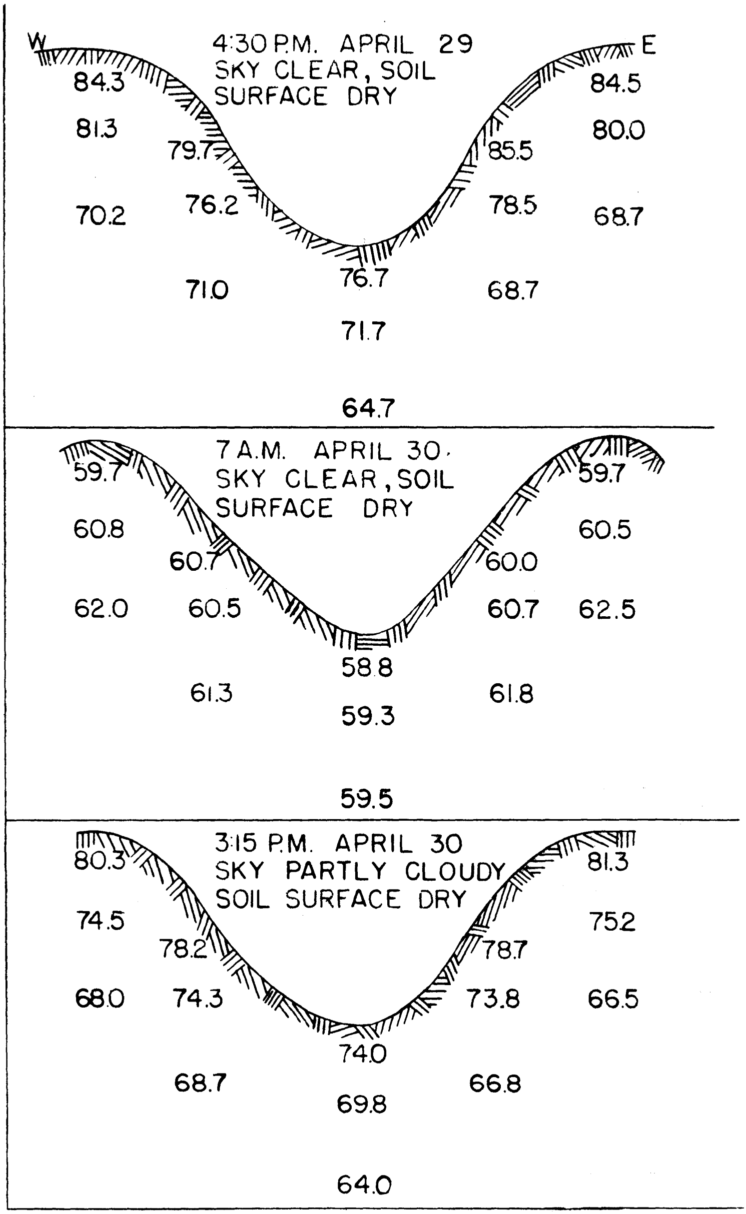


Fig. 2. Soil temperatures 1, 3, 6 inch depths, April 29 and 30.

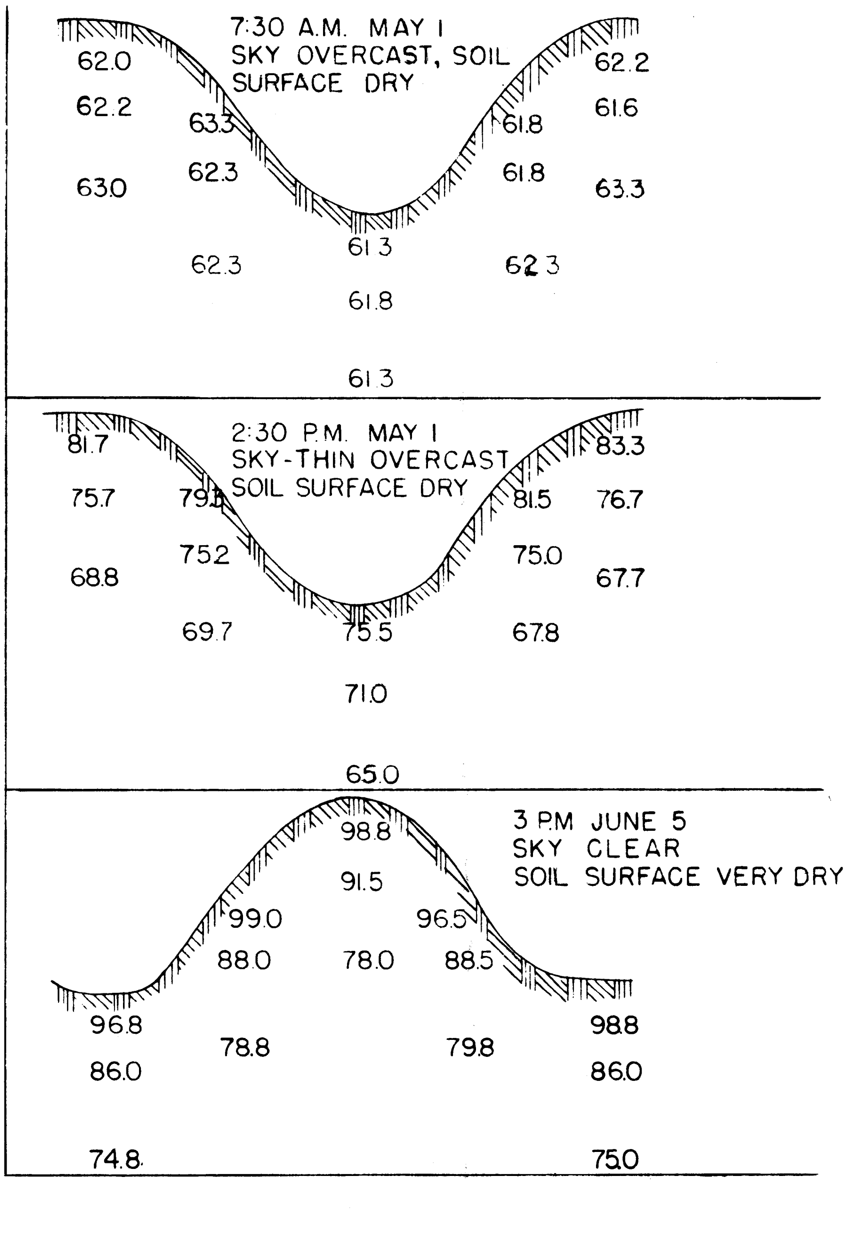


Fig. 3. Soil temperatures 1, 3, 6-inch depths, May 1 and June 5.

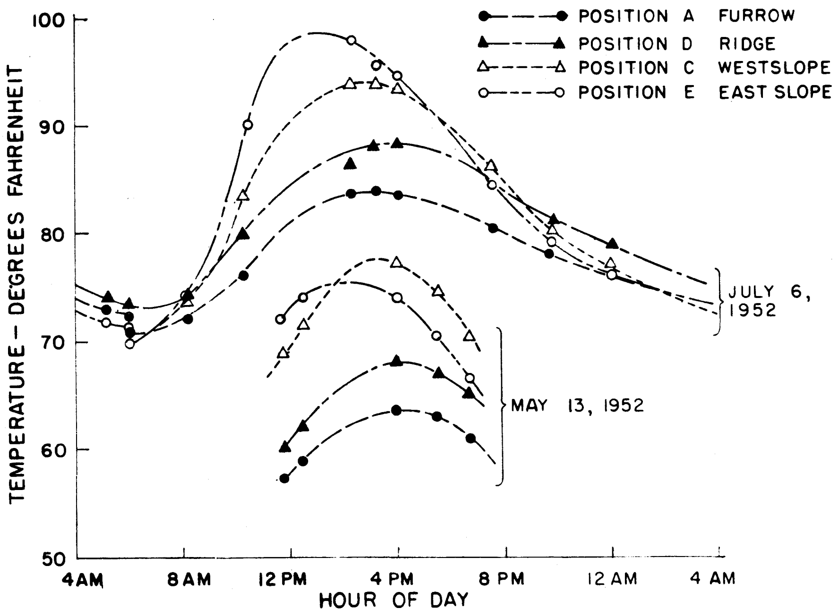


Fig. 4. Soil temperatures 3-inch depth in ridge-furrow profile.

heating to a higher temperature than the furrow. The ridge, due to its elevation of approximately 10 inches, is drained quickly of its gravitational water after a rain, and its moisture content approaches that of field capacity. This loss of moisture reduced the specific heat of the soil in the ridge. Dry soil has a specific heat of approximately 0.2, thus a given quantity of radiation will raise the temperature of the drier surface of the ridge higher than the furrow. This higher temperature contributes to both evaporation from and further drainage of the ridge. The field capacity of a ridge has been shown to be dependent on temperature (2). The above cycle, with other factors (to be discussed) repeats itself within the ridge until an equilibrium is established at a temperature somewhat above that of the furrow, and a moisture content near the surface lower than that of the furrow. An example of the soil moisture is given in Fig. 5.

Another factor contributing to the heating of the ridge is the limited area of heat transfer between the ridge and the soil underneath the ridge. The side of the ridge facing the sun receives a greater quantity of radiation than the top of the ridge or the bottom of the furrow, and as noted in the experimental data, becomes hotter because the angle of incidence (θ) approaches one. Heat waves move into the ridge along the streamiines which are perpendicular to the soil surface only at the surface. Thus heat waves generated at the sloping side of the ridge tend to contribute to the heating of both the top of the ridge and the bottom of the furrow.

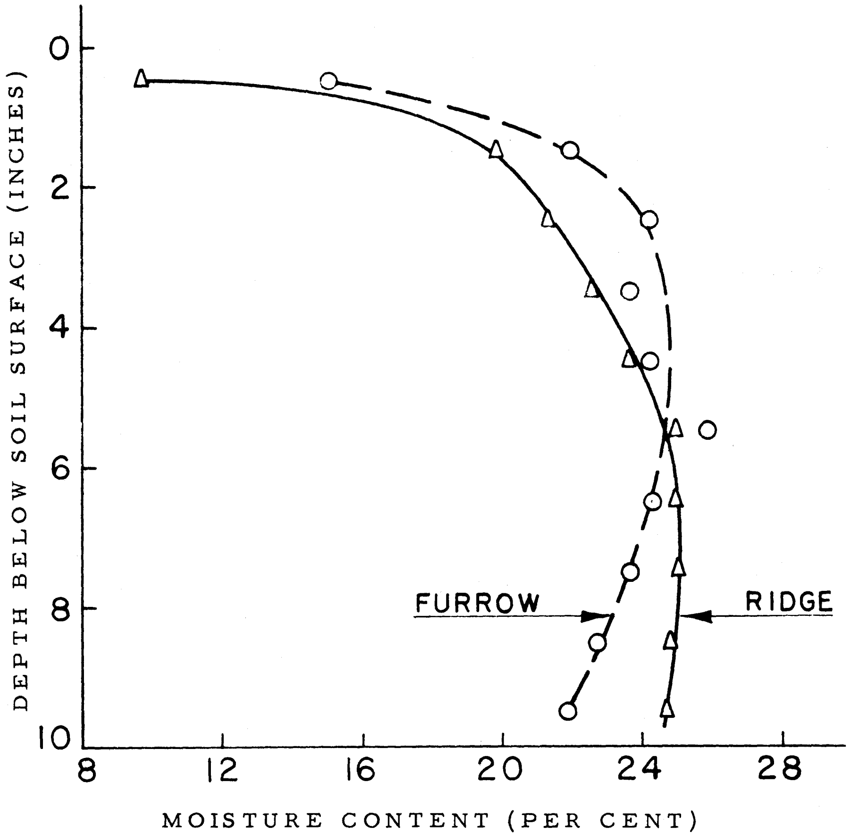


Fig. 5. Soil moisture at different depths in ridge and furrow.

If the horizontal center line in Fig. 1 is considered to divide the ridge from the furrow, their radiation receiving areas are equal. The difference in the temperature between the ridge and furrow is believed to be partially the result of the fact that the side slope heat, in the case of the furrow, flows along streamlines which bend toward the furrow and tend to heat the large volume of soil immediately below the furrow; while in the case of the ridge, the streamlines bend upward where they are met by streamlines emitted from the ridge surface. This congestion of streamlines means higher soil temperatures. In other words, the heat generated at the top of the ridge by impinging radiation does not necessarily pass downward into the underlying soil as a heat wave. The reason for this is that the wave would have to pass through higher temperature areas created by the heat wave from the side slope of the ridge. The result is an accumulation of heat in the ridge which raises the temperature of the top and/or other side of the ridge.

The information indicates there is an advantage in soil temperatures on the ridge as compared to the furrow. These higher temperatures should result in more rapid emergence and getting the crop off to a better start. The drier soil in the ridge in the spring is beneficial in wet years. Once the crop shades the ground there is little difference in temperature (2).

SUMMARY

The formulae for computing the radiation which falls on different slopes are presented.

Data are presented on temperature measurements across a ridged row profile. The top of the ridge is shown to be warmer than the bottom of the furrow and the reasons for this are discussed. Advantages of increased soil temperatures in the spring of the year are mentioned. A comparison of soil moisture in the ridge and furrow is made.

REFERENCES

1. Bouyouces, George J. 1915. Effect of temperature on some of the most important processes in soils. Michigan Agric. Exp. Sta. Tech. Bull. 22.
2. Buchele, Wesley F. 1954. Ridge farming and plant root environment. Unpublished Ph.D. Thesis. Ames, Iowa, Iowa State College Library.
3. Dale, Alvin C. 1950. The effect of roofing materials on temperature in farm buildings. Unpublished Ph.D. Thesis. Ames, Iowa, Iowa State College Library.
4. Dickson, J.G. 1923. Influences of soil temperature and moisture in the development of the seedling-blight of wheat and corn caused by Gibberella saubinettii. Jour. Agric. Res. 23:837-870.
5. Hamid, Q. and Robert H. Shaw. 1955. Measurement of soil temperatures with laboratory mercury-in-glass thermometers. Iowa State Coll. Jour. Sci. 30:243-247.
6. Ives, Norton C. 1950. Factors affecting heat flow through roof section covered with sheet metal. Unpublished M.S. Thesis. Ames, Iowa. Iowa State College Library.
7. Keen, Bernard A. 1931. The physical properties of the soil. London. Longmans, Green and Co.
8. King, H.F. 1914. A text book of the physics of agriculture. 6th ed. Madison, Wisconsin. Published by Mrs. H.F. King.
9. Pillsbury, A.F. 1950. Effects of particle size and temperature on the permeability of sand to water. Soil Sci. 70:299-300.
10. Richards, S.J., R.M. Hagan, and T.M. McCalla. 1952. Soil temperature and plant growth. In: Shaw, B.T., ed. Soil physical conditions and plant growth. pp. 303-480. New York. Academic Press, Inc.
11. Shaw, Robert H. 1955. The measurement of soil temperature. Iowa State Coll. Jour. Sci. 30:255-261.

12. Shreve, F. 1924. Influence of slope exposure on soil temperature. Washington. Carnegie Inst. Yearbook. 23:141-142.
13. Tull, Jethro. 1829. The horse-hoeing husbandry. London. Wm. Cobbett.
14. Wollny, R. 1878. Untersuchungen uber den Einfluss der Exposition auf die Erwarmung des Bodens. Forsch. Gebiete Agr.-Phys. 1:263-294.

IOWA STATE COLLEGE JOURNAL OF SCIENCE
Vol. 32 No. 1 August 15, 1957 pp. 105-109

VARIATION IN PATHOGENICITY OF DIAPORTHE PHASEOLORUM VAR. SOJAE TO SOYBEAN[1]

John Dunleavy[2]

Abstract

Diaporthe phaseolorum var. sojae is generally considered to be a weak parasite of soybean. Reports by various workers range from the organism being an aggressive saprophyte to a definite parasite. Two isolates of D. phaseolorum var. sojae were compared with an isolate of D. phaseolorum var. caulivora known to be very pathogenic. All isolates were tested on 2 groups of Hawkeye plants: 60 and 80 days old; and on Lincoln plants 100 days old. In all cases one isolate of D. phaseolorum var. sojae was more pathogenic than the other.

Diaporthe phaseolorum var. sojae (Phomopsis sojae) is generally considered to be a weak parasite of soybean. The fungus usually infects stems and pods of plants nearing maturity (5, 6) and consequently the name "pod and stem blight" has been applied to the disease. Diseased plants are readily identified by the presence of small, black pycnidia that appear on infected plant parts (Fig. 1). Luttrell (6) considers the fungus to be a vigorous saprophyte that may quickly fruit on plants killed by other organisms or by adverse growing conditions. Athow and Caldwell (1) believe the fungus is a weak parasite that appears to hasten maturity rather than kill plants abruptly. Hildebrand (4) reported five isolates of D. phaseolorum var. sojae were virtually nonpathogenic to 62- and 76-day-old Lincoln and 55- and 71-day-old Blackhawk plants, respectively. No infection was observed on any plants until 50 days after inoculation when a few plants showed disease symptoms. In contrast, the author has observed that the fungus was able to grow as much as 75 mm in 18 days in soybean plants 70 to 80 days old at time of inoculation (3). Such a growth rate would seem to classify the fungus as a parasite since it approximates the rate of growth of the stem canker fungus, D. phaseolorum var. caulivora, during the first 20 days of development in soybean stems. The stem canker fungus has been reported to be pathogenic on soybean by several workers (1, 3, 4, 7).

---

[1] Joint contribution from the Iowa Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture. Journal paper No. J-3170 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1179.
[2] Plant pathologist, Crops Research Division, ARS, USDA, and Iowa Agricultural Experiment Station.

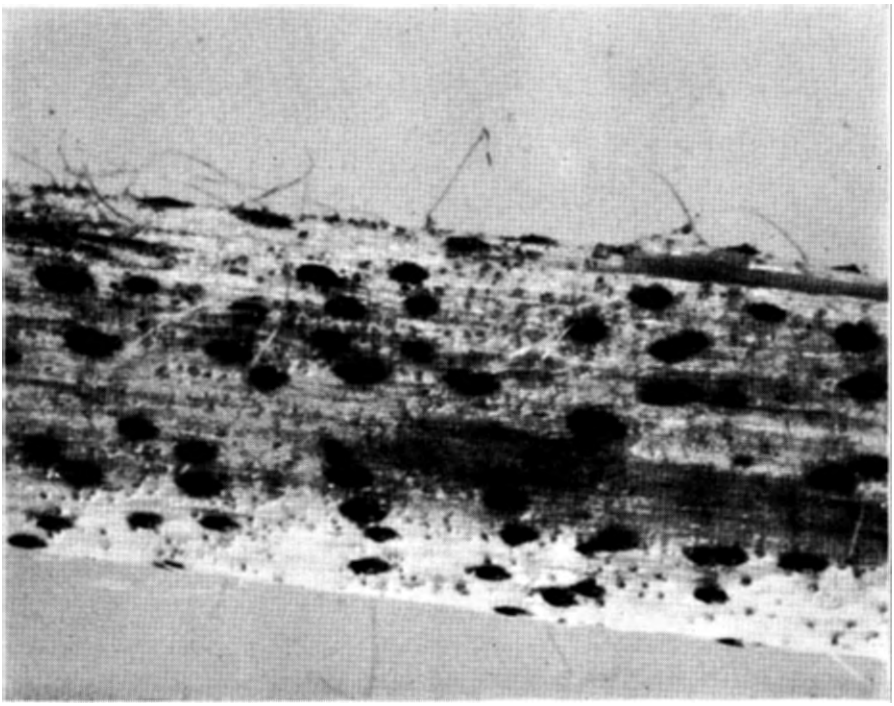


Fig. 1. Pycnidia of Diaporthe phaseolorum var. sojae on a dead soybean stem.

Since opinions concerning the pathogenicity of D. phaseolorum var. sojae are in conflict, the question arises: does variation in pathogenicity exist between different isolates of this organism? In order to answer this question the following study was undertaken.

Materials and Methods

Several isolates of D. phaseolorum var. sojae were tested for pathogenicity in a preliminary experiment. Two of the isolates were selected for future testing. The first was obtained from pycnidia on a soybean petiole near the base of a main stem. Numerous pycnidia were found on such petioles. Other petioles that had fallen to the ground also had many pycnidia on them. In no case were pycnidia found on living petioles. This isolate of the fungus was also observed to form pycnidia on branches killed by injury and was designated as isolate DPS-1.

The second isolate of the pod and stem blight fungus was obtained from a light brown stem lesion about 1 inch long and 0.25 inch wide on an actively growing soybean plant 73 days old. The lesion was unusual because of its size and the lack of the dark brown to black color at the

Table 1. Comparative pathogenicity of 1 isolate of *D. phaseolorum* var. *caulivora* (DPC) and 2 isolates of *D. phaseolorum* var. *sojae* (DPS1 and DPS2) to Hawkeye soybeans at 2 stages of vegetative development.

Days after inocu-lation	Flowering, pods setting						Pods filled					
	% Plants killed			% Plants infected			% Plants killed			% Plants infected		
	DPC	DPS1	DPS2	DPC	DPS1	DPS2	DPC	DPS1	DPS2	DPC	DPS1	DPS2
13	20	0	0	40	50	0						
14							40	40	0	60	30	40
21	100	0	0	-	50	20						
24							100	50	0	-	40	50
31							100*	70*	40*	-	20*	40*
33	100	10	0	-	40	20						
52	100*	20*	0	-	30*	20*						

*Plants approaching maturity.

margins typical for stem canker lesions. *D. phaseolorum* var. *sojae* was the only fungus isolated from the lesion with any frequency. This isolate was designated DPS-2. Both isolates of the pod and stem blight fungus conformed to the description of Luttrell (6) for *D. phaseolorum* var. *sojae*.

The above 2 isolates of *D. phaseolorum* var. *sojae* were compared with an isolate of *D. phaseolorum* var. *caulivora*, the pathogenicity of which had been previously established. This isolate was designated DPC.

All plants were inoculated between the fourth and fifth nodes by means of the toothpick tip method (2). The fungi were tested on Hawkeye plants 60 days old that were in full flower with a few pods developing at the base of the main stem. Hawkeye plants 80 days old which were no longer blooming and were beginning to form pods at the tip of the stem were also used. In the later test, Lincoln plants 100 days old were used which had full length pods at the tip of the stem and pods on the lower half of the plant approaching the "green bean stage." All tests were conducted in a greenhouse at a temperature of 85 °F. Plants were grown in 4-inch pots, 1 plant per pot.

The single culture of *D. phaseolorum* var. *caulivora* (DPC) and the 2 cultures of *D. phaseolorum* var. *sojae* (DPS-1 and DPS-2) were used to inoculate soybean plants 60 days old. Each isolate was inoculated separately into 10 plants. In addition, a sterile toothpick tip was placed in each of 10 control plants. Hawkeye plants 80 days old were similarly inoculated with the same isolates so that pathogenicity of all cultures could be compared on plants of 2 age groups. Plants were observed from time of inoculation until maturity. The percentage of plants infected and killed was recorded and the data are presented in Table 1.

Table 2. Comparative pathogenicity of 1 isolate of D. phaseolorum var. caulivora (DPC) and 2 isolates of D. phaseolorum var. sojae (DPS1 and DPS2) to Lincoln soybeans inoculated when 70 per cent of the pods were filled.

Days after	% Plants killed			% Plants infected		
inoculation	DPC	DPS1	DPS2	DPC	DPS1	DPS2
6	0	0	0	60	80	20
14	70	0	0	30	80	20
24	100	30	10	--	50	10
43	100*	70*	10*	--	30*	10*

*Plants approaching maturity.

Results

Thirteen days after inoculation 60 per cent of the younger plants 60 days old inoculated with the stem canker fungus (DPC) were infected or killed as opposed to 50 per cent infected by the pot and stem blight isolate DPS-1. No infection resulted with the pod and stem blight isolate DPS-2. Twenty-one days after inoculation all of the younger plants had been killed by the stem canker fungus. Within 52 days after inoculation, just prior to maturity, the DPS-1 isolate of pod and stem blight had killed 20 per cent and infected 30 per cent of the younger plants, whereas the DPS-2 isolate had not killed any plants and had infected only 20 per cent. (Table 1)

Both of the pod and stem blight isolates were more pathogenic on older 80 day old plants; however, DPS-1 remained considerably more pathogenic than DPS-2. Fourteen days after inoculation DPS-1 had killed 40 per cent of the plants and infected 30 per cent, whereas DPS-2 had infected only 40 per cent of the plants. Just prior to maturity DPS-1 had killed 70 per cent of the plants and DPS-2 had killed 40 per cent.

In order to determine if isolates DPS-1 and DPS-2 would retain their relative pathogenicity on another variety, the experiment was repeated using Lincoln plants 100 days old. Results of the test are presented in Table 2. As in the earlier tests, isolate DPS-1 was much more pathogenic than DPS-2; in fact, 6 days after inoculation this isolate had infected more plants than the stem canker fungus (DPC). Although DPS-1 was observed to be considerably less pathogenic than the stem canker fungus in later observations, it had killed 70 per cent of the plants and infected 30 per cent just prior to maturity. In contrast, the DPS-2 isolate had killed 10 per cent of the plants and had infected only 10 per cent. None of the control plants containing sterile toothpick tips showed any discoloration which might be interpreted as infection.

Results of both tests demonstrate that variation in pathogenicity of D. phaseolorum var. sojae exists. This difference was less obvious when 60-day-old plants were inoculated. Isolate DPS-1 was pathogenic on soybean and, although less pathogenic than *D. phaseolorum* var. *caulivora*, could not be considered a weak pathogen or aggressive saprophyte. Isolate DPS-2 was, however, a weak pathogen. It is possible that strains of *D. phaseolorum* var. *sojae* may exist in nature that differ even more widely in pathogenicity than the 2 isolates tested.

During periods of drought in August and September, field grown plants were observed to be killed by *D. phaseolorum* var. *sojae*. The fungus has not been reported to cause serious crop damage but the more pathogenic forms under the proper environmental conditions might present a disease problem.

Literature Cited

1. Athow, K.L. and R.M. Caldwell. 1954. A comparative study of Diaporthe stem canker and pod and stem blight of soybean. Phytopath. 44:319-325.
2. Crall, J.M. 1952. A toothpick tip method of inoculation. Phytopath. 42:5-6.
3. Dunleavy, J.M. 1956. A method for determining stem canker resistance in soybean. Proc. Iowa Acad. Sci. 63:274-279.
4. Hildebrand, A.A. 1956. Observations on stem canker and pod and stem blight of soybeans in Ontario. Canad. Jour. Bot. 34:577-599.
5. Lehman, S.G. 1923. Pod and stem blight of soybean. Missouri Bot. Gard. Ann. 10:111-178.
6. Luttrell, E.S. 1947. *Diaporthe phaseolorum* var. *sojae* on crop plants. Phytopath. 37:445-465.
7. Welch, A.W. and J.C. Gilman. 1948. Hetero- and homo-thallic types of Diaporthe on soybeans. Phytopath. 38:628-637.

Department of Botany and Plant Pathology
Iowa State College, Ames

AUTHOR INDEX

SUBJECT INDEX