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CORNELL UNIVERSITY

ITHACA, N. Y.

April 12, 1929

TO STUDENTS OF MAIZE GENETICS:-

You who attended the "cornfab" in my hotel room at the time of the winter science meetings in New York will recall that I promised to prepare a summary of the published data involving linkage groups in maize, to add my own unpublished data, and to send these records to each of you for criticism and the addition of such unpublished records as you may care to furnish me. I am now enclosing the records promised, but can claim no credit for having assembled them. Professor Fraser had, before leaving for a year in Europe, abstracted the available published papers. Mr. Beadle has completed that work, has assembled my own unpublished records, and has arranged all the tables and charts.

I hope that each of you, whether or not you attended the New York meeting, will send me such relevant data as you have not yet published, showing either linkage or independent inheritance. In so far as you have data ready for publication, I prefer to receive a copy of your manuscript, but shall be glad to have also records which you are not ready to publish, if you care to send them. I agree not to publish any such data without your consent and in any case to give proper credit. Any records sent, however, should be with the understanding that I am at liberty to use them in an early revision of the mimeographed sheets for distribution to other workers, pending the publication of the general linkage paper which I have been threatening to bring out for some years now.

I indicated at New York that the records were too incomplete to warrant publication now, a fact made strikingly obvious by the "rainbows" on the maps. The distribution of the data in mimeographed form should serve temporarily the needs of those actively studying maize genetics; and others can wait. The coordination of effort agreed to in New York should go far toward straightening out many of the question marks in the next year or two.

In this connection, I add here, as a reminder, a list of those to whom linkage groups were parcelled out at New York.

C-Wx group - Eyster, Bucknell; Beadle, Cornell.

R-G group - Lindstrom, Jenkins, Wentz, Ames.

Su-Tu group - Emerson, Cornell.

B-Lg group - Stadler, Missouri; McClintock, Cornell.

Y-Pl group - Hill, Cornell.

P-Br group - Emerson, Cornell.

$Ra\text{-}Gl_1$ group - Brewbaker, Minnesota; Brunson, Manhattan; Fraser, Cornell.

$Pr\text{-}V_2$ group - Eyster, Bucknell; Jorgenson, Ohio; Li, Cornell.

$D\text{-}Pg_2$ group - Not assigned.

$A\text{-}Ts_4$ group - Brink, Wisconsin; Li, Cornell.

To those not at the New York meeting, it should be explained that this assignment of groups was, so far as possible, made in accordance with the expressed interests of those assuming the responsibilities entailed. It was far from our purpose to preempt groups for ourselves and thereby warn off other workers. Our purpose rather was to make sure that each known group would be given immediate and adequate attention to the end that the not very exciting job of chromosome mapping may go forward with some dispatch, thereby making possible an attack on certain important genetic problems now awaiting just such tools as accurate linkage maps afford. It should go without saying therefore that the help of those of you who were not at the New York conference will be welcomed.

I suggest that those who have made themselves responsible for any group, request needed material directly from the workers most likely to have it, as indicated by the names in the last column of the table for that group. We at Cornell shall be glad to furnish on request tester stocks in so far as our somewhat limited supply will permit. It would doubtless be helpful if those who have particularly desirable testers for any group would proffer them to the ones who are primarily responsible for that group.

Sincerely,

R. A. Emerson

GENERAL NOTES

Linkage data.-

In the last column of the tables giving the linkage data for the several linkage groups, papers from which the records have been summarized are indicated by author and year. Not all published data are included. For instance, F_2 data are omitted when abundant back-cross data are available. Records credited to an author without indication of the year are unpublished. In general, unpublished data received in personal correspondence are not included, except when no published records are available. Such data are doubtless incomplete. It is thought, therefore, that workers will prefer to add their complete data as of the spring of 1929.

X and Y in the column headings of the several tables indicate the dominant genes of the first column and x and y their respective recessive allelomorphs.

In the second column under the heading "Link. phase", C = coupling and R = repulsion, Bc = back-crossed and S = selfed.

Data presented in the table of three-point tests are included in, not additional to, data in the several group tables. The first column of this table shows the genotype of one parent only, the other parent having obviously the respective allelomorphs of the genes of parent no. 1. The genotypes involved in columns 2 - 5 will be clear from the following illustration:

Parent	Parental combinations			Region 1	Region 2	Regions 1 and 2
No. 1	No. 1		No. 2			
C	sh Wx	C	sh Wx-c	Sh wx	C Sh wx-c	sh Wx C sh wx-c Sh Wx C Sh Wx-c sh w
I	Sh wx	I	Sh wx-i	sh Wx	I sh Wx-i	Sh wx I Sh wx-i sh wx I sh wx-i Sh W

Maps.-

No attempt has been made to indicate map distance other than by observed cross-over percentages; 3 mm. = 1 per cent crossing over.

Starred genes (*) are those located with reasonable certainty; others probably belong in the general region indicated.

A gene tested with only one of the located genes is placed opposite that gene at a distance determined by the cross-over percentage, its locus being approximately at one end or other of the "rainbow".

Independence of linkage groups.-

This chart shows what tests have been made between genes of any one linkage group and those of other, presumably independent, groups. Thus, there are records involving approximately 9900 individuals from selfed parents indicating independence between C or I and A and approximately 2000 individuals in back-cross progenies indicating independence of sh and A. It is obvious that the data are not adequate to establish the independence of all the groups, and it is hoped that other workers will have unpublished data to fill in some of the "holes". As an example of the necessity of obtaining more nearly adequate data, a manuscript by Hayes and Brubaker (received after the stencils for the linkage tables had been cut) indicates that gl_2-fl belong to the B-Jg group, while Beadle's unpublished records suggest that fl is in the C-wx group. The independence of these two groups is, therefore, questionable.

C-SH-WX GROUP

List of Genes

ar	Argentia - finely striped leaf	Eyster 1929
au_1	Aurea chlorophyll-yellow plant	Eyster 1929
au_2	Aurea chlorophyll-yellow seedling	Eyster 1929
bp	Brown pericarp with a	Meyers 1927
C	Colored aleurone with A and R	East and Hayes 1911
d_3	Dwarf plant	Suttle (Unpub.)
de_{15}	Defective endosperm	Brink 1927
~~fl~~	~~Floury endosperm~~	~~Hayes and East 1915~~
~~gl_2~~	~~Glossy seedling~~	~~Hayes and Brewbaker 1925~~
gm_1	Germless	Eyster 1929
I	Inhibitor for aleurone color	East and Hayes 1911
pk	Polkadot leaf	Eyster 1929
v_1	Virescent seedling	Demerec 1924
v_{14}	Virescent seedling	Phipps (Unpub.)
v_{15}	Virescent seedling	Phipps (Unpub.)
w_{11}	White seedling	Demerec 1926
wx	Waxy endosperm	Collins 1909
yg	Yellow-green plant	Jenkins 1927

Notes

pk — The 1929 data of Eyster on pk are not consistent with his earlier data. He makes the statement in his 1929 paper that pk and ar show relatively close linkage--hence pk probably lies on the wx side of C.

d_3, w_{11} — In the material on which the d_3 and w_{11} counts were made, the C and R factors were segregating. Demerec states that a calculation of the recombination percentage with C would suggest that both d_3 and w_{11} were on the wx side of sh but that a calculation on such material could not be depended on.

au_1 — The location of au_1 to the right of sh is somewhat doubtful. Recombination values with C and sh are based on separate progenies. Neither au_1 or au_2 have been tested with yg for allelomorphism.

v_{14} — V_{14} is known to be located in the C-sh-wx linkage group but the data (Phipps unpub.) are of such a nature that a recombination value cannot be calculated.

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals XY	Xy	xY	xy	Total	Recombinations No.	Recombinations %	Authority
C	Wx	R Bc	115	340	298	92	845	207	24.5	Bregger '18
		C Bc	858	310	311	781	2260	621	27.5	Bregger '18
		C Bc	371	115	125	397	1008	240	23.8	Kempton '19
		C Bc	2542	717	739	2710	6708	1456	21.7	Hutchison '22
							42511	9388	22.1	Stadler '25
							249663	67402	27.0	Collins and
							302995	79314	26.2	(Kempton '27
C	Sh	C Bc	4032	149	152	4035	8368	301	3.6	Hutchison '22
		C Bc	10077	366	397	9866	20706	763	3.7	Eyster '29
		R Bc	638	21379	21096	672	43785	1310	3.0	Hutchison '22
							72849	2374	3.3	
Sh	Wx	R Bc	1531	5991	5885	1488	14895	3019	20.3	Hutchison '22
C	Sh	C Bc	9452	384	402	9377	19615	786	4.0	Hutchison '22
C	Wx	C Bc	1487	584	547	1520	4138	1131	27.3	Hutchison '22
		R Bc	790	2217	2283	792	6082	1582	26.0	Hutchison '22
							10220	2713	26.6	
C	V_1	R Bc	300	676	711	294	1981	594	30.0	Demerec '24
Wx	V_1	R	70	84	40	3	197		7±	Demerec '24
C	Pk	C S[1]	128	6	54	56	244		2	Eyster '24
		C S[2]	148	5	128	92	373		2	Eyster '24
Sh	Pk	R S[3]	140	61	60	2	263		10	Eyster '24
		R S[3]	382	173	173	11	739		24.5	Eyster '29
		R Bc[3]	73	363	366	70	872	143	16.4	Eyster '29
Sh	D_3	R S	329	162	138	8	637		22.8	Demerec '26
Sh	W_{11}	R S	487	193	161	16	857		31.2	Demerec '26
		C S	320	26	25	67	438		13.4	Demerec '26
C	Yg	C S					30817		20.5	Jenkins '27
		R S					3885		23.0	Jenkins '27
		R Bc	10	57	52	7	126	17	13.5	Jenkins '27
Sh	Yg	R Bc	193	546	429	99	1267	292	23.0	Jenkins '27
		R S	2583	1212	1057	89	4941		28.6	Jenkins '27
Wx	Yg	C Bc	397	289	297	412	1395	586	42.0	Jenkins '27
		R Bc	78	120	136	80	414	158	38.2	Jenkins '27
							1809	744	41.1	Jenkins '27
De_{15}	Wx	C S	4075	461	1609		6145		19.4	Brink '27
De_{15}	Sh	R S	2449	1146	1237		4832		16.5	Brink '27
Wx	Bp	R Bc	9	56	49	9	123	18	14.6	Meyers '27
C	Ar	R Bc[4]	2178	4692	4166	1507	12543	3685	29.4	Eyster '29
Sh	Ar	R Bc[4]	1925	4763	4177	1221	12086	3146	26.0	Eyster '29
Sh	Au_1	C S	2108	311	310	492	3221		21.6	Eyster '29
C	Au_1	C S[1]	546	79	638	305	1568		26.5	Eyster '29
Sh	Au_2	R S[3]	340	133	146	10	629		28.0[5]	Eyster '29
Sh	Gm_1	C S	2693	301	258	702	3954		15.3	Eyster '29
Wx	V_{15}	R S[3]	297	128	139	2	566		19	Phipps
Sh	V_{15}	R S[3]	366	171	172	5	714		20	Phipps

[1] C and R segregating - 9:7 ratio

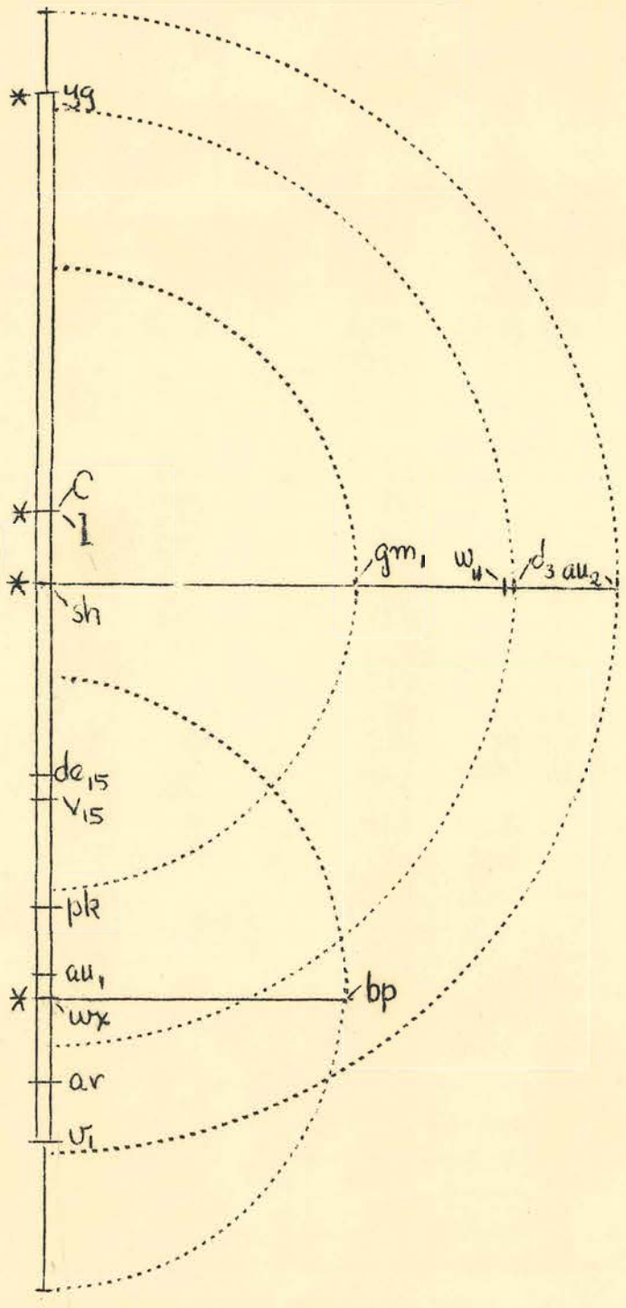
[2] A, C and R segregating - 27:37 ratio

[3] Ratio corrected for germination by author

[4] See Three-point test data

[5] Recombination value recalculated - author's calculation given as 39.7

C sh wx Group



R-G GROUP

List of Genes

df	Flint defective	Lindstrom 1925
g	Golden plant	Lindstrom 1918
gm_2	Germless	Demerec 1926
li_1	Lineate - striped leaves	Kempton 1920
l_1	Luteus seedlings	Lindstrom 1917
l_2	Luteus seedlings	Lindstrom 1925
nl	Narrow-leaf	Emerson (Unpub.)
pg_1	Pale-green seedling	Brunson 1924
R	Aleurone color	East and Hayes 191[illegible]
S	Spotted aleurone with Rrr	Kempton 1919
v_{18}	Virescent seedling	Phipps (Unpub.)
v_{20}	Virescent seedling	Phipps (Unpub.)
w_2	White seedling	Carver 1924

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals: X Y	X y	x Y	x y	Total	Recombinations: No.	%	Authority
R	G	C Bc	200	55	58	174	487	113	23.2	Lindstrom '17 & '18
		C Bc	227	36	33	195	491	69	14.1	Emerson
		R Bc	29	81	86	18	214	47	22.0	Lindstrom '18
		R Bc	18	117	156	28	319	46	14.4	Emerson
							1511	275	18.2	
R	L_1	C S	303	2	5	121	431		1.6[1]	Lindstrom '21
G	L_1	R Bc	8	35	21	5	69	13	18.8	Lindstrom '18
R	Pg_1	C S[2]	1907	300	1053	686	3946		23.3	Brunson '24
		R S	1199	506	445	32	2182		27.2	Brunson '24
G	Pg_1	C S	628	59	57	146	890		14.6	Wentz
Li_1	Pg_1	R S	194	71			265		45	Brunson '24
R	W_2	C S	1329	171	202	402	2104		18.5	Carver '24
		C S	648	74	81	157	960		17.8	Lindstrom '24
		R S	43	16	22	2	83		30.8	Carver '24
W_2	L_1	R S	815		210	10	1035			Lindstrom '25
		R S[3]	585		348	84	1017			Lindstrom '25
		R S[4]	560		318	70	948			Lindstrom '25
		R S[5]	380		402	115	897		22.0	Lindstrom '25
R	L_2	R S	986	405	473	69	1893		33.9	Lindstrom '25
		C S[2]	837	197	582	277	1893		35.4	Lindstrom '25
R	Gm_2	R S	2239	784	976	84	4083		31	Demerec '26
		R S	6876	2947	1182	90	11095		27	Wentz
Gm_2	G	R S	2810	873			3683		50 ±	Wentz
Gm_2	Pg_1	R S	835	255			1090		50 ±	Wentz
R	V_{18}	C[6]	51	15	43	93	202		20	Phipps
R	V_{20}	C Bc[6]	77	10	80	152	319		12.5	Phipps
G	Li_1	R Bc	148	817	924	111	2000	259	13.0	Hutchison
R	Li_1	C Bc	208	74	86	138	506	160	31.6	Hutchison
		C Bc[6]	460	191	282	374	651[7]	191	29.3	Hutchison
							1157	351	30.3	
G	Nl	R Bc	69	389	382	49	889	118	13.3	Emerson
R	Nl	C Bc	219	93	116	191	619	209	33.8	Emerson

[1] 1918 data indicate complete linkage

[2] C and R segregating - 9:7 aleurone ratio

[3] W_1 and w_2 segregating

[4] W_2 and w_3 segregating

[5] W_1, w_2 and w_3 segregating

[6] C and R segregating

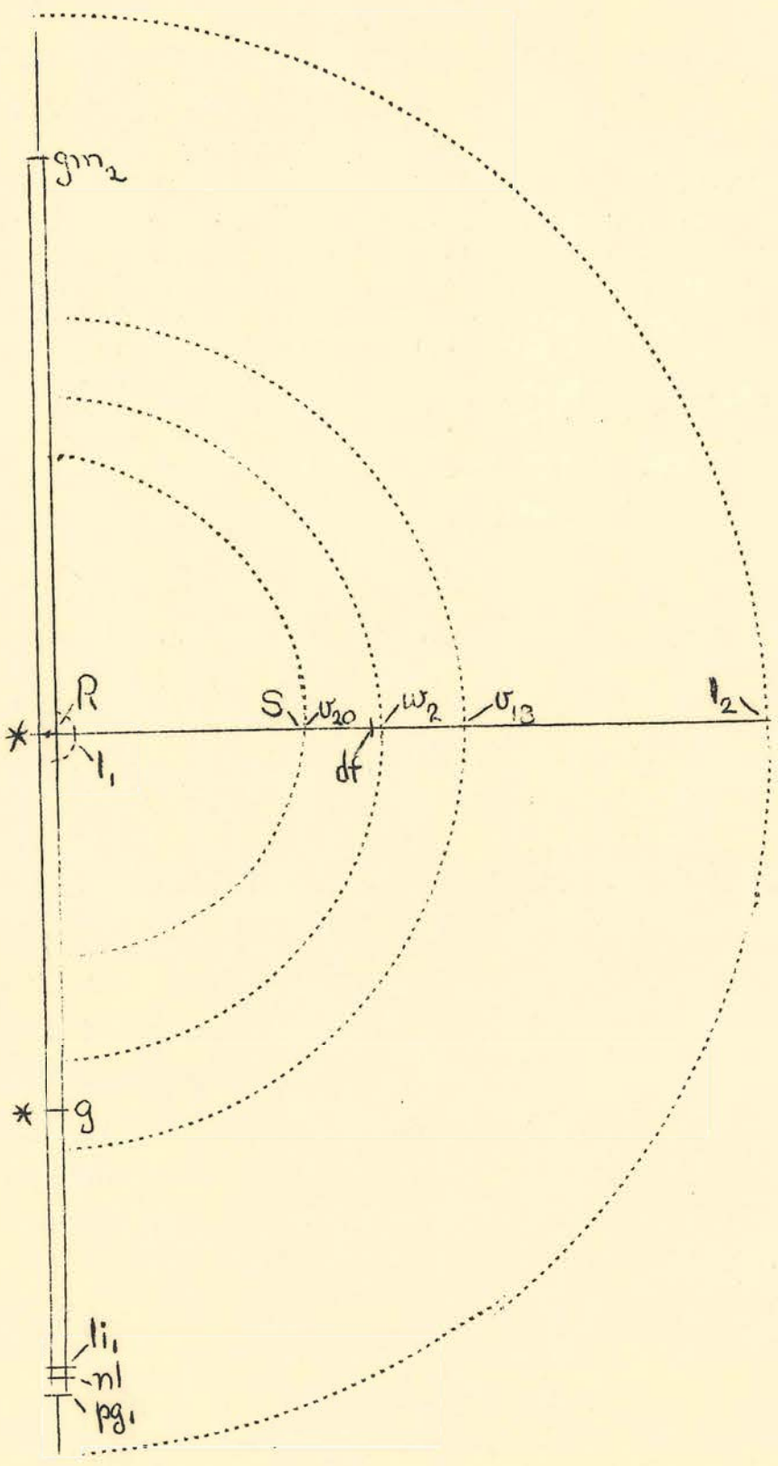
[7] First two classes only

Notes

df Lindstrom states that df and w_3 are very closely linked but presents no data.

S Kempton (1919) postulated this spotting factor, located so as to give about 12.5% recombinations with R. Emerson (Unpub.) has additional evidence in support of this assumption.

R g Group



SU-TU GROUP

List of Genes

de_1	Defective endosperm	Mangelsdorf & Jones 1925
de_6	Defective endosperm	Mangelsdorf 1926
de_{16}	Defective endosperm	Wentz 1925
Ga	Gamete - pollen tube growth	Mangelsdorf & Jones 1925
ge_1	Premature germination	Mangelsdorf 1926
su	Sugary endosperm	East and Hayes 1911
Ts_5	Tassel-seed	Emerson (Unpub.)
Tu	Tunicate ear	Collins 1917
wl	White-base leaf	Stroman 1925

Linkage Data

Genes X Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	%	Authority
Su Tu	C S	113	4	7	25	149	-	8.3	Jones & Gallastegui '19
	C Bc	430	175	169	406	1180	344	29.1	Eyster '21
	C Bc	612	290	208	562	1672	498	29.8	Emerson
	R Bc	1031	2498	2093	807	6429	1838	28.6	Eyster '22
	R Bc	63	215	164	57	499	120	24.0	Emerson
						9780	2800	28.6	
Su Wl	R S	44	19	11	1	75		25.0	Stroman '24
	R S	4492	2018	1961	93	8564		22.0	Carver '27
De_{16} Su	C S	20622	453	7201		28276	-	3.2	Wentz '25
Su V_8	C S	940	214	179	148	1481	-	32.4	Demerec '26
V_8 Tu	C S	450	1	Lethal		451		<1	Phipps
De_1 Su	R S	601	238	247	64	1150	-	39	Mangelsdorf & Jones '25
De_6 Su	R S	204	92	-	-	296		26	Mangelsdorf '25
Ge_1 Su	R S	1218	474			1692		40	Mangelsdorf '26
Su Ts_5	C Bc	578	41	42	457	1118	83	7.4	Emerson
Ts_5 Tu	R Bc	49	166	115	48	378	97	25.7	Emerson

Notes

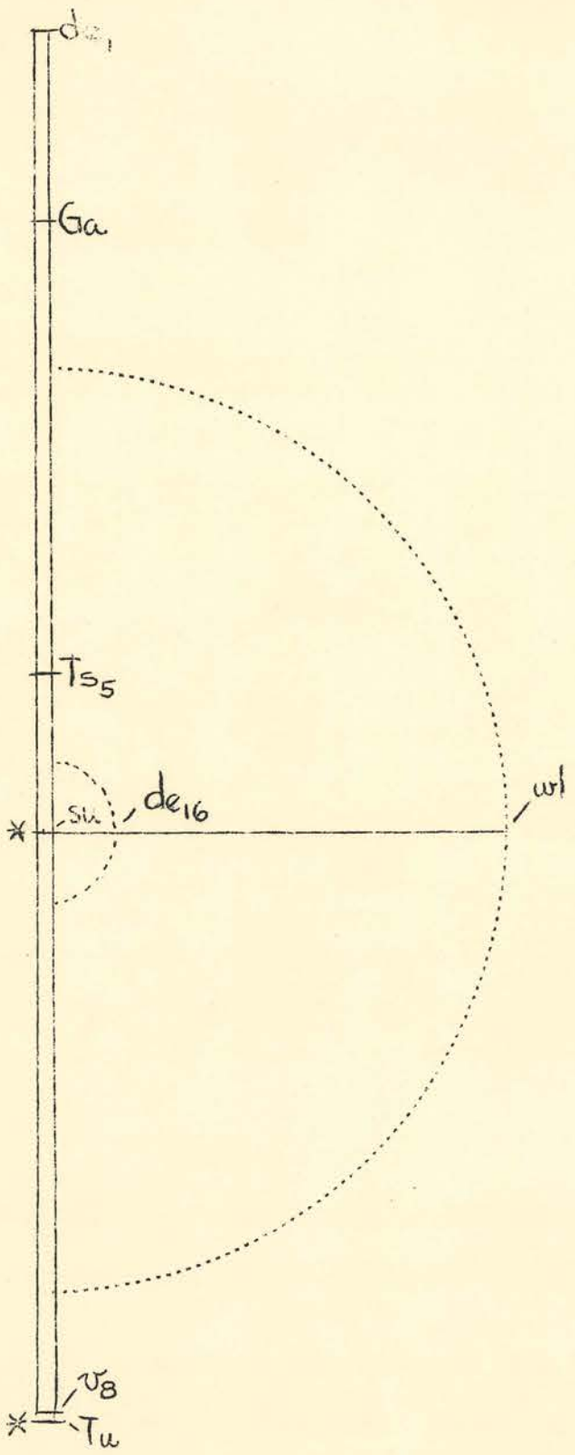
de_{16} is used instead of de_{su} for sugary defective of Wentz.

V_8 is very near Tu but whether to the left or right is unknown.

Ga is to the left of su because it disturbs the Tu-tu ratio very little if at all in pedigrees in which it disturbs the Su-su ratio materially (Emerson, Unpub.).

de_1 is presumably to the left of Ga, because Ga is between de and su (Mangelsdorf and Jones 1925).

su Tu Group



B-LG GROUP

List of Genes

B	Intensifier of plant color	Emerson 1918
lg	Liguleless	Emerson 1918
sk	Silkless	Jones 1925
ts_1	Tassel-seed	Emerson 1920
v_4	Virescent seedling	Demerec 1924

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	Recombinations %	Authority
B	lg	C Bc	240	134	102	243	719	236	32.8	Emerson '18
		C Bc	642	291	282	620	1835	573	31.2	Emerson
		C Bc	2487	1469	1557	2609	8122	3026	37.2	Emerson & Hutchison '21
		R Bc	498	1085	1037	504	3124	1002	32.1	Emerson
							13800	4837	35.0	
lg	ts_1	C Bc	117	52	72	74	315	124	39.4	Emerson
		R Bc	51	65	64	42	222	93	41.9	Emerson
							537	217	40.4	
B	V_4	C Bc	113	24	21	110	268	45	16.8	Demerec '24
V_4	lg	R Bc	412	501	521	366	1800	778	43.2	Demerec '24
B	Sk	C Bc	1332	97	106	1226	2761	203	7.4	Anderson
		R Bc	2	82	66	6	156	8	5.1	Anderson
							2917	211	7.2	
lg	Sk	R Bc	187	288	315	167	957	354	37.0	Anderson
			148	60	67	133	408	127	31.1	Anderson
							1365	481	35.2	

B lg Group

Y-PL GROUP

List of Genes

Bh	Blotched aleurone with A c R	Emerson (Unpub.)
fi	Fine streaked leaves	Anderson 1922
Pl	Purple plant color	Emerson 1918
sm	Salmon silks	Anderson 1921
v_6	Virescent seedling	Carver 1927
v_7	Virescent seedling	Carver 1927
w_1	White seedling	Stroman 1924
w_5	White seedling with w_6	Demerec 1924
w_6	White seedling with w_5	Demerec 1924

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	Recombinations %	Authority
Y	Pl	C Bc	79	22	28	71	200	50	25.0	Emerson '18
			545	221	234	506	1506	455	30.2	Anderson '21
			80	51	30	55	216	81	37.5	Anderson
			173	46	59	176	454	105	23.1	Hutchison
		R Bc	367	880	897	372	2516	739	29.4	Anderson '21
			135	398	374	118	1025	253	24.7	Anderson
							5917	1683	28.5	
Pl	Sm	C Bc	1076	145	146	994	2361	291	12.3	Anderson '21
			84	1014	971	76	2145	160	7.5	Anderson '21
							4506	451	10.0	
Y	Fi	C Bc	353	0		many				Anderson '23
Y	W_5	C S	250	37	35	54	376		24.3	Demerec '23
Y	W_5 / W_6	S[1]	349	12	60	33	454		24.3 / 24.5	Demerec '23
Y	W_1	C S	1020	237	259	191	1707		35	Lindstrom '24
		C S	1132	321	347	175	1975		42	Stroman '24
		R S	456	181	186	41	864		42	Stroman '24
Y	V_6	R S	467	225	209	12	913		23	Carver '27
Y	V_7	C S	592	149	178	79	998		42	Carver '27
		C S[2]	445	277	106	116	944		36	Carver '27
V_6	V_7	R S	497	179	237		913		42	Carver '27
Bh	Y	C Bc	144	51	118	210[3]	523	169	32.3	Anderson
Bh	Pl	C Bc	58	1	26	47[3]	132		1.7[4]	Anderson

[1] w_5 and w_6 duplicate genes

[2] Segregating for another v - not linked

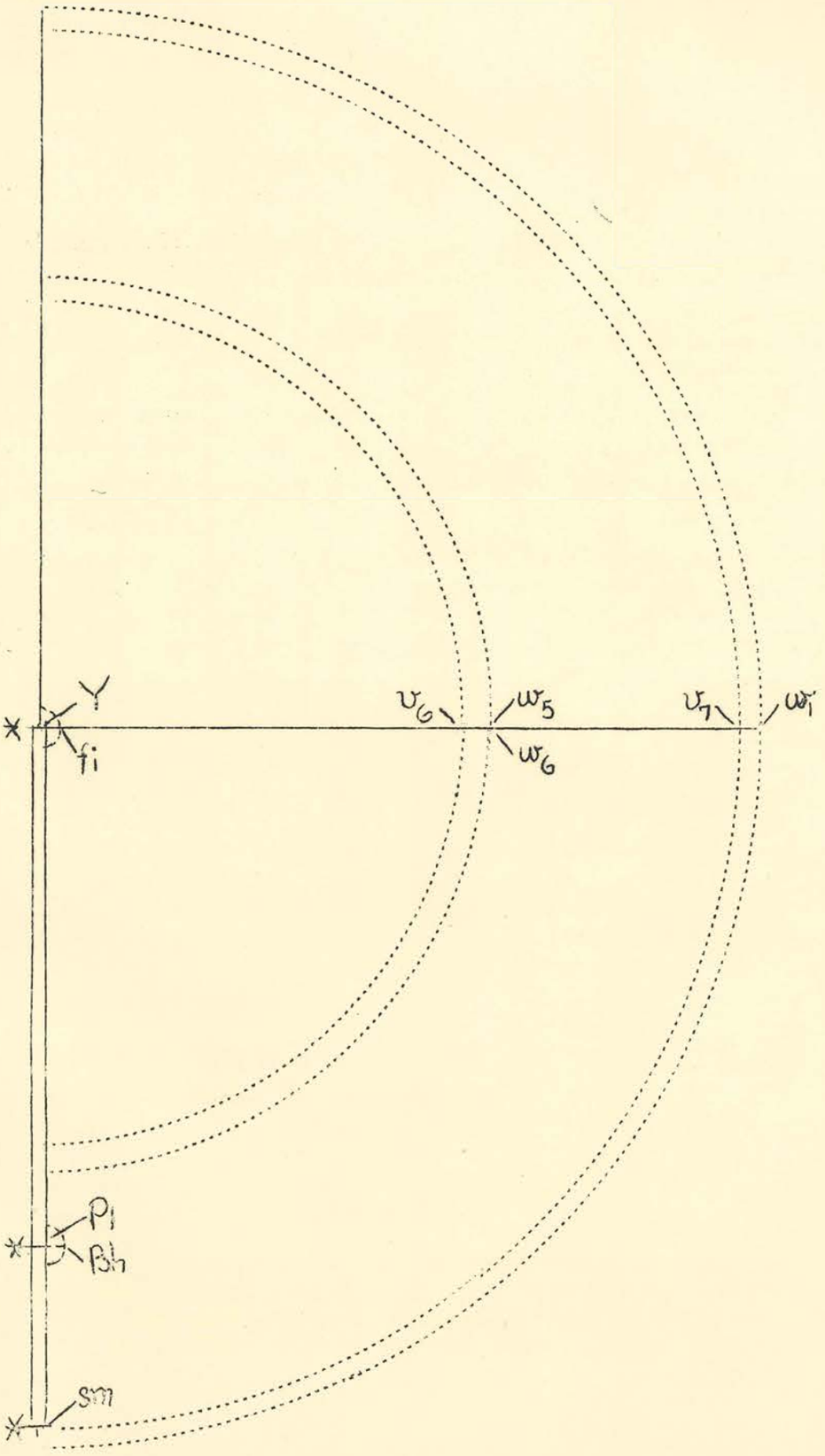
[3] Probably part of this class actually Bh

[4] From Bh class

Notes

m_1, m_2 — Stroman presents data which he interprets as showing linkage between m_1 and m_2 and also between m_1 and Y. His data are sufficiently extensive only to suggest that these factors may belong to this linkage group.

Y Pl Group



RA-GL_1 GROUP

List of Genes

Bn	Brown aleurone	Kvakan 1924
gl_1	Glossy seedling	Kvakan 1924
in	Intensifier of aleurone	Fraser 1924
pg_1	Pale-green seedling	Demerec 1925
ra	Ramosa	Gernert 1912
sl	Slashed seedling	Hayes and Brewbaker 1928
sr_2	Striate - striped leaf	Brunson (Unpub.)

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	Recombinations %	Authority
Bn	Gl_1	C Bc	177	63	54	192	486	117	24.1	Kvakan '24
Gl_1	V_5	C Bc	106	9	6	120	241	15	6.2	Kvakan '24
Bn	V_5	C Bc	83	31	29	98	241	60	24.9	Kvakan '24
Bn	Ra	C Bc	169	104	100	161	534	204	38.2	Kvakan '24
Bn	Pg_1	C S	203	8	5	65	281		4.5	Demerec '25
Gl_1	Sr_2	R Bc	97	289	342	63	791	160	20.2	Brunson

Notes

sl Hayes and Brewbaker state that sl belongs to this linkage group.

Y_2, Yp } Hayes and Brewbaker present data showing a linkage between two factors for yellow endosperm (Y_2 and Yp) and a glossy seedling factor. Since the relation of the glossy character to gl_1 is not evident, the placing of these two genes in this linkage group would appear uncertain.

RA-GL$_1$ GROUP

List of Genes

Bn	Brown aleurone	Kvakan 1924
gl$_1$	Glossy seedling	Kvakan 1924
in	Intensifier of aleurone	Fraser 1924
pg$_1$	Pale-green seedling	Demerec 1925
ra	Ramosa	Gernert 1912
sl	Slashed seedling	Hayes and Brewbaker 1928
sr$_2$	Striate - striped leaf	Brunson (Unpub.)
v$_5$	Virescent	Demerec 1924

dup. - Shap 2

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	%	Authority
Bn	gl$_1$	C Bc	177	63	54	192	486	117	24.1	Kvakan '24
gl$_1$	v$_5$	C Bc	106	9	6	120	241	15	6.2	Kvakan '24
Bn	v$_5$	C Bc	83	31	29	98	241	60	24.9	Kvakan '24
Bn	Ra	C Bc	169	104	100	161	534	204	38.2	Kvakan '24
Bn	Pg$_1$	C S	203	8	5	65	281		4.5	Demerec '25
gl$_1$	Sr$_2$	R Bc	97	289	342	63	791	160	20.2	Brunson

Notes

sl Hayes and Brewbaker state that sl belongs to this linkage group.

Y$_2$, Yp Hayes and Brewbaker present data showing a linkage between two factors for yellow endosperm (Y$_2$ and Yp) and a glossy seedling factor. Since the relation of the glossy character to gl$_1$ is not evident, the placing of these two genes in this linkage group would appear uncertain.

RA-GL_1 GROUP

List of Genes

Bn	Brown aleurone	Kvakan 1924
gl_1	Glossy seedling	Kvakan 1924
in	Intensifier of aleurone	Fraser 1924
pg_1	Pale-green seedling	Demerec 1925
ra	Ramosa	Gernert 1912
sl	Slashed seedling	Hayes and Brewbaker 1928
sr_2	Striate - striped leaf	Brunson (Unpub.)
v_5	Virescent	Demerec 1924

Linkage Data

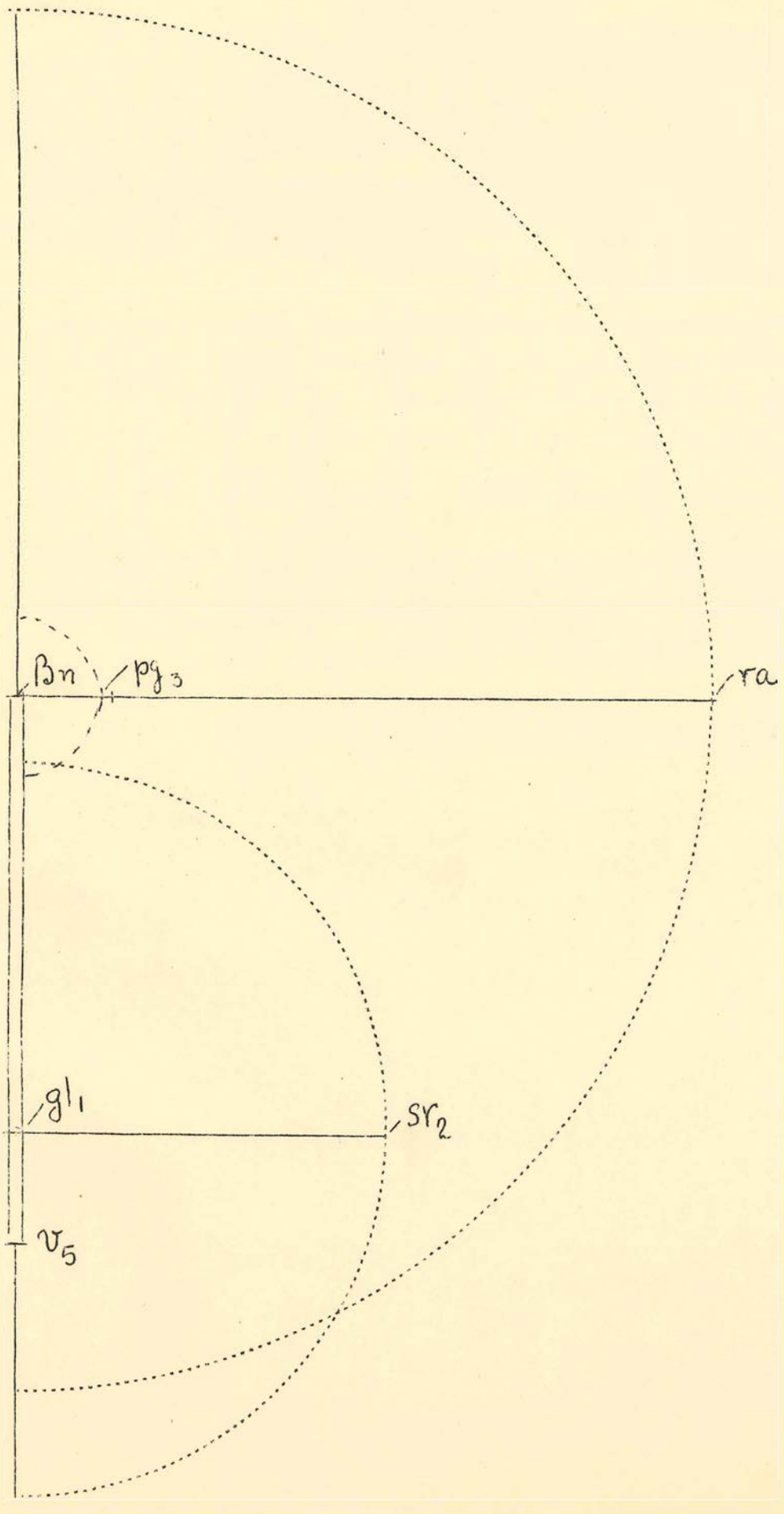
Genes X	Genes Y	Link. phase	Number of individuals: X Y	X y	x Y	x y	Total	Recombinations: No.	%	Authority
Bn	Gl_1	C Bc	177	63	54	192	486	117	24.1	Kvakan '24
Gl_1	V_5	C Bc	106	9	6	120	241	15	6.2	Kvakan '24
Bn	V_5	C Bc	83	31	29	98	241	60	24.9	Kvakan '24
Bn	Ra	C Bc	169	104	100	161	534	204	38.2	Kvakan '24
Bn	Pg_1	C S	203	8	5	65	281		4.5	Demerec '25
Gl_1	Sr_2	R Bc	97	289	342	63	791	160	20.2	Brunson

Notes

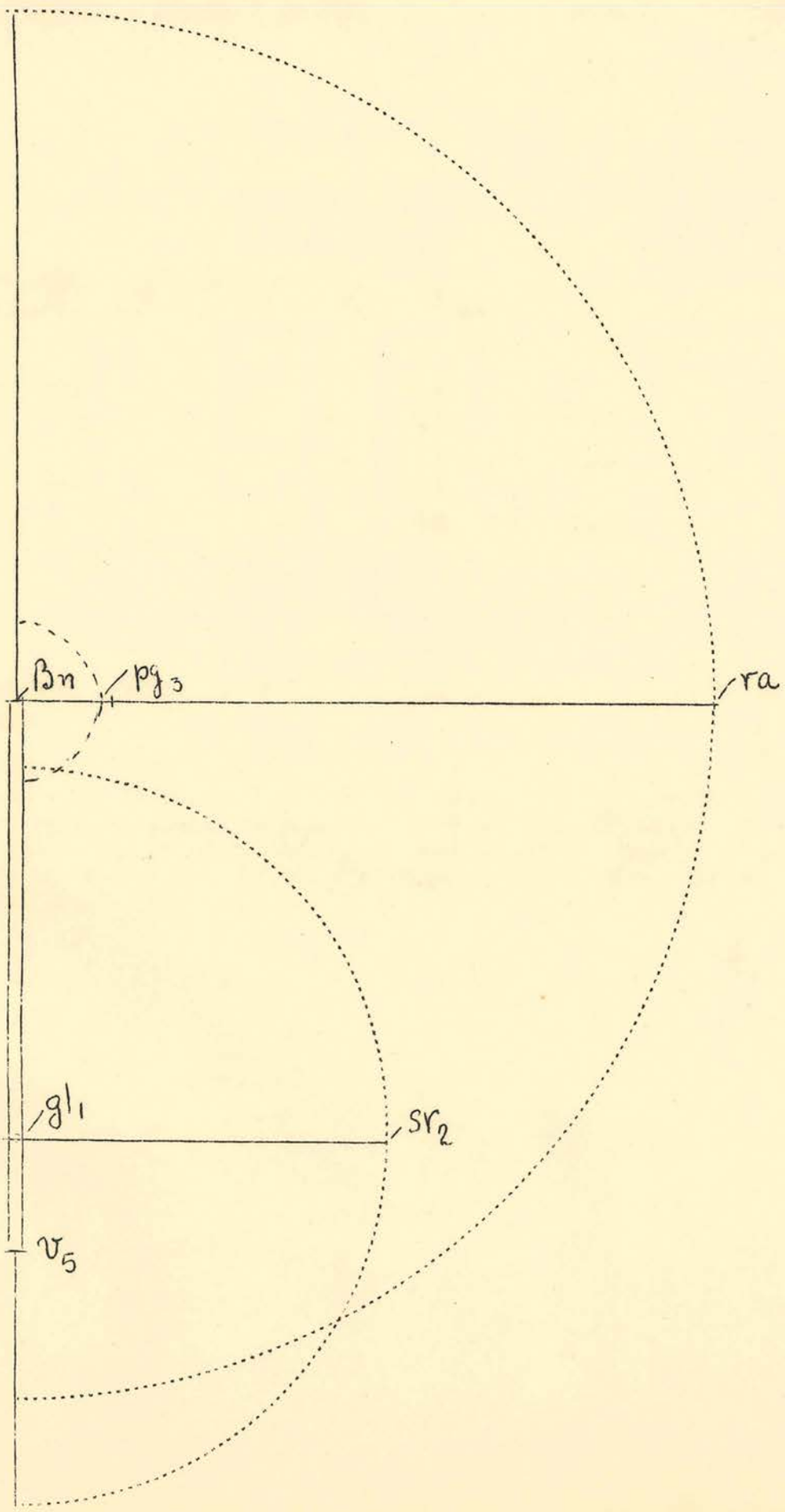
sl Hayes and Brewbaker state that sl belongs to this linkage group.

Y_2, Yp } Hayes and Brewbaker present data showing a linkage between two factors for yellow endosperm (Y_2 and Yp) and a glossy seedling factor. Since the relation of the glossy character to gl_1 is not evident, the placing of these two genes in this linkage group would appear uncertain.

ra-gl_1 Group



ra-gl_1 Group



PR-V_2 GROUP

List of Genes

bm	Brown midrib	Eyster 1926
bv	Brevis - semi-dwarf plant	Suttle (Unpub.)
f_2	Fine striped leaves	Eyster 1926
Pr	Purple aleurone	East and Hayes 1911
sc_1	Scarred endosperm	Eyster 1926
tn	Tiny plant	Eyster 1926
v_2	Virescent seedling	Demerec 1924
v_3	Virescent seedling	Demerec 1924
v_{12}	Virescent seedling	Phipps (Unpub.)
yg	Yellow green	Eyster 1926
ys	Yellow-stripe	Beadle 1929

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	Recombinations %	Authority
Pr	V_2	R Bc	377	532	499	366	1774	743	41.9	Phipps
		C Bc	67	46	41	51	205	87	42.4	
							1979	830	42.0	
Pr	V_3	R Bc	123	296	320	102	841	225	26.8	Phipps
Pr	V_{12}	C Bc	61	15	4	75	155	19	12.4	Phipps
		C S	492	37	39	137	705		11.4	
Pr	Ys	R	219	323	209	19	770		8.3	Beadle '29

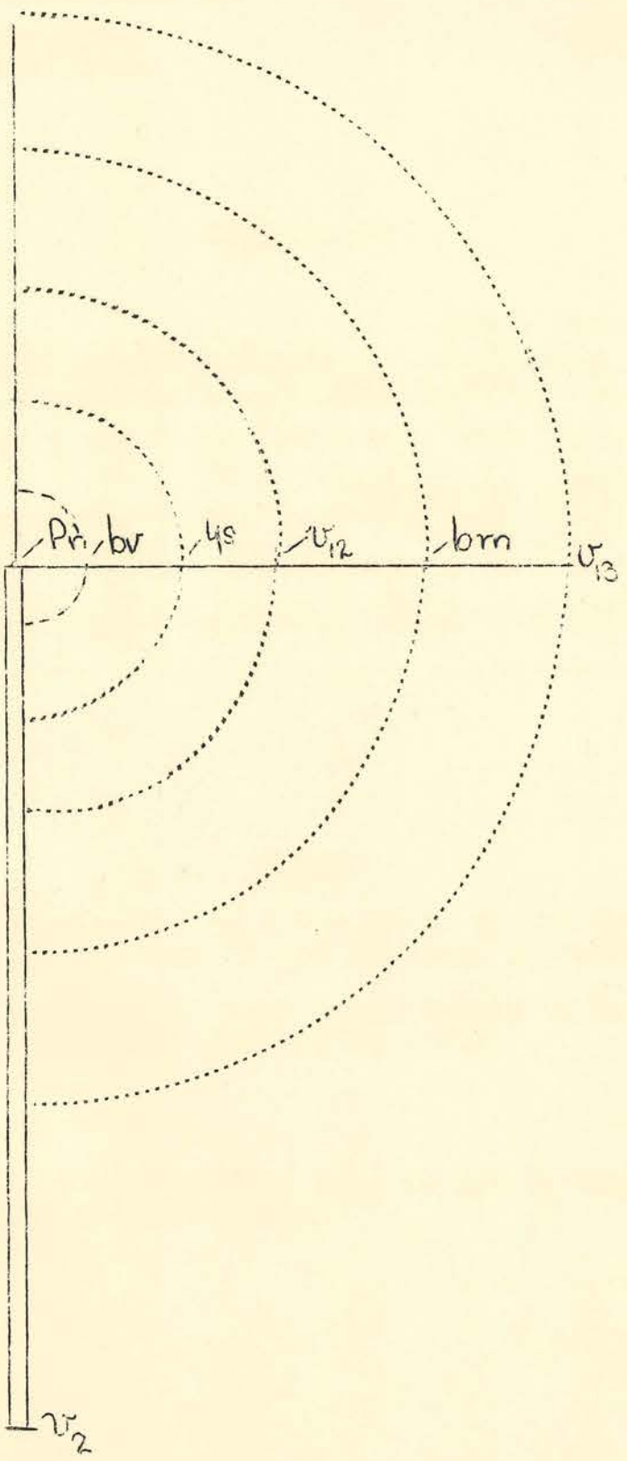
Notes

bm — Eyster states that bm shows about 20 per cent recombinations with Pr but presents no data.

f_2, sc_1, tn, yg — Eyster states that these genes belong to the Pr linkage group but presents no data.

bv — Li (Unpub.) has evidence that bv and Pr are relatively closely linked.

Pr v_2 Group



D_1- PG_2 GROUP

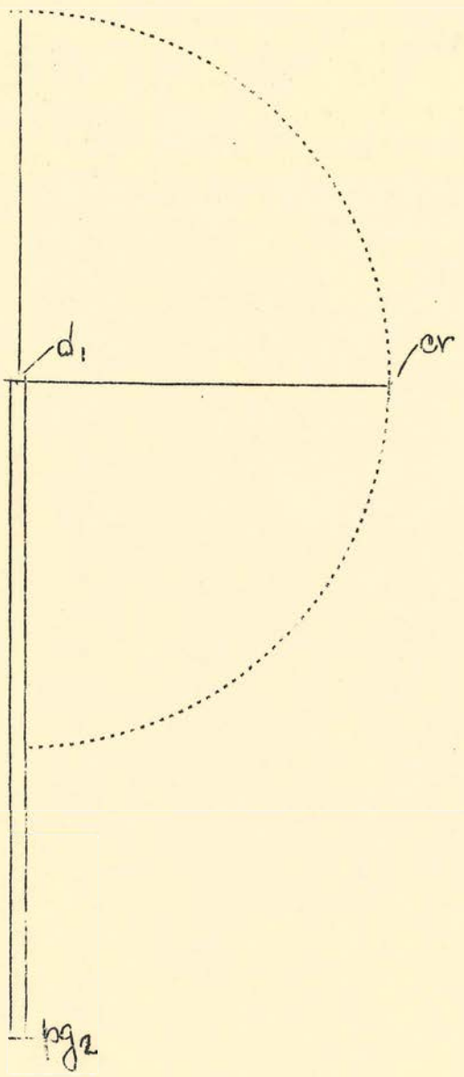
List of Genes

d_1	Dwarf plant	Emerson 1912
pg_2	Pale-green seedling	Demerec 1924
cr	Crinkly leaves	Emerson 1921

Linkage Data

Genes X	Genes Y	Link. phase	Number of individuals X Y	X y	x Y	x y	Total	Recombinations No.	Recombinations %	Authority
D_1	Pg_2	R S	1364	584	580	65	2593		32	Demerec '24
D_1	Cr	R Bc	15	53	48	15	131	30	22.9	Emerson
		C Bc	518	102	107	482	1209	209	17.3	Emerson
							1340	239	17.8	

d pg_2 Group



A-Ts_4 GROUP

List of Genes

A	Anthocyanin pigment	Emerson 1918
na	Nana - dwarf plant	Suttle (Unpub.)
ts_4	Tassel-seed	Phipps 1928

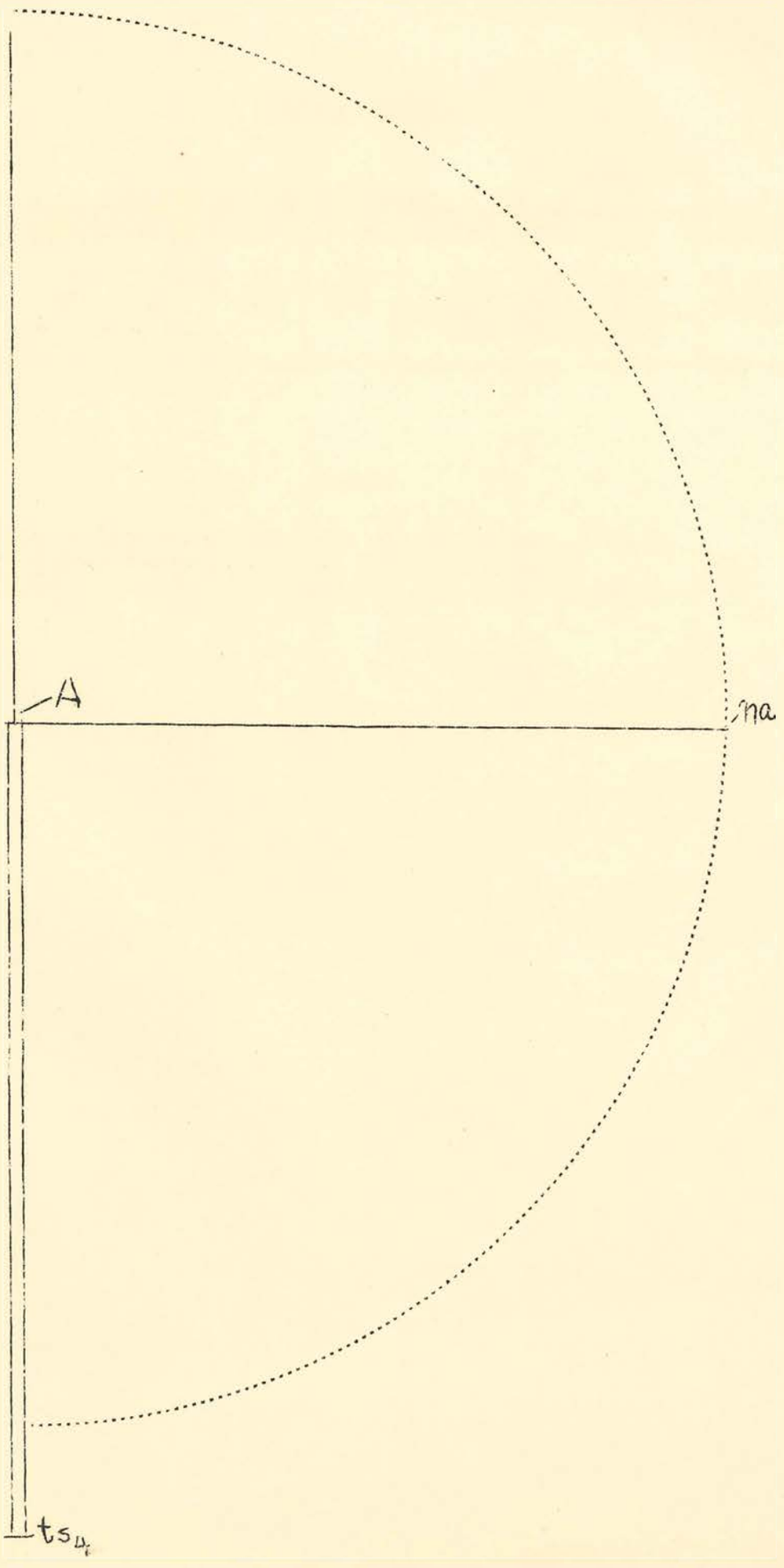
Linkage Data

Genes X Y	Link. phase	Number of individuals					Recombinations		Authority
		X Y	X y	x Y	x y	Total	No.	%	
A Ts_4	C Bc	90	63	70	85	308	133	43.2	Phipps '28
	R Bc	262	351	372	333	1318	595	45.1	Phipps '28
						1626	728	44.8	

Notes

Li (Unpub.) has evidence that na is linked with A, showing about 40 per cent of recombinations.
Jones (Unpub.) also has evidence of this linkage.

A ts_4 Group



SUMMARY OF THREE-POINT LINKAGE TESTS IN MAIZE

Parent No. 1	Parental combinations No.1 No.2	Recombinations Region 1	Region 2	Regions 1 & 2	Total	Coincidence	Authority
C sh Wx	2538 2708 5246	116 113 229 3.4%	601 626 1227 18.3%	4 2 6 0.12%	6708	0.14	Hutchis '22
I Sh wx	2215 2280 4495	121 139 260 4.3%	669 653 1322 21.7%	2 3 5 0.08%	6082	0.09	Hutchison '22
yg C Sh	54 51 105	7 9 16 12.7%	3 1 4 3.2%	1 0 1 0.8%	126		Jenkins '27
C sh ar	4678 4138 8816	259 192 451 3.6%	1248 1986 3234 25.8%	14 28 42 0.34%	12543	0.33	Eyster '2?
Ts_5 Su tu	163 113 276	9 12 21 5.6%	37 39 76 20.1%	2 3 5 1.3%	378	0.88	Emerson
Ts_1 b Lg	111 71	24 17	48 35	6 3	315		Emerson
Ts_1 B lg	57 57 296	20 21 82 15.3%	31 21 135 25.1%	7 8 24 4.5%	222 537	0.77	
Sk B Lg	148 131 279	13 8 21 5.1%	56 52 108 26.3%	0 2 2 0.5%	410	0.36	Anderson
Y Pl Sm Y pl Sm Y Pl sm Y pl sm	191 180 436 377 305 265 333 411 2498	109 104 165 206 107 124 183 152 1150 28.6%	21 31 45 50 28 30 66 59 330 8.2%	5 5 5 1 0 1 16 12 45 1.12%	4023	0.40	Anderson '21
Ts_2 br F_1	12 8 20	3 9 12 34.3%	0 3 3 8.6%	0 0 0 0.0%	35		Emerson
Bn Cl_1 V_5	83 98 181	22 23 45 18.7%	9 6 15 6.2%	0 0 0 0.0%	241		Kvakan '24

Summary of Data on the Independence of the Linkage Groups in Maize

	yg	Cl	sh	wx	v_1	au_1	R	g_1	nl	li_1	v_{18}	v_{20}	Ts_5	su	Tu	ts_1	v_4	sk	B	lg	Y	Pl	sm	w_1	P	ts_2	br	f_1	Bn	gl_1	v_5	ra	d_1	pg_2	cr	Pr	v_2	v_3	v_{12}	bv
A	99	20		5	46		99	9	6				2	30	1			12	13	30	6	11	10		10	15				15			7			7		20	14	3	5
ts_4	2			2			5	5						4	1					4	10	3	4																	5
ma	1	5					20	12						2						5	8	1	5			1		3		1		5				5		3		
Pr			8	5			20	6	1					5	3					1	1		2		?			5	11			13	2		5					
v_2								2						3								5						8					1							
v_3				13										34						14	1	2	1										4							
v_{12}			8											6						4		1				4			3											
bv																																								
d_1	4				11		5	2						8	5		27		3			3	3		2	5					5									
pg_2	7	4		4			7							6								26																		
cr	4	10		3			12	5		4				9	5	2				15	9	1	6			1		1				3								
Bn	26	14	14		9		6							29	2						5	41	6		3			7												
gl_1																																									
v_5																																									
ra	7	6	4				16	3		3				10	7					14	4	4	6		8			7												
in	45																																								
P		8	3				12	5	6					7	6	1				30	15	18	23	9																	
ts_2		1						3	2					1						5	3	7	7																	
br		1					5						3								16	1																		
f_1			9						2						7	15				2	6	2	3																	
Y		9	8	12			15	4	2	10	1	10		13	1		14			14	10																			
Pl		6	5			6	12	5	7	8			4	11	3			14		44	19																			
sm																				1																				
ts_1								5																																
v_4		12		7			12							8																										
sk		3					13							4																										
B		33	11				46	1	7	7			5	13	19																									
lg		11	19			15	55	3	10	7		10		21	23																									
Ts_5				2			4																																	
su		50					71	5	2	5		3																													
Tu		9					9	5	3																															
R		17	23	6																																				
g_1		1	3																																				
nl			3	3																																				
li_1			8																																				
v_{18}			2	2																																			
v_{20}			2																																				

Figures in table represent approximately the number of hundreds of individuals counted, the counts suggesting independent inheritance.

Counts on backcross progenies are distinquished by an underscore from counts from self pollinations.

Summary of Data on the Independence of the Linkage

	yg	Cl	sh	wx	v_1	au_1	R	g_1	nl	li_1	v_{18}	v_{20}	Ts_5	su	Tu	ts_1	v_4	sk	B	lg	Y	Pl	sm
A		99	20	5	48		99	9	6				2	30	1		12	13	30	6	11	10	
ts_4		2		2			5	5						4	1				4	10	3	4	
ma		1	5				20	12						2					5	8	1	5	
Pr			8	5			20	6	1					5	3				1	1		2	
v_2								2						3							5		
v_3				13										34						14	2	1	
v_{12}			8											6						4	1		
b_7																							
d_1		4			11		5	2						8	5		27		3		3	3	
pg_2		7	4	4			7							6							26		
cr		4	10	3			12	5		4				9	5	2			15	9	1	6	
Bn		26	14	14	9		6							29	2					5	41	6	
gl_1																							
v_5																							
ra		7	6	4			16	3		3				10	7				14	4	4	6	
in		45																					
P		8	3				12	5	6					7	6	1			30	15	18	23	9
ts_2		1						3	2					1					5	3	7	7	
br		1					5						3							16	1		
f_1			9						2						7		15		2	6	2	3	
Y		9	8	12			15	4	2	10	1	10		13	1		14		14	10			
Pl		6	5		6		12	5	7	8			4	11	3			14	44	19			
sm																			1				
ts_1								5															
v_4		12		7			12							8									
sk		3					13							4									
B		33	11				46	1	7	7			5	13	19								
lg		11	19			15	55	3	10	7		10		21	23								
Ts_5				2			4																
su		50					71	5	2	5		3											
Tu		9					9	5	3														
R		17	23	6																			
g_1		1	3																				
nl			3	3																			
li_1			8																				
v_{18}			2	2																			
v_{20}			2																				

endence of the Linkage Groups in Maize

l	v_4	sk	B	lg	Y	Pl	sm	w_1	P	ts_2	br	f_1	Bn	gl_1	v_5	ra	d_1	pg_2	cr	Pr	v_2	v_3	v_{12}	bv
	12	13	20	6	11	10		10	15				15			7			7		20	14	3	5
			4	10	3	4					5	1												5
			5	8	1	5				1		3		1		5				5		3		
			1	1		2			?			5	11			13	2		5					
					5							8					1							
				14	2	1											4							
				4	1					4			3											
	27		3		3	3			2	5						5								
					26																			
			15	9	1	6				1		1				3								
				5	41	6			3			7												
			14	4	4	6			8			7												
			30	15	18	23	9																	
			5	3	7	7																		
				16	1																			
	15		2	6	2	3																		
	14		14	10																				
		14	44	19																				
			1																					

Figures in table represent approximately the number of hundreds of individuals counted, the counts suggesting independent inheritance.

Counts on backcross progenies are distinquished by an underscore from counts from self pollinations.

LITERATURE ON LINKAGE IN MAIZE

In general, only papers containing data on the linkage or independence of factors in known linkage groups are listed.

Anderson, E. G. - The inheritance of salmon silk color in maize. Cornell Univ. Agric. Exp. Sta. Mem. 48: 539-554. 1921.

_____ - Heritable characters of maize. XI. Fine streaked leaves. Jour. Heredity 13: 91-92. 1922.

_____ - Pericarp studies in maize. II. The allelomorphism of a series of factors for pericarp color. Genetics 9: 442-453. 1924.

_____ - Genetic factors for yellow endosperm color in maize. Papers Mich. Acad. Science, Arts & Letters 4: 51-54. 1924.

_____ and Emerson, R. A. - Pericarp studies in maize. I. The inheritance of pericarp colors. Genetics 8: 466-476. 1923.

Beadle, G. W. - Yellow stripe - a factor for chlorophyll deficiency in maize located in the Pr pr chromosome. Amer. Nat. 63: 139-151. 1929.

Bregger, T. - Linkage in maize: The C aleurone factor and waxy endosperm. Amer. Nat. 52: 57-61. 1918.

Brink, R. A. - A lethal mutation in maize affecting the seed. Amer. Nat. 61: 528-530. 1927.

Brunson, A. M. - The inheritance of a lethal pale green seedling character in maize. Cornell Univ. Agric. Exp. Sta. Mem. 72: 5-22. 1924.

Carver, W. A. - The genetic relation of endosperm and chlorophyll characters in maize. Proc. Iowa Acad. Sci. 31: 129. 1924. (A short note without data in which it is stated that brindled, a chlorophyll defect, shows linkage with sw with about 26 % of recombinations).

_____ - A genetic study of certain chlorophyll deficiencies in maize. Genetics 12: 415-440. 1927.

Collins, G. N. - Gametic coupling as a cause of correlations. Amer. Nat. 46: 569-590. 1912.

_____ - Mosaic coherence of characters in seeds of maize. U.S.D.A. B.P.I. Circ. 132: 19-21. 1913.

_____ - Hybrids of Zea tunicata and Zea ramosa. Proc. Nat. Acad. Sci. 3: 345-349. 1917.

_____ - Hybrids of Zea ramosa and Zea tunicata. Jour. Agric. Res. 9: 383-395. 1917.

_____ and Kempton, J. H. - Inheritance of waxy endosperm in hybrids of Chinese maize. IV. Conference internat de genetique (Paris). Compt. rend. 1911: 347-356. 1913.

_____ and _____ - Inheritance of waxy endosperm in hybrids with sweet corn. U.S.D.A. B.P.I. Circ. 120: 21-27. 1913.

_____ and _____ - Inheritance of endosperm texture in sweet X waxy hybrids of maize. Amer. Nat. 48: 584-594 1914.

Collins, G. N. and Kempton, J. H. - Variability in the linkage of two seed characters of maize. U.S.D.A. Bul. 1468: 64. 1927.

Demerec, M. - Inheritance of white seedlings in maize. Genetics 8: 561-593. 1923.

_____ - Genetic relations of five factor pairs for virescent seedlings in maize. N. Y. (Cornell) Agric. Exp. Sta. Mem. 84: 3-38. 1924.

_____ - Inheritance of pale green seedlings in maize. Genetics 10: 318-344. 1925.

_____ - Notes on linkages in maize. Amer. Nat. 60: 172-176. 1926.

East, E. M. - Inheritance of color in the aleurone cells of maize. Amer. Nat. 46: 363-365. 1912.

_____ and Hayes, H. K. - Inheritance in maize. Conn. Agric. Exp. Sta. Bul. 167: 1-142. 1911.

Emerson, R. A. - Genetic correlation and spurious allelomorphism in maize. Neb. Agric. Exp. Sta. Ann. Rept. 24: 58-90. 1911.

_____ - The inheritance of the ligule and auricles of corn leaves. Neb. Agric. Exp. Sta. Rept. 25: 81-88. 1912.

_____ - A fifth pair of factors, A a, for aleurone color in maize, and its relation to the C c and R r pairs. Cornell Univ. Agric. Exp. Sta. Mem. 16: 231-289. 1918.

_____ - Heritable characters of maize. II. Pistillate-flowered maize plants. Jour. Heredity 11: 65-76. 1920.

_____ - The genetic relations of plant colors in maize. Cornell Univ. Agric. Exp. Sta. Mem. 39: 7-156. 1921.

_____ - Aberrant endosperm development as a means of distinguishing linkage groups in maize. Amer. Nat. 58: 272-277. 1924.

_____ - A possible case of selective fertilization in maize hybrids. Abstract in Anat. Rec. 29: 136. 1924.

_____ and Emerson, Sterling H. - Genetic interrelations of two andromonoecious types of maize, dwarf and anther ear. Genetics 7: 202-236. 1922.

_____ and Hutchison, C. B. - The relative frequency of crossing over in microspore and in megaspore development in maize. Genetics 6: 417-432. 1921.

Eyster, W. H. - The linkage relations between the factors for tunicate ear and starchy-sugary endosperm in maize. Genetics 6: 209-240. 1921.

_____ - Inheritance of zigzag culms in maize. Genetics 7: 559-567. 1922.

_____ - The intensity of linkage between the factors for sugary endosperm and for tunicate ears and the relative frequency of their crossing over in microspore and megaspore development. Genetics 7: 597-601. 1922.

_____ - A primitive sporophyte in maize. Amer. Jour. Bot. 11: 7-14. 1924.

Eyster, W. H. - Heritable characters of maize. Polkadot leaves. Jour. Heredity 15: 397-400. 1924.

_____ - Chromosome VIII in maize. Science 64: 22. 1926.

_____ - Five new genes in chromosome I in maize. Ztsch. f. Ind. Ab. u Vererb. 59: 105-130. 1929.

Fraser, A. C. - Heritable characters of maize - XVII. Intensified red and purple aleurone color. Jour. Heredity 15: 119-123. 1924.

Hayes, H. K. and Brewbaker, H. E. - Factors for color of aleurone and endosperm in maize. Jour. Amer. Soc. Agron. 18 (9): 761-767. 1926.

_____ and _____ - Glossy seedlings in maize. Amer. Nat. 62: 228-235. 1928.

_____ and East, E. M. - Further experiments on inheritance in maize. Conn. Agric. Exp. Sta. Bul. 188: 1-31. 1915.

Hutchison, C. B. - Heritable characters of maize. VII. Shrunken endosperm. Jour. Heredity 12: 76-83. 1921.

_____ - The linkage of certain aleurone and endosperm factors in maize, and their relation to other linkage groups. Cornell Univ. Agric. Exp. Sta. Mem. 60: 1425-1473. 1922.

Immer, F. R. - The inheritance of reaction to Ustilago Zeae in maize. Univ. of Minn. Tech. Bul. 51: 62. 1927.

Jenkins, M. T. - A factor for yellow-green chlorophyll color in maize and its linkage relations. Genetics 12: 492-518. 1927.

Jones, D. F. - Heritable characters of maize XXIII - Silkless. Jour. Heredity 16: 339-341. 1925.

_____ and Mangelsdorf, P. C. - The expression of Mendelian factors in the gametophyte of maize. (Paper given at Kansas meetings of A. A. A. S., Dec., 1925). Anat. Rec. 31: 351. 1925.

_____ and Gallastegui, C. A. - Some factor relations in maize with reference to linkage. Amer. Nat. 53: 239-246. 1919.

Kempton, J. H. - A correlation between endosperm color and albinism in maize. Jour. Wash. Acad. Sci. 7: 146-149. 1917.

_____ - Inheritance of spotted aleurone color in hybrids of Chinese maize. Genetics 4: 261-274. 1919.

_____ - Heritable characters of maize. V. Adherence. Jour. Heredity 11: 317-322. 1920.

_____ - Linkage between brachytic culms and pericarp and cob color in maize. Jour. Wash. Acad. Sci. 11: 13-20. 1921.

_____ - Linkage between brachysm and adherence in maize. Amer. Nat. 56: 461-464. 1922.

_____ - Heritable characters of maize. XVI. Dead leaf margins. Jour. Heredity 14: 349-351. 1923.

_____ - Inheritance of dwarfing in maize. Jour. Agric. Res. 25: 297-321. 1923.

Kvakan, P. - The inheritance of brown aleurone in maize. N. Y. (Cornell) Agric. Exp. Sta. Mem. 83: 3-22. 1924.

Lindstrom, E. W. - Linkage in maize: aleurone and chlorophyll factors. Amer. Nat. 51: 225-237. 1917.

_____ - Chlorophyll inheritance in maize. Cornell Univ. Agric. Exp. Sta. Mem. 13: 7-68. 1918.

_____ - Chlorophyll factors of maize. Jour. Heredity 11: 269-277. 1920.

_____ - Concerning the inheritance of green and yellow pigments in maize seedlings. Genetics 6: 91-110. 1921.

_____ - Hereditable characters of maize XIII. Endosperm defects - sweet defective and faint defective. Jour. Heredity 14: 126-135. 1923.

_____ - Genetic research with maize. Genetics 5: 327-356. 1923.

_____ - Complementary genes for chlorophyll development in maize and their linkage relations. Genetics 9: 305-326. 1924.

_____ - Genetic factors for yellow pigment in maize and their linkage relations. Genetics 10: 442-455. 1925.

Mangelsdorf, P. C. - The genetics and morphology of some endosperm characters in maize. Conn. Agric. Exp. Sta. Bul. 279: 513-614. 1926.

_____ and Jones, D. F. - The expression of Mendelian factors in the gametophyte of maize. Genetics 11: 423-455. 1926.

Meyers, Marion T. - A second recessive factor for brown pericarp in maize. Ohio Jour. of Science XXVII: 295-300. 1927.

Phipps, I. F. - Heritable characters in maize. XXXI. Tassel seed-4. Jour. Heredity 19: 399-404. 1928.

Stadler, L. J. - Variation in the intensity of linkage in maize. Amer. Nat. 59: 366-370. 1925.

_____ - The variability of crossing over in maize. Genetics 11: 1-37. 1926.

Stroman, G. N. - Genetic relations of chlorophyll and anthocyanin seedling characters in maize. Genetics 9: 91-123. 1924.

_____ - The inheritance of certain chlorophyll characters in maize. Genetics 9: 493-512. 1924.

Webber, H. J. - Correlation of characters in plant breeding. Amer. Breeders' Assoc. Rept. 2: 73-83. 1906.

Wentz, J. B. - Linkage between sweet-defective and sugary endosperm in maize. Genetics 10: 395-401. 1925.