RESISTANCE OF EARTHWORMS TO SOIL ACIDITY

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The following bit of experimental research was undertaken at the suggestion, and under the direction of Dr. W. C. Allee, Department of Zoology, the University of Chicago, during the year of 1923, following an article by O. Arrhenius, "Influence of Soil Reaction on Earthworms", published in Ecology, Vol. II, No. 3, pp. 193-197, 1921.

The results as here given are from a second set of experiments performed with earthworms involving the chemicals, H_2SO_4, KOH, HCl, NaOH, & $C_{14}H_{10}O_9$. The purpose was to determine the influence of varying soil acidities on earthworms and to study the difference in resistance between some of the common varieties of the same.

Four different species were used. As determined by Miss Hyman they were:

Octolasium lacteum.
Allolobophora foetida.
Megascolecidae.
Lumbricus terrestris.

The above species were put in as nearly similar conditions as possible. Five individuals were used in each pot of earth.

In the use of chemicals, KOH was used in the series with tannic acid, and NaOH was run in that with HCl. In a previous experiment H_2SO_4 had been run parallel with HCl for comparison of results. All acidities were run with each species of earthworm and the results tabulated for comparison.

In the first experiments titrated normal acidities, with exact percents of acidity, were used for securing the soil acidities. This was found impracticable, since the buffer in the soil gave reversal of action such that exactness of normality counted for nothing. In this experiment measured normalities were used and percents of these solutions to water the soil to bring it to the desired acidity.

The percents used were n, n/2, n/5, n/10, n/20, n/100 respectively. The soil used had an initial pH of 8, so that any percent less than n/100 had no practical value for the experiment.

The amounts of the solutions used to bring about the desired acidities depended on the buffer in the soil, on the time elapsing between treatments, the length of time since the last treatment, the temperature of the soil and perhaps some other external conditions of atmospheric conditions, etc., on the initial pH value; so that these will be passed over and the data will begin with the final experimental values. Data on the two series only will be given in this paper.

In each series twelve pots were used. Of these, ten represent those treated to secure the range of acidities; Nos. 5 and 6 are the controls, watered with tap and distilled water respectively.

In the first experiments inorganic acids only had been used. In this set one organic acid was chosen, the one probably most common in our soils, tannic acid. The action of the HCl and that of the tannic acids were very different in their effect on the soil itself. The HCl produced a strong reaction in contact with the Calcium of the soil, so much so that the soil for days boiled over the top of the pots and thus became full of small air spaces. In the treatment with the tannic acid there was no effervescense, but a black sediment settled on the inside of the pot which later passed through the porous earthenware and blackened even the outside. The soil in this case became very loamy, crumbling like sand.

When the desired acidities were secured, the pots were placed in an underground room with temperature 25-27° C. In order to prevent the escape of the worms they were covered with plates of tin and set in stone trays sprinkled with fine soil, that any escape might be detected. The worms were used always within about two days after digging, so as to provide the best chances for life, and to give opportunity for any injured in the process to be cast out.

In the given tables the following abbreviations are used:

TA—tannic acid
g—good condition
d—dead
sl—sluggish
ot—ontop of the soil
ex—outside the pot
np—between earth and pot
k—tied in knots
A—worms added
R—worms replaced
7-9—alkalinity
5-7—acidity
y—young worms
ls—large size

Octl—Octolasium lacteum
Allo—Allolobophora foetida
Mega—Megascolecidae
Lumb—Lumbricus terrestris
p—poor condition (below medium)
b—bad condition, nearly dead
m—fair to medium condition
dp—worms dead where placed
sg—soil in good condition
sc—Soil crumbling, loamy
sp—Soil puddled, sticky
co—cocoon
sw—soil wet
to—taken out

In the results each species is first given separately, with its peculiar reactions and resistance to each series; then the results of each given for comparison of species; next the effect of each chemical on our common species, and finally the effect of the tannic acid series during the longer period of twenty-one days.

The soils were tested with the LoMotte Indicators, purchased new at the beginning of the set of experiments.

Octolasium lacteum was abundant in all moist soils, testing from 7.8 to 8.0 pH. Characteristic of garden and forest loam.

Allolobophora foetida was abundant with Megascolecidae in the refuse and leaves through out from the greenhouse, soils testing 8.0 pH.

Lumbricus terrestris was not so easily found, but was most abundant near a building, or in the loose turf on the lawn, in soil testing 7.5 to 8.0 pH.

Octolasium lacteum, which was used in the first experiments also, is taken as the basis for comparison of the action of the different chemicals used in producing acidities, as the best type. It was always in medium conditions, not too wet, too rich, nor too sandy.

TABLE I.

Reaction of Octolasium Lacteum to KOH and TA Series.

Pot	pH	Worms	1-da.	2-da.	pH	3-da.	4-da.	pH	7-da.	8-da.
1	9.0	5	3b, 2d	od-R	8.0	3b, 2d	od—	8.5		
2	8.5	5	4m, 1k	5sl	8.4	5k	4k, 1ls	8.5	2k, 3d	1b
3	8.2	5	5g	1m, 4np	8.0	4m 1d	5g	8.2	4p —	2m 2k
4	8.0	5	5g	1m 4ot	8.0	5g, sp	5g	8.0	5m	3g 2k
5	8.0	5	5g	5g	7.5	5g np	5g	8.0	5m	3g 2k
6	8.0	5	5g	5g	7.5	5g sp	5g	7.5	5g	4g —
7	7.8	5	5g	5g sg	7.0	5g	5g	7.5	5g	4g —
8	7.5	5	5g 3np	5g np	6.5	5g sg	5g ls	7.4	5g ls	5g ls
9	7.2	5	5g 3np	5g np	6.2	5g ls	5g ls	7.2	3g ls	5g ls
10	7.0	5	5g 3np	5g np	6.0	5g ls	5g ls	7.2	5g ls	5g ls
11	6.2	5	5g	5g	6.0	5g ls	5g ls	6.5	5g ls	5g ls
12	6.0	5	5g	5g sg	5.5	5g ls	5g ls	6.0	5g ls	5g ls

TABLE I—Continued.

Pot	9-da.	11-da.	12-da.	15-da.	pH	16-da.	17-da.	21-da.	25-da.
1	R	0d	—	—	8.5	—	—	—	—
2	0d	R	—	—	8.2	—	—	—	—
3	3b 2d	2m 1d	1m	1b	8.0	—	—	—	—
4	4m	4m	4m	3k 2p	7.8	3b	1b 2d	—	—
5	5g	5g	5g	5g	7.5	5g	5g	5g	5g
6	4g	4g	4g	4g	7.0	4g	4g	4g	4g
7	4g	4sg	4g	4g	7.0	4m	3m	3m	od
8	5g	5g	4g 1d	4g	6.8	4g	3m	3m	3m
9	5g	5g co	5g	5g	6.6	4g	4m	4m	3m
10	5g	5g ls	5g ls	5g	6.5	4g 1d	4g	4m	4m
11	5g	5g sl	5g sl	5g sl	6.4	4g 1d	4g	4m	4m
12	5g	5g ls	5g sw	5m	6.0	2 sl 3d	2m	2p	2d

TABLE II.

Reaction of Octolasium Lacteum to NaOH and HC1 Series.

Pot	pH	E-W	1-da.	3-da.	7-da.	12-da.	pH
1	8.8	5	4m	4m	1b	0d	8.5
2	8.6	5	3m	3m	3k	3p	8.5
3	8.2	5	1p 4d	0d	—	—	8.0
4	7.8	5	5g	5g 1d	0d	—	7.5
5	7.6	5	5g	5g	5g	5g	7.5
6	7.2	5	4g 1d	4g	3g 1d	3g	7.2
7	7.2	5	3p 2d	3p	1p 2d	0d	7.2
8	7.2	5	5 0d	—	—	—	6.5
9	7.0	5	0d sp	—	—	—	6.4
10	6.6	5	0d sg	—	—	—	6.2
11	6.5	5	0d sg	—	—	—	6.2
12	6.0	5	0d sp	—	—	—	6.0

TABLE III.

Reaction of Allalobophora Foetida to KOH & TA Series.

Pot	pH	E-W	1-da.	2-da.	3-da.	6-da.	pH	7-da.	8-da.
1	8.5	5	5b	od...	...	—	8.5	—	—
2	8.5	5	3b 2d	3m	3g	3g	8.2	3g 2y	3g 2y
3	8.2	5	5g	5g	5g	5m	8.0	4m 1d	4m
4	8.0	5	5m	5g	5g	5m	7.8	5m	4m
5	8.0	5	5g	5g	5g	5g	7.5	4m 1d	4m
6	7.5	5	5g	5g	5g	5g	7.0	4m 1d	4m sp
7	7.5	5	5g	5g	5g	5g	7.0	5g	5m
8	7.4	5	5g	5g	5g	5g	6.8	5g 3y	5g 3y
9	7.2	5	5g	5g	5g	5g	6.6	5g	5g
10	7.2	5	5g	5g	5g	5g	6.5	5g	5g
11	6.5	5	5g	5g	5g	5g sw	6.4	4g 1d	4g
12	6.0	5	5g	5m sw	5m	5m	6.0	5m	5m

TABLE III.—Continued.

Pot	10-da.	11-da.	13-da.	16-da.	21-da.	pH
1	—	—	—	—	—	8.5
2	3g 3y	3m 3y	3g 3y	3g 3y	3g 3y	7.5
3	4m	3m sp	3m sp	3m sp	3m dp	8.0
4	4m	4m 1y	4m —	4m	4m	7.5
5	4m	4m	4m	4m	4m	7.5
6	4m	4m	4m	4m	4m	7.0
7	5m	5g	5g	4g 1d	4g	7.0
8	5g 3y	5g 2y	5g 2y	5g 5y	4g —	6.5
9	5g 1y	5m	5g	4g 1d	4g	6.4
10	5g	5m	5g	4g 1y	4g 1y	6.2
11	4g	4m sw	4m sw	4m 1y	4m 1y	6.2
12	5m	5m sw	5m sw	5m sw	4m 1y	6.0

TABLE IV.

Reaction of Allobophora Foetida to NaOH & HCl Series.

Pot	pH	E-W	1-da.	pH	2-da.	pH	5-da.	pH	6-da.	7-da.
1	8.5	5	5g np	8.5	4m 1p	8.5	5g	8.5	5m	5g
2	8.5	5	5m 3np	8.4	5m	8.0	5g	8.5	5g	5g
3	8.5	5	5np	8.2	5g	8.0	5g	8.5	5g	5g
4	7.5	5	5g 3np	8.0	5g	7.8	5g	8.0	5g	5g
5	7.5	5	5g 3np	8.0	5g	7.5	5g	7.5	5g	5g
6	7.5	5	5g np	7.5	5g	7.5	5g	7.5	5g	5g
7	7.2	5	5g	6.5	4g 1p	7.0	5m	7.5	5g	5m
8	7.0	5	3m 2p	6.5	od sp	6.8	—	7.2	—	—
9	6.5	5	1b 4d	6.4	odp sw	6.5	—	7.0	—	—
10	6.5	5	od sw	6.2	odp sw	6.0	—	6.8	—	—
11	6.5	5	odp sw	6.0	odp sg	5.5	—	6.5	—	—
12	6.5	5	odp sg	5.5	odp sw	5.5	—	6.0	—	—

TABLE IV—Continued.

Pot	8-da	9-da.	11-da.	pH	12-day.	14-da.	16-da.	19-da.	23-da.	pH
1	5g	5g	5g	8.8	5g	1p 4d	1p	1p	1p	8.5
2	5g	5g	5g	8.6	5g	4m 1d	4m	4g sg	4g	8.2
3	5g	5g	5g	8.2	4g 1d	3m 1d	3m	3m	2m 1d	7.5
4	5g	5g	5g	7.8	5g	5g sp	5g 1y	4g 1d	2m 2d	7.2
5	5g	5g	5g	7.6	5g	5g sp	5g 1y	5g	5g 1y	7.2
6	5g	5g	5g	7.2	5g	5g sp	5g	4g 1d	3g 1d	7.2
7	5g	5g	5g	7.5	5g 1y	5g 1y	3g 2d	3m	3g	7.0
8	—R	0dp	—	7.2	—R	3g 2b	3g 2d	2p 1d	2g co	7.0
9	—R	0dp	—	7.0	—R	0dp sp	—	—	—	6.5
10	—R	0dp	—	6.8	—R	0dp sg	—	—	—	6.0
11	—R	0dp	—	6.5	—R	0dp sg	—	—	—	6.0
12	—R	0dp	—	6.0	—R	0dp sp	—	—	—	—

TABLE V.

Reaction of Lumbricus Terrestris to KOH and TA Series.

Pot	pH	E-W	1-da.	2-da.	3-da.	5-da.	9-da.	12-da.	14-da.	pH
1	8.5	5	0dp	—	—sp	—	—	—	—	8.5
2	8.2	5	3ot 2d	0d—	—sp	—	—	—	—	8.2
3	8.0	5	4g 1d	4m	4k	4k	3k	3k	3k	8.0
4	7.8	5	4g 1d	4m	4p	4k	4k	3k	3k	8.0
5	7.5	5	5m	5m	5m	5m	5m	5m	4m	7.5
6	7.2	5	5g	5g	5g	5g	4g 1k	4g 1d	4g	7.0
7	7.0	5	5g	5g	5g	5g	3g 2b	3g 2d	3g 1y	7.5
8	6.8	5	5g	5g	5g	4g 1k	3k	3k	3k	8.0
9	6.6	5	5g	5g	4m 1d	4k	4k	3k	3k	6.5
10	6.5	5	5g	5g	4m 1d	3m 1k	4m	4m	4m	6.4
11	6.4	5	5g	4g 1b	4m 1d	4g	4m	4g	4g	6.2
12	6.0	5	5g	5g	4g 1d	4g	4k	4g	4g	6.0

TABLE VI.

Reaction of Lumbricus Terrestris to NaOH and HC1 Series.

Pot	pH	E-W	1-da.	2-da.	3-da.	5-da.	9-da.	12-da.	14-da.	pH
1	8.8	5	3ot 2m	2ot 3m	3ot 2d	3m	3k	3k	1p	8.5
2	8.5	5	5g	5m	4m 1d	4m	3m 1d	3k	2k	8.2
3	8.2	5	5g	3m 2d	1m 2d	1p	1p	1k	1d	8.0
4	8.0	5	5g	4m 1d	4m	4m	4m	4m	4m	7.5
5	7.8	5	5g	5g	5m	5g	5g	4g 1d	4m	7.2
6	7.6	5	5g	5g	4g	4g	4g	4m	4m	7.2
7	7.5	5	3p 2d	2m 3d	2b	2b	2b	1k 1d	1k	7.0
8	7.2	5	0d—	—	—	—	—	—	—	7.0
9	7.0	5	0dp—	—	—	—	—	—	—	—
10	6.8	5	0dp—	—	—	—	—	—	—	—
11	6.2	5	0dp—	—	—	—	—	—	—	—
12	6.0	5	0dp—	—	—	—	—	—	—	—

TABLE VII.

Reaction of Megascolecidae to KOH & TA Series.

Pot	E-W	pH	1-da.	3-da.	4-da.	5-da.	6-da.	8-da.	12-da.	pH
1	5	8.5	0dp—	—	—	—R	1p 4d sp	0d—	—	8.5
2	5	8.2	1m 4d	0d	—	—R	1m 4d sp	0d—	—	8.2
3	5	8.0	4g 1d	4g	4m	4m	3m 1d	3m	2p	8.0
4	5	7.8	5g	5g	5g 2y	5g 2y	5g 2y	5g 1y	4m	8.0
5	5	7.5	5g	5g	5g	3g 2y 2d	3g 2y	3g 2y	2m 2y	7.5
6	5	7.2	5g	5g	5g	5g 3y	5g 2y	5g 1y	5g 1y	7.0
7	5	7.0	5g	5g	5g	3g 2d	3g 1y	3g 2y	3g 1y	6.5
8	5	6.6	5g	5g	4g 1d	3g 1d	3g 2y	3g 2y	3g 3y	6.4
9	5	6.6	5g	5g	5g 1y	5g	5g	5g	4g 1d	6.2
10	5	6.5	5g	5g	5g	5g 1y	5g 1y	3g 2d	3g 2y	6.2
11	5	6.2	5g	5g	5g	5g 1y	5g 2y	5g 2y	5g 1y	6.0
12	5	6.0	5g	5g	4g 1d 2y	4g 2y	4g 3y	4g 1y	4g 1y	6.0

TABLE VIII.

Reaction of Megascolecidae to NaOH & HCl Series.

Pot	pH	E-W	1-da.	2-da.	3-da.	5-day.	pH	6-da.	7-da.	8-da.
1	8.5	5	5m	5g	5g	3m 2d	8.8	2m 1b	1b 2d	1b
2	8.5	5	5g	4m 1d	4m	4m	8.6	4m	3g 4d	2g 1d
3	7.5	5	5g	4m 1d	4m	4m	8.2	4m 1y	4m	4m
4	8.0	5	5g	3m 2b	5m	5g	7.8	5g	5g	5g 1y
5	7.5	5	5g	5g	4g 1d	4g	7.6	4g	4g	4g 1y
6	7.5	5	5g	5g	5g	5g	7.2	5g	5g	5g
7	7.5	5	5m	5g	5g	5g	7.5	5g	4g 1p	3g 2d
8	7.2	5	0dp	—	—	—R	7.2	0dp	—	—
9	7.0	5	0dp	—	—	—R	7.0	0dp	—	—
10	6.8	5	0dp	—	—	—R	6.8	0dp	—	—
11	6.5	5	0dp	—	—	—R	6.5	0dp	—	—
12	6.0	5	0dp	—	—	—R	6.0	0dp	—	—

TABLE VIII.—Continued.

Pot	9-da.	10-da.	12-da.	16-da.	21-da.	pH
1	1b	1b	0d—	—	—	8.5
2	3m	3m 2y	3g 2y	3k 1y	0d sp	8.2
3	3g 1d	3m 2y	2g 1d	2g	1b	8.0
4	5g 1y	5g 2y	3m 2d	3k	2k	7.5
5	4g 1y	4g 1y	4g 1y	4m	2p	7.2
6	5g	5g	5g	4m 1d	2m 2d	7.2
7	3g	3g	3g	3g	3g	7.0
8	—R	0dp	—	—	—	6.8
9	—R	0dp	—	—	—	6.5
10	—R	0dp	—	—	—	6.2
11	—R	0dp	—	—	—	6.2
12	—R	0dp	—	—	—	6.0

0dp—died in place.

TABLE IX.

Effects During Twelve Days of the Two Series of Chemicals on the Different Species of Earthworms.

Series: KOH & $C_{14}H_{10}O_9$ — NaOH & HCl Series.

pH	Octl.	Megl.	Allo.	Lumb.		pH	Octl.	Megl.	Allo.	Lumb.	
8.8	—	—	—	—	KOH	8.8	0	0	100	20	NaOH
8.5	0	0	0	0		8.6	60	60	100	40	
8.2	0	0	60	0		8.2	0	40	80	0	
8.0	20	40	60	60		8.0	—	—	—	80	
7.8	80	80	80			7.8	0	60	100	—	
	—	—	—	—			—	—	—	—	
7.5	80			60		7.5		60	100	20	HCl
7.2	90	—	—	—	TA	7.2	0	0	0	0	
7.0	—	60	100	—		7.0	0	0	0	0	
6.8	—	60	100	—		6.8	0	0	0	0	
6.5	100	—	100	75		6.5	0	0	0	—	
6.2	—	80	—	80		6.2	—	—	—	0	
6.0	100	90	100	80		6.0	0	0	0	0	
7.5	100	40	80	80	Tap w	7.0	100	80	100	80	
7.0	80	100	80	60	Dist. W	7.5	60	100	100	80	

TABLE X.

Comparing Effects of Different Chemicals used on the same Species.

	Octolasium		Allolobaphora		Megascolecidae		Lumbricus		
pH	KOH	NaOH	KOH	NaOH	KOH	NaOH	KOH	NaOH	
8.8	0	—	—	100	—	—	—	—	
8.5	0	10	0	100	0	0	0	20	
8.2	0	—	—	80	0	60	0	60	
8.0	20	0	60	—	40	40	60	60	
7.8	90	0	60	100	80	—	—	—	
7.5	—	0	80	100	—	60	100	70	
7.2	TA	HCl	TA	HCl	TA	HCl	TA	HCl	80
7.0	80	0	100	100	—	60	60		20
6.8	80	0	100	0	60	0	60		0
6.5	100	0	90	0	60	0	60		0
6.2	100	0	100	0	80	0	80		0
6.0	100	0	100	0	90	0	80		0
7.5	100	100	80	100	40	80	80	80	
7.0	80	100	80	100	100	100	60	80	Cont'ls

In Table IX it is seen that Allolobophora foetida shows greater resistance to KOH than any other species; also shows the most perfect stimulation in reaction to Tannic acid. The latter is much better than the control.

According to Table VII Megascolecidae far exceeds the other species in its power of reproduction under the stimulation of the tannic acid, yet in Table IX we see that it is below both Octolasium and Allolobophora in its resistance to higher concentrations of this acid.

Of the species used, Octolasium shows the least resistance to three of the chemicals, NaOH, KOH and HCl; yet it is as strong as Allolobophora in its resistance to tannic acid.

Besides its endurance of tannic acid, Allolobophora is the most resistant to HCl and NaOH. If, then, we rank the four species in accordance with their relation to pH concentration, Allolobophora is most resistant, Lumbricoides ranks second, Megascolecidai third, and Octolasium least resistant.

In Table XI are two charts, the first a ranking of the species according to resistance, No. 1 being the least resistant; and the second chart is a ranking of the chemicals according to their deadliness, No. 1 being the most deadly. The first chart is made from Table IX, the second from Table X.

TABLE XI.

Chart 1.

Ranking in Resistance.

Species	KOH.	NaOH.	TA.	HCl.	Rank.
Octl	1	1	4	1	I.
Megl.	2	2	2	3	II.
Allo	3	4	3	4	IV.
Lumb	4	3	1	2	III.

Chart 2.

Chem.	Standing					Rank
KOH	6	7	8	9	30	II.
NaOH	2	18	10	14	34	III.
TA	11	12	13	15	51	IV.
HCl	1	3	4	5	13	I.

From Table X and Chart 2 it is evident that the inorganic acid is the most deadly of the chemicals, and the organic acid the least harmful. Of the two bases used the KOH is the more harmful. From the previous experiment with Octolasium using also the acid H_2SO_4, it was seen that placed with these chemicals it ranks fourth in harmfulness, while tannic acid stands fifth. From this it might appear that not every inorganic acid is deadly; so we must not infer that all organic acids may be stimulating.

TABLE XII.

Data for 21 Days of Two Species in KOH and $C_{14}H_{10}O_9$.

PH	Octolasium KOH		Allolobophora KOH	
8.8	0		0	
8.5	0		0	
8.2	0		50	
8.0	0		0	
7.8	0			
7.5			70	
7.2	TA		TA	
7.0	60			
6.8	60			
6.5	80		80	
6.2			80	
6.0	40		80	
7.0	100	tap w.	80	
7.5	80	distill	80	controls

From Table XII it is seen that when species are carried through the series for a longer time the reactions may be different. What appeared to be stimulation by tannic acid at the end of twelve days now becomes harmful and the animals lose their resistance to strong concentrations. Octolasium has lost all resistance to the power of KOH. That of Allolobophora is nearly gone. Their power to resist the tannic acid is weakening, particularly that of the Octolasium. This shows that the length of the time exposed to a certain acidity is an important factor in the study of resistance of an animal.

From Tables III, VI, VII and VIII it may be seen that certain chemicals seem to effect the reproductive organs in a hastening as well as in a deterioration of the reproductive product. The tannic acid seemed most active in hastening the process, noticeable in the Megascolecidae. In the former experiments with Sulphuric acid the cocoons were very abundant, but the most of them did not develop. The male reproductive organs were greatly distended in the acids, but time has not yet permitted a histological examination.

The ionization of acids decreases with the concentration: so it is evident that the color indicator does not indicate the concentration of the solution—only the ionization. There is much evidence to show that pH concentration of KOH, for instance, was a very different thing at the close from what it was at the beginning of the experiment. From twelve to twenty-one days of moistening the soil with concentrations of it, though it did not change the ionization, did change the texture of the soil making it a different habitat for worms. This may have been caused by increased concentration, without increase of ionization, or probably by increase of salts by reaction with soil constituents. For instance, the tannic acid soil and that treated with NaOH remained granular no matter how wet, while that treated with KOH and HC_1 were soon puddled, and drying did not mend this condition. As a consequence the aeration of the granular and that of the puddled soils was very different, and that, other things being equal, made them a very different habitat for worms. The tendency of the worms to stay next the pot in many cases may have been tied up with this. True it is that they were not so found in the case of the granular tannic acid soil.

Another question that enters into the question of the deadliness of the HCl is that in combination with calcareous soil it forms a soluble salt with the calcium, $CaC1_2$. The salt formed by the sulphuric acid is insoluble, $CaSO_4$. That formed with tannic acid is probably also insoluble. The increase in injury may be due to the soluble salt.

INFERENCES AND CONCLUSIONS

Similar concentrations of acids may ionize differently, and the same pH value may have different concentrations. So the same acid concentration may affect life differently because of difference in pH value or because of the difference in soluble salts formed in the soil.

So the same pH value may affect life differently because of difference in chemical concentration or difference in soluble salts.

Different chemicals placed in similar soils may produce better or poorer aeration of soil, thus creating different soil habitats, even with the same pH value.

Animals accustomed by natural environment to different habitats may differ greatly in their reaction to a given habitat. Thus Allolobophora found in manure is most resistant to all pH values, while Octolasium of ordinary lawn soil, of all our common species of worms, may be least resistant of the pH values.

Because a soil puddles is no sign that it is acid, and not all acid soils puddle.

A habitat that appears stimulating for a short period of time may prove in the long run very injurious.

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