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H. A. McGinnis

A Comparison of the transpiration Rates
of corn and soy beans with those of
certain common weeds

A COMPARISON OF THE TRANSPIRATION RATES
OF CORN AND SOY BEANS WITH THOSE OF
CERTAIN COMMON WEEDS

BY

HELEN ANASTASIA MCGINNIS
A. B. University of Illinois, 1918

THESIS

Submitted in Partial Fulfillment of the Requirements for the

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY
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THE DEGREE OF Master of Arts

W. B. McDougall

In Charge of Thesis

Wm. J. Reese

Head of Department

Recommendation concurred in*

Committee
on
Final Examination*

*Required for doctor's degree but not for master's

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A C K N O W L E D G E M E N T

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Table of Contents.

	Page
I. Introduction	1
II. Materials and Methods	2
A. Description of Materials	2
B. Description of Methods	4
III. Results	6
A. Description of Tables	6
B. Description of Plates	7
IV. Discussion	7
V. Summary	10
VI. Bibliography	11 - 12
VII. Tables and Plates	13 - 19
Table I.	13
Table II.	14
Table III.	15
Plate I.	16
Plate II.	17
Plate III.	18
Plate IV.	19

A COMPARISON OF THE TRANSPIRATION RATES OF
CORN AND SOY BEANS WITH THOSE OF
CERTAIN COMMON WEEDS.

I. INTRODUCTION.

That the presence of weeds in a cornfield is detrimental to the intake of moisture, the reception of light, and the manufacture of food by the corn plant has been demonstrated by experiment (15). Such experiments do not show, however, either the amount or the rate of removal of water from the soil by the weed invaders. It is the purpose of the present paper to give in some degree the relative rates of water loss by transpiration from the leaves of corn plants and soy beans and from those of corn-field weeds, all three kinds of plants growing under the same external conditions.

The study of transpiration from the leaves of plants in place is by no means a new one. Trelease and Livingston (19), for instance, measured the relative transpiring power of several plants. They were interested, however, in the diurnal fluctuations of this power rather than with the difference in power between different plants. Bakke (1) also measured the index of transpiring power of various plants and the same might be said of several other authors. A historical resume of the literature will not be attempted here as a fairly complete bibliography of the subject is given by Kiesselbach (10). But a survey of the literature shows that most of the writers are concerned, as the above mentioned, with the relative transpiring power of plants as compared with the evaporation from a free water surface, the latter being the standard for comparison.

The experiments described in the present paper do not give quantita-

tive data as to the rate of water loss but they do show the comparative rates of water loss from a given area of corn leaf and equal areas of soy bean leaf and the various weed leaves, thus determining which transpires more rapidly area for area. In these experiments the corn plant, rather than a free water surface, is the standard of comparison.

The greater part of the present work has been carried on with plants growing in the Botanical Greenhouses at the University of Illinois. The problem was commenced in the fall of 1918 and extended to the spring of 1920.

II. MATERIALS AND METHODS.

A. Description of Materials.

The cultivated plants used in the project were Reed's yellow dent corn and dwarf early soy beans, the seed of which was of the previous summer's crop and obtained in the fall of 1918 from Vaughan's Seed Store, Chicago. In the later experiments Wisconsin black soy beans obtained in the spring of 1920 from the same place were substituted for the former variety. The seeds of the various weeds employed were gathered in the fall of 1918 from cornfields lying on the out-skirts of the city of Urbana.

The weed seeds collected were of *Aster ericoides*, *Aster azureus*, *Euphorbia maculata*, *Solanum carolinense*, *Amaranthus retroflexus*, *Polygonum pennsylvanicum*, *Setaria glauca*, *Digitaria sanguinalis*, *Sida spinosa*, *Acalypha virginica*, *Panicum capillare*, *Echinochloa crusgalli*, and *Xanthium spinosum*. In addition seed of *Ambrosia artemisiifolia* and *Abutilon Theophrasti* was obtained from the Agri-

cultural Experimental Station of the University of Illinois. Since some of the seeds produced plants which did not grow well in the greenhouse, and others failed to germinate, all could not be used in the experimental work. Because of this difference in behavior, therefore, only *Sida spinosa*, *Amaranthus retroflexus* (pigweed), *Polygonum pennsylvanicum* (smartweed), *Setaria glauca* (foxtail), *Ambrosia artemisiifolia* (ragweed), and *Abutilon Theophrasti* (mallow) survived and were available for tests.

Since the soy bean seed obtained in 1918 failed to germinate the following fall experimental work upon this cultivated crop had to be discontinued until more seed could be obtained. New seed of the Wisconsin black variety was received in the spring of 1920 and the experiments were again resumed.

Zea Mays (corn), *Glycine soja* (soy bean), *Setaria glauca* (foxtail), *Sida spinosa*, and *Amaranthus retroflexus* (pigweed) were planted side by side in the ordinary green-house boxes of good soil during the months of January and February 1919. They grew very well, were healthy and so furnished excellent material for the experiments. All were allowed to remain until they had produced seed and died naturally. A single specimen of jimson weed (*Datura stramonium*) invaded the plot, and since this is often found prevalent in cornfields a number of readings were made from its leaves. The weeds and cultivated plants were grown side by side so as to insure, as nearly as possible, a similarity of the kind of environmental factors exerting an influence upon their functions and also to insure a similarity of the extent of influence of these factors.

In the fall of 1919, as was mentioned before, the soy beans would not germinate and the *Amaranthus* produced only very weak plants so that corn, *Setaria glauca*, and *Sida spinosa* were the only plants grown that had been used the preceding year. In addition *Abutilon Theophrasti*, *Ambrosia artemisiifolia*, and *Polygonum pennsylvanicum* were grown. Seeds of these species were planted at intervals

during the fall and winter of 1919-1920 and when the new soy bean seed arrived this was grown again. Transpiration tests were made from the time of the appearance of the first leaves of any of the plants to the middle of April 1920. Very few readings were taken from plants growing in the open.

By stripping off pieces of the upper and lower epidermis of each type of leaf used and examining these with the compound microscope the relative abundance of stomata upon each surface was noted. Leaf sections were also cut of all of the plants. These were embedded in paraffin, sectioned, and mounted in order to ascertain the differences existing between the various leaf structures and to determine more accurately, if possible, the number of stomata present on both surfaces of the various kinds of leaves.

B. Description of Methods.

In selecting leaves to be tested care was taken to choose, as nearly as possible, the same leaves each time, or, if not the same ones, those having the same relative position on the stem. This was observed since Bakke and Livingston (3) have pointed out that leaves of different ages and occupying different positions on the stem may vary markedly in their transpiring power. At each period of observation readings were made from both cultivated plants and weeds so that any changing of the time rate of transpiration of the standard corn and the weeds would be due to the same environmental factors and the intensity of action would be comparable as regards both types of plants.

The well-known cobalt chloride paper of Stahl (18) as described by Livingston (12) and recently improved by Livingston and Shreve (13) was employed for the tests. The improved method makes use of composite paper slips consisting of a cobalt chloride paper and one of each of two permanent color standards joined together into a composite slip which can be manipulated as a single piece. The

permanent color standards are both blue; one is a little less intense than the dry cobalt paper and the other a very pale blue. Since this hygrometric paper which is blue when dry absorbs moisture and becomes pink it is well adapted to comparative tests of the transpiring rate of different plants. The method of placing the slips between two pieces of adhesive tape and pasting to a glass cover as described by Shive and Martin (16) was tried but was not found to be very satisfactory because the time required for the tests was greatly increased by this modification. As the high humidity of the air in the greenhouse retarded the rate of transpiration any method which furthered this effect was hardly practical. The lateral leakage which the Shive and Martin method reduces, while an error, may be disregarded here since it should occur in relatively equal intensities in the readings from the standard as well as from those of the weeds.

Each test was begun when the color of the hygrometric paper exactly matched that of the more intense standard. As the leaf transpired the cobalt paper absorbed the water and gradually became paler until its color just matched the blue of the pale standard. The time required for this color change of the cobalt paper from the dark to the light standard was determined by means of a stop watch. After the tests the composite slips were dried over an electric hot-plate in the greenhouse or an acetylene miner's lamp when in the field. They were then placed in dessicators until the next period for observation. Care was exercised in always using the same slip for all readings made at any one of the test periods. The Livingston method of applying the slips of hygrometric paper to the plant surface by spring wire clips was adopted; both the composite slips and the wire clips were obtained from the Plant World, Tucson, Arizona.

Transpiration readings were made from both the upper and lower surfaces of the leaves employed. The number of seconds required for a color change over the two surfaces was averaged; also all readings of each period of observation were

averaged for each plant. The data in its entirety is given in tables and graphs below.

III. RESULTS.

The results are given in detail in tables I, II, and III and are shown graphically in plates I, II, III, and IV.

A. Description of Tables.

In the preparation of the tables only averages of the readings on each date were used, the number of readings taken in each case varying from one to seven. That is, the number of seconds required for the color change from the upper and lower surfaces of the corn leaves was averaged for each reading. Then the average of all readings made from the corn on the one date of observation was computed. In a similar way readings were also taken from the weeds which were of the same age as the corn and the averages of these computed as for the corn. The numbers thus derived appear in column two under the name of each plant used. The first column indicates the age of the plant in each instance. The columns headed A-B, A-C, etc. are difference columns. Wherever a minus sign, as -14.1, appears in these columns it means that the average number of seconds required for the color change on the corn leaf was greater than on the weed leaf compared with the corn. A plus sign, as +14.1, in these columns indicates that the weed compared required more seconds for the color change than did the corn. The averages at the ends of the tables were obtained by averaging all preceding figures in the respective columns. For the final averages plants of all ages are included but in averages for the individual dates plants of different ages are arranged separately so that whenever possible only plants of the same age are compared. Some readings

of both cultivated and weed plants were discarded in the compilation of the tables because of differences in individual age.

B. Description of Plates.

As all of the plates were made in the same manner we may confine the description to the construction of Plate I as an example. In the first place all readings made at any time appear in the graphs, none being discarded except for reasons given above in the description of the tables. Plate I consists of six graphs. The abscissae of these graphs represent the dates of observations and the ordinates represent the number of seconds required for the color changes. These latter are the averages of all of the readings made upon the plant on the date indicated, no distinction in ages being made here. These averages were arranged for each plant and the individual curves plotted on the plate as shown. The plates therefore, containing the graph of each plant's average, give a summation of all readings taken.

IV. DISCUSSION.

In discussing the results as given in the tables and graphs it is necessary to keep in mind the fact that the data are recorded in seconds and that a large number of seconds means a low transpiration rate while a small number of seconds means a high transpiration rate. Thus a minus sign in a difference column of the tables indicates that the transpiration rate of corn is higher than that of the weed concerned while a plus sign means a lower rate for corn than for the weed. Similarly, in the case of the plates, a high curve indicates a low transpiration rate while a low curve shows a high transpiration rate.

With these points in mind it is readily seen that both tables and plates show quite conclusively that corn loses water less rapidly by transpiration area for area than do any of the other plants under observation. The one that approaches corn most closely is foxtail, another grass, which probably has relatively the same rate as the cultivated plant since it sometimes transpires more and sometimes less than the corn. Taking the other plants used for comparison we find very interesting results. Pigweed is found to have a more rapid transpiration rate on all but two periods. Ragweed always has a higher rate than corn. In one instance the difference is -306.6 and in another -22.3. Again we find the mallow in all but a few cases, transpiring more rapidly than the standard, and when its rate is slower the difference between it and that of corn is so slight that it probably falls within the limits of experimental error.

Soy bean, the other cultivated crop used, was found to transpire more rapidly in every instance but two. At these times, however, the difference in time was small being only +4.8 and +10.1 so that these might be ignored and the rate said to be practically uniformly more rapid than that of corn. *Sida spinosa* also, loses water more rapidly than the standard. It is of interest also to make comparisons between the weeds themselves and between these and the soy bean. An inspection of table I shows that the soy bean and pigweed transpire at relatively the same rates and that the ragweed compares quite closely with them in this respect. We find also, that the foxtail and mallow are quite similar in their respective rates. In tables II and III ragweed and smartweed have relatively the same rates, the difference between the two in the latter table being only .8. Between the *Sida spinosa* and mallow rates the difference is also slight, being only 1.8 in table III. The soy bean rate is intermediate between the two groups, ragweed, smartweed and mallow, and foxtail and corn.

Plates III and IV are more complete and probably much more reliable than

Plates I and II. These plates show clearly that corn, having the highest graphs, has the lowest transpiration rate. This fact is brought out also by the tables but shows in the graph more concretely. Foxtail follows corn in a slightly lower curve or a higher rate of water loss. Then mallow, *Sida spinosa*, smartweed, and ragweed follow in order of increasing rates. The last named has the lowest curve and the highest rate.

These graphs are fairly consistent with the number of stomata per given area of each type of leaf. The corn and foxtail have stomata about evenly distributed on the upper and lower leaf surfaces and approximately the same number per unit area. This number was very small as compared with the number found on any one of the weed leaves. The latter, in all cases, had more stomata on the lower surfaces than on the upper surfaces.

The statement made above that corn transpires more slowly area for area than the soy beans or weeds with which it was compared has been definitely shown to be true. Nothing has been determined, however, as to the amount of water lost in the process. Whether or not the fact that the weeds transpire more rapidly than the corn is an important one under any conditions has not been demonstrated. Kiesselbach (10) does show that weeds rob corn of some moisture but other factors such as food supply, light relations, etc., are frequently considered of more paramount importance. However, it seems logical to suppose that in case the moisture content of a soil were low the robbing by the weeds of a portion of this water might prove a very serious obstacle to the life of the corn plant and in this case the rate at which the weeds take water from the soil and transpire it into the atmosphere would be a factor of great practical importance.

V. SUMMARY.

1. The relative rate of transpiration of *Zea Mays*, as indicated by cobalt paper, is lower per unit area than that of *Polygonum pennsylvanicum*, *Sida spinosa*, *Ambrosia artemisiifolia*, *Amaranthus retroflexus*, *Abutilon Theophrasti*, and *Glycine soja*.
2. Of the weeds compared with *Zea Mays*, *Ambrosia artemisiifolia* has the highest rate of water loss.
3. The transpiration rates of *Zea Mays* and *Setaria glauca* are more nearly similar than those of the corn and any of the dicotyledonous weeds studied.
4. The transpiration rate of *Glycine soja* is greater per unit area than that of *Zea Mays* and *Setaria glauca* but less than that of *Ambrosia artemisiifolia*, *Abutilon Theophrasti*, *Sida spinosa*, and *Polygonum pennsylvanicum*.

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Table I. Relative Rates of Transpiration from the Foliar Surfaces of Plants used from February 27, 1919 to February 5, 1920.

Date	Corn	Pigweed	Ragweed	Foxtail	Mallow	Soy bean	A-B	A-C	A-D	A-E	A-F
	age	A	age	B	age	C	age	D	age	E	F
Feb. 27	44	62.7	37	27.4			44	29.5	-35.3		-35.2
Mar. 4	49	45.0	49	15.1			49	41.6	-29.9		- 3.4
" 6	44	216.8	44	88.2			44	191.5	-128.6		-25.3
" 8	53	174.9	53	131.6			53	80.8	- 43.3	+98.3	-94.1
" 8	46	142.0	46	76.6			46	45.9	-65.4		-96.1
" 11	49	88.0	49	79.4			49	92.8	- 8.6		+ 4.8
" 13	58	69.8	58	29.5			58	60.6	-40.3	+31.4	- 9.2
" 18	56	48.2	56	37.5			56	32.7	-10.7		-15.5
" 18	40	48.1	40	32.7					-15.4		
Apr. 5	74	50.8	74	85.0			74	34.8	+34.2		-16.0
" 9	85	76.6	85	39.8			85	52.4	-36.8		-24.2
" 16	85	92.5	85	163.1			85	102.6	+70.6		+10.1
Dec. 17	58	150.1			58	170.5		180.1			
Jan. 7	30	128.8			30	59.7					
" 9	32	83.1	30	77.9	32	56.8		-50.9	+20.4	+30.0	
" 12	35	148.7	32	56.8	32	39.1		-26.3	+86.3	-69.1	
" 15	38	271.3	35	44.6	35	190.4		-104.1		-44.0	
" 28	46	210.6	87	227.2	38	274.9			-44.1	+41.7	
" 30	48	65.3	46	52.8	48	44.6		-157.8		+ 3.6	
Feb. 5	55	99.4	48	43.0	55	88.4		- 22.3	-27.1	-20.7	
			55	41.1				- 58.3		-11.0	
Total											
Averages	113.6	67.1	73.9	117.9	125.3	69.4	-46.5	- 39.7	+ 4.3	+11.7	-44.2

Table II. Relative Rates of Transpiration from the Foliar Surfaces of Plants used
from February 6, 1920 to March 13, 1920.

Date	Corn		Ragweed		Smartweed		Foxtail		Mallow		Sida Spinosa		A-B	A-C	A-D	A-E	A-F
	age	A	age	B	age	C	age	D	age	E	age	F					
Feb. 6	56	87.3	56	63.7	56	56.5	74	178.7	56	167.4			-23.6	-30.8	+91.4	-180.1	
" 12	62	89.8	62	38.5	62	30.4	80	116.7	62	45.7	80	47.7	-51.3	-59.4	+26.9	-44.1	-42.1
" 13	16	128.3	63	54.2	63	83.3	16	119.7	25	100.7	81	89.9	-74.1	-45.0	-8.6	-27.6	-38.4
" 14	64	222.2	64	68.3	64	43.9	17	89.0	64	233.2	82	76.9	-153.9	-178.3	-133.2	+11.0	-145.3
" 16	66	112.3	66	47.7	66	47.3			66	111.5	84	54.8	-64.6	-65.0		-0.8	-57.5
" 18	68	153.9	68	41.0	68	52.2	86	183.1	68	66.0	86	93.0	-112.9	-101.7	+29.2	-87.9	-60.9
" 23	73	220.6	73	41.4	73	96.3			35	231.6			-179.2	-124.3		+11.0	
" 23	26	292.3			26		26	228.8	26	110.8	26	157.4			-63.5	-171.5	-134.7
" 25	75	371.1	75	64.5	75	97.8	113	150.7	75	180.1	75	125	-306.6	-273.3	-220.4	-191.0	-246.1
" 27	77	164.9	77	44.5	77	68.0	95	230.7	10	93.2	77	57.9	-120.4	-96.9	+65.8	-71.7	-107.0
Mar. 3	92	99.3	92	24.6	92	45.2	92	156.2	92	95.1	49	61.0	-74.7	-54.1	+56.9	-4.2	-38.3
" 3	58	46.7			58				58	84.7						+38.0	
" 5	94	106.0	94	56.3	94	49.8	94	200.5	94	50.7	51	57.2	-49.7	-56.2	+94.5	-55.3	-48.8
" 5	60	74.4			60	54.8	60	51.4						-19.6	-23.0		
" 13	102	88.0	102	33.7	102	21.0	102	153.8	59	92.4	59	24.9	-54.3	-67.	+65.8	+4.4	-63.1
Total																	
Averages		150.4		52.5		57.4		154.9		118.7		76.6	-97.9	-93.0	+4.5	-31.7	-73.8

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Table III. Relative Rates of Transpiration from the Foliar Surfaces of Plants Grown in 1920.

Date	Corn	Ragweed	Smartweed	Foxtail	Mallow	<i>Sida spinosa</i>	Soy bean	A	age	B	age	C	age	D	age	E	age	F	age	G	A-B	A-C	A-D	A-E	A-F	A-G
Mar. 15	104	146.4	104	21.4	104	30.9	104	114.8												-125.0	-115.5	-31.6				
"	15	70	69.9				70	85.6	61	77.7	61	57.8	10	63.8								+15.7	+7.8	-12.1		-6.1
"	18	107	183.2	107	38.3	107	18.7	107	126.2	64	127.6	64	64.6	13	120.0							-57.0	-55.7	-118.6		-63.2
"	20	109	51.4	109	8.2	109	26.9	109	14.4	66	10.9	66	25.2	15	22.1							-37.0	-39.5	-26.2		-29.3
"	20	74	84.0				74	17.5	74	12.1	74	35.3										-66.5	-61.9	-48.7		
"	22	111	86.1	111	19.4	111	20.6	111	74.3	111	15.1	111	24.5	17	35.4							-11.8	-71.0	-61.6		-52.7
"	22	76	46.9				76	89.4	76	36.1	76	27.0										+42.5	-10.8	-19.0		
"	25	114	92.2	114	24.0	114	22.8	114	58.3	114	30.2	114	27.0	20	25.8							-33.9	-62.0	-65.2		-66.4
"	25	79	40.2				79	31.1	79	34.2	71	37.1										-9.1	-6.0	-3.1		
"	26	115	91.6	115	21.6	115	20.5	115	55.1	115	28.7	115	22.4	21	21.1							-36.5	-62.9	-69.2		-70.5
"	26	80	39.5				80	31.2	80	35.1	72	31.8										-8.3	-4.4	-7.7		
"	29	118	158.9	118	11.5	118	11.6	118	44.6	118	20.6	118	28.1	24	36.6							-114.3	-138.3	-130.8		-122.3
"	29	83	40.3				83	35.2	83	52.9	75	32.4										-5.1	+12.6	-20.5		
Apr. 3	123	84.1	123	21.0	123	20.3	123	55.4	123	21.8	123	19.1	29	66.1								-28.7	-62.3	-65.0		-18.0
"	3	88	33.0				88	36.2	88	26.1	88	22.4										+3.2	-6.9	-10.6		
"	7	127	63.7	127	17.5	127	17.8	127	61.4	127	27.1	127	54.2	33	34.0							-2.3	-56.6	-9.5		-29.7
"	7	90	37.0				90	58.7	90	30.1	90	51.5										+21.7	-6.9	+14.5		
"	10	130	46.7	130	11.4	130	12.6	130	54.1	130	35.6	130	21.7	36	33.5							+7.4	-11.1	-25.0		-13.2
"	10	93	76.0				93	58.2	93	19.6	93	25.1										-17.8	-56.4	-50.9		
Total																										
Averages		72.1		19.4		20.2		57.9		33.7		31.9		45.6		-52.7		-51.9		-14.2		-38.4		-40.2		-26.5

PLATE I

PLATE II

PLATE III

400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20

o-Zea Mays
o-Amaranthus retrofractus
o-Setaria glauca
o-Astilum Theophrasti
o-Bidens spinosa
o-Polygonum pennsylvanicum

Feb. 12 Feb. 13 Feb. 14 Feb. 16 Feb. 18 Feb. 23 Feb. 25 Feb. 29 March 5

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