

Cicadas and Their Effect Upon Soil Genesis in Certain Soils in Southern Idaho, Northern Utah, and Northeastern Nevada¹

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ABSTRACT

The occurrence, activity and effect of Western species of cicadas on soil formation and their relationship to soil characteristics were studied on 70 semiarid rangeland soils. The distinctive soil structure of some Western soils is attributed to the burrowing of cicada nymphs and has been produced over a long period of time. Filled cicada nymph burrows are called "cicada krotovinas." Little mixing of soil horizons results from the activities of these insects.

A new type of blocky soil structure, "cylindrical," is proposed to describe cicada-induced soil structure.

Well-drained, moderately permeable, moderately deep and deep silt loam, Brown and Sierozem soils, formed in loess parent materials, are well suited to cicada nymph activity. Few cicada nymphs or krotovinas are observed in soils with coarse textures, fine textural B horizons, and high bulk density.

SOIL SCIENCE has long recognized the effect of various forms of soil fauna on the decomposition, distribution, and mixing of organic matter and the influence of these organisms on soil tilth. Several authors (6, 7, 12, 13) have discussed the influence of such animals as earthworms, nematodes, mites, millipedes, springtails, beetle larvae, flies, ants, termites, and rodents on soil formation and plant growth, but the widespread Cicadidae has received little attention from most writers.

A prominent feature in some soils of the Western United States is the extensive burrowing activity of a specific group of insects, Cicadidae. Only a few investigators (1, 5, 8, 9) treat the cicadas as soil formers and, of these, only Harper (5) and Clark (1) discuss the effects of cicada nymphs on soil.

Besides the paucity of information on the movements of cicada nymphs in the soil, there is also a lack of uniformity among soil scientists in terminology used to describe the soil structure resulting from the activity of these insects. Harper (5) described the C_{ca} horizon of the Portneuf soil as "massive but owing to filled cicada channels, it breaks into medium subangular blocks and tubes." In unpublished soil profile descriptions, the structure resulting from cicada nymph burrowing has been variously described as "medium subangular blocky," "containing dense rounded nodules of soil material," "cicada nodules," "cicada cylindricals," "cicada casts" and other such terms.

The objectives of this paper are to describe the effect of cicada nymphs on soil formation, to relate some of the environmental factors associated with their distribution and activity, and to propose terminology for describing cicada-induced soil structure.

Description and Life History of Cicada Insects

There is a great deal known about the Eastern species of cicadas (11). They are described and their life histories outlined in a number of entomological texts (2, 3, 4, 10). Little detailed study has been made of Western species of these insects.

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The adult Eastern cicada is described as a medium to large insect approximately 1 inch long. It has a stout body, a proboscis arising plainly from the head, three ocelli, small bristlelike antennae, a three-jointed tarsus, and two pairs of many-veined membranous wings. The front pair of wings is much larger than the hind pair.

Adult male cicadas have sound-producing organs and are shrill "singers." The female apparently has no sound organs. The adult female cicada, during the early summer, slits the bark on twigs of shrubs and trees with her sharp ovipositor and lays eggs in these slits. Eggs hatch within a few days. The newly hatched nymphs drop to the ground and burrow into the soil where they attach themselves to the roots of plants from which they suck plant juices. The length of time the nymph spends within the soil varies with the species. The Eastern "Periodical Cicada" requires 17 years to complete its life cycle. Western species of cicada resemble the Eastern species in most respects but are usually slightly smaller and require only 2 to 6 years to complete their life cycle (2).

A number of cicada species are known to occur within the area of study. Adult cicadas collected are identified as Putnam's cicada, (*Platypedia putnami* var. *lutea*, Davis)³ and (*Okanagana rimosa*, Say)⁴ and are apparently the most common species. Identification of the cicada nymphs as to species is impractical but three genera have been recognized, *Okanagana*, *Platypedia*, and *Tibicen*.⁴

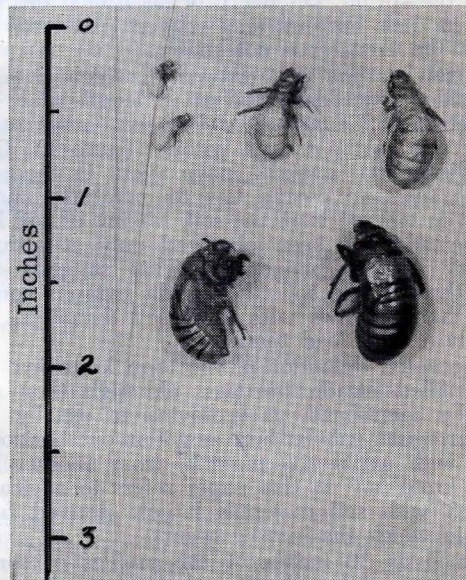


Figure 1—Developmental stages of Western cicada nymphs.

METHODS

In connection with soil-vegetation-climate relationship investigations in southern Idaho, northern Utah and northeastern Nevada, the distribution and effect on soils of cicada nymphs have been studied. The area of study is generally characterized by Sierozem, Brown, Chestnut, and Prairie soils and by elements of the Bluebunch wheatgrass-Idaho fescue-Sandberg bluegrass plant association. The climate of this area is noted for its hot, dry summers and cold winters. Mean annual temperatures range from 40° to 50°F. Annual precipitation ranges from 8

³Collected by Maynard A. Fosberg, Assoc. Prof. Agronomy, Univ. of Idaho.

⁴Collected by authors.

to 25 inches, the major portion of which occurs during the winter months. The amount and distribution of precipitation fluctuates considerably from year to year and over a period of years. Studies were conducted only on areas of relatively undisturbed vegetation, and do not represent a uniform sampling of all the soils or plant communities within the area of study.

Detailed soil and vegetation data have been collected from a total of 70 separate study locations. At each location, a soil pit was excavated to permit the close examination of each soil horizon. The number and distribution of cicada nymphs and other soil fauna were noted and recorded as the soil pits were dug. The nature and extent of cicada-induced soil structure was also studied and described.

Soils studied were segregated into two general groups: (1) soils whose characteristics restrict cicada nymph activity and in which nymph burrowing has not affected the soil structure, and (2) soils whose characteristics provide a suitable habitat for cicada nymphs and in which cicada burrowing has affected the structure of one or more soil horizons.

RESULTS AND DISCUSSION

Occurrence of Cicada Nymphs in the Soil

In the current studies, cicada nymphs have been observed at depths ranging from 6 to 50 inches below the soil surface but are more numerous between 12 and 40 inches. Small, young nymphs are usually found at greater depths than the larger mature nymphs. The relatively greater abundance of large nymphs in the upper soil horizons may indicate that they concentrate near the soil surface prior to emergence. Although present evidence is insufficient to fully substantiate the possibility, it is believed that the nymphs move downward in the soil to a level below the frost line in winter and upward again in the spring. Discovery of occasional dead cicada nymphs in their burrows may suggest predation but the nature of the predator is not known.

The open portion of burrows in which nymphs are found seldom exceeds 3 inches in length and $\frac{3}{4}$ inch in diameter. The diameter of burrows varies somewhat with the size of the nymph within (figure 1). Observations indicate that nymphs move about in the soil only to secure food, to escape low temperatures and, upon maturity, to emerge from the soil. Mixing of soil horizons by the cicada has been observed only at abrupt and clear soil horizon boundaries. This suggests that in moving through the soil, the cicada nymphs continually backfill their burrows with local soil materials, keeping open only a short lead tunnel.

The accepted definition of the term krotovina (7, 14) includes filled cicada burrows, although they are not specifically mentioned. A krotovina is usually thought of as an irregular tubular burrow within one horizon which is filled with unlike soil material from another horizon. "Cicada krotovina" in this paper refers to a cicada burrow filled with soil materials largely derived from the horizon in which the burrow occurs.

As much as 30 inches of the profiles of some soils appear to be made up almost entirely of cicada krotovinas, indicating a great deal of nymph activity. Although the number of nymphs in the soil undoubtedly varies from time to time, no more than 1 or 2 live nymphs per cubic foot of soil have been found in the present studies. For so few nymphs to affect such large masses of soil, it is obvious that they either move about rapidly or that such activity has been taking place over a long period of time.

The nature of the cicada krotovinas supports the theory that cicada activity is of great antiquity. An indication of the relative age of products of cicada activity is found in the degree of calcification of their krotovinas found within calcium carbonate soil horizons. It appears that with increasing age of cicada krotovinas, carbonate accumulation in them becomes more pronounced to the

point of converting the krotovinas into cemented calcium carbonate nodules and cylinders.

Buried paleosols examined by the authors in southern New Mexico contain blocky structure and calcium carbonate nodules and cylinders which are very similar to those produced by cicada in soils of the present study. The nature of the structure and the presence of calcium carbonate nodules and cylinders may indicate that cicada krotovinas were formed in these paleosols many thousands of years ago.⁵

The Effect of Cicada Nymphs on Soil Structure

The vertical orientation of cicada krotovinas indicates that nymphs generally move vertically through the soil. The horizontal component in the movement is recorded by (1) detours of burrows around stones, and (2) numerous instances of interruption and fragmentation of old krotovinas by young krotovinas at points of intersection. Resulting soil structure is illustrated in figure 2. Primary, undisturbed cicada krotovinas break out into cylindrical blocklike peds, but secondary or interrupted structure produced by later movements of nymphs across old krotovinas, is angular and subangular blocky.

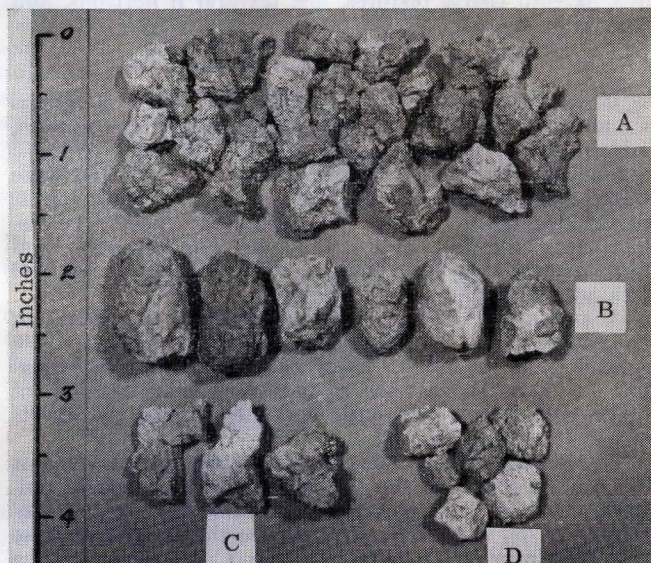


Figure 2—Cicada-induced soil structure: A—General appearance as removed from the soil; B—Cylindrical blocky; C—Angular blocky; D—Subangular blocky.

Description of the strong soil peds characteristic of the cicada krotovinas, within the limits of present nomenclature, is difficult. Although soil material within the krotovinas is massive, the structure of entire soil horizons strongly affected by these krotovinas can hardly be classed as "massive" as suggested by Harper (5). Cylindrical blocklike soil peds do not fit the definition of "angular" or "subangular blocky" structure as described in the Soil Survey Manual (14). It is herewith proposed that a new type of blocky structure, "cylindrical," be recognized to represent the kind of structure characteristic of the cicada krotovinas.

"Cylindrical blocky" structure is defined as soil structure consisting of peds which are cylindrical in appearance, 0.5 to 1.5 inches long, 0.3 to 0.75 inches wide, with convex faces roughly paralleling the long axis or sides of the cylinder, and dominantly concave or convex faces paralleling the short axis or ends of the peds.

⁵Personal communication R. V. Ruhe, Geologist, Soil Conservation Service, USDA.

With the adoption of this proposed type of blocky structure, it would be possible to describe cicada-induced structure as "angular blocky," "subangular blocky," "cylindrical blocky" or any combination of these types of structure as the case may require (figure 2). Classes and grades of cylindrical blocky soil structure would be as stated for angular and subangular blocky in the Soil Survey Manual (14).

The broken surface of the face of a pit dug in a soil profile dominated by cicada krotovinas is rough, exhibiting many pits, nodules, and krotovinal sections in the forms of circles, ellipses, rods, and short hollow half-cylinders (figure 3). The soil breaks readily into medium and coarse peds as illustrated in figure 2.

The Relationship of Cicada to Soils

There is considerable variation in the number of cicadas and the extent of their activity among the soils included in the present study. Twenty-eight of the 70 soils studied have characteristics that provide a suitable environment for cicada nymphs and contain abundant cicada krotovinas. The presence, absence, or relative abundance of cicada activity is associated with different soil taxonomic units and with characteristics of the soils involved in the studies. The results of the studies are shown on table 1 and are discussed as follows:

Great Soil Groups

The soils included in this study fall within eight great soil groups, Prairie, Chestnut, Brown, Sierozem, Planosol, Calcisol, Lithosol, and Solodized Solonetz. Relationship at the great soil group level is of a general nature. The small number of soils studied and their uneven distribution within great soil groups will not support definite conclusions but some interesting trends are evident.

Cicada krotovinas are more abundant in Brown and Sierozem soils than in Chestnut and Prairie soils. Planosolic, lithosolic and solonetzic soils restrict cicada nymph activity. Calcisolic soils do not appear to have any limiting effect upon cicada nymphs. The presence of cicadas in calcisolic soils is dependent upon parent materials, soil textures, climate, or other factors.

In general, data and field observations indicate that textural B horizons tend to restrict cicada nymph activities, and that this restriction varies inversely with the amount of clay present in the B horizon. Of the 42 zonal soils examined in this study, 21 have silty clay loam or clay loam textural B horizons and 21 have color or structural B horizons. All of the soils that have color and structural B horizons, except one Prairie soil, contain numerous krotovinas. Only 6 soils with silty clay loam and clay loam B horizons contain abundant krotovinas.

Parent Material

Soils of this study have formed from five general groups of parent materials; loess, alluvium, lacustrine sediments, colluvium, and residuum. The number of soils within these groups is 39, 7, 11, 8, and 3, respectively. Due to the small number of studies in some of these groups, relationship between cicada nymphs and parent materials is only indicative.

Soils formed in loess, lacustrine, and colluvial parent materials contain numerous cicada krotovinas. The loess parent materials are derived principally from metamorphic and basic igneous rocks, whereas the lacustrine and colluvial parent materials are derived from mixed rocks and vary in composition from place to place.

Seven soils from alluvial materials have little or no cicada activity. All these soils are coarse textured and are predominantly gravelly or sandy in the lower horizons.

With one exception, few cicada nymphs are found in the 11 soils formed in colluvium. The exception is a



Figure 3—Broken surface of the face of a pit dug in a soil dominated by cicada krotovinas. The A horizon (0-9 inches) contains 10% or less of cicada krotovinas in the soil matrix, whereas the remainder of the profile, down to the basalt at the bottom of the pit, consists of 80-100% of cicada krotovinas. The C_{ca} horizon (21-42 inches) contains a mixture of recent, old, and very old krotovinas in which accumulations of CaCO₃ range from none (recent) to weak and to moderate (very old).

silt loam soil which is derived from sedimentary rocks relatively free of stones and pebbles. Three soils, developed in residuum from acid igneous materials, contain no cicadas.

Soil Texture

The soils studied are grouped into textural classes as follows: 37 silt loams, 10 stony silt loams, 9 gravelly loams, 5 gravelly silt loams, 2 silty clay loams, 2 loams, 2 gravelly sandy loams, 2 fine sandy loams, and 1 sandy loam.

Numerous krotovinas occur in soils with silt loam, stony silt loam, or silty clay loam textures. Although the presence of cicada activity is closely associated with silty soil textures, 26 of the 53 silt loams contain few cicada nymphs or krotovinas. It is evident, therefore, that soil texture cannot be used as a single criterion to indicate soils with a suitable habitat for cicada nymphs. Soil depth, drainage, compaction, textural B horizons, and perhaps other characteristics, in addition to texture, affect the activity of these insects.

Bulk Density

Although bulk density values as shown on table 1 are inconclusive, there appears to be an inverse relationship between the abundance of cicada krotovinas in the soil and bulk density. The average bulk density of the B₂ and C horizons of those soils that restrict cicada activities is slightly higher than for those soils with a suitable habitat for cicada nymphs.

The Relationship of Cicada Activity to Vegetation

All soils with common cicada krotovinas supported Bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith) and either Big sagebrush (*Artemisia tridentata* Nutt.) or Threetip sagebrush (*A. tripartita* Nutt.)

Table 1—Soil characteristics and distribution of cicada nymphs and krotovinas.

Parent materials	Texture A ₁ horizon	No.	Bulk density of soils that restrict cicadas†			Bulk density of soils suitable to cicadas‡		
			A ₁	B ₂ , C	No.	A ₁	B ₂ , C	No.
<u>Prairie</u>								
Lacustrine sed.	Silt loam	1	1.00	1.06	1			
	Loam	1	1.32	1.63	1			
	Sandy loam	1	1.41	1.68	1			
		3	1.25	1.57	3			0
<u>Chestnut</u>								
Loess	Silt loam*	6	1.30	1.44	1	1.13	1.66	5
Alluvium	Silt loam†	2	1.17	1.32	2			
	Loam†	3	1.25	1.62	3			
Colluvium	Silt loam*	4	1.24	1.70	4			
	Loam	1	1.16	1.61	1			
Residuum	Loam†	2	1.39	1.43	2			
		18	1.25	1.56	13	1.13	1.66	5
<u>Brown</u>								
Loess	Silt loam*	14	1.14	1.21	1	1.20	1.43	13
Lacustrine sed.	Silt loam	1				1.18	1.44	1
	Loam†	1	1.36		1			
		16	1.33	1.21	2	1.20	1.43	14
<u>Sierozem</u>								
Loess	Silt loam*	5				1.26	1.45	5
		5				1.26	1.45	5
<u>Planosol</u>								
Loess	Silt loam*	5	1.18	1.85	5			
Colluvium	Silt loam	1	1.19	1.89	1			
Residuum	Silt loam†	3	1.34	1.79	3			
		9	1.23	1.83	9			0
<u>Calcisol</u>								
Loess	Silt loam*	1				1.11	1.40	1
Alluvium	Sandy loam†	1	1.50	1.79	1			
	Loam†	1	1.43	1.81	1			
Colluvium	Silt loam†	2	1.26	1.69	1	1.24	1.48	1
Lacustrine sed.	Silt loam	1				1.20	1.81	1
	Silty clay							
	loam	1						1
	Loam†	2	1.37	1.60	2			
	Fine sandy loam	2	1.28	1.43	2			
		11	1.35	1.62	7	1.18	1.56	4
<u>Lithosol</u>								
Loess	Silt loam*	5	1.22	1.33	5			
	Loam*, †	1	1.10	0.98	1			
		6	1.20	1.27	6			0
<u>Solonetz</u>								
Loess	Silt loam	2	1.33	1.57	2			
		2	1.33	1.57	2			0
		70	1.26	1.57	42	1.23	1.49	28

* Includes stony phases. † Includes gravelly phases.

‡ Soils whose characteristics restrict cicada nymph activities.

§ Soils whose characteristics provide a suitable habitat for cicadas.

Rydb.) as prominent members of their plant communities. These same plant species also occurred, however, on soils which were relatively free of cicadas.

No nymphs nor cicada krotovinas are found on any of the eight planosolic soils on which Low sagebrush (*A. arbuscula* Nutt.) is found.

Although shrubby plant species occur on all soils in which living cicadas are found, on two study locations there are no shrubby species in the immediate vicinity of the soil pit. This may indicate that shrubby species are not essential to the western species of Cicadidae and that these insects likely feed upon a variety of plant species.

The direct effect of feeding by cicada nymphs upon the fluids from plant roots cannot be evaluated from the data presently available. Whether the effect of their feeding is great enough to influence either the kind or amount of plant species making up natural plant communities on

cicada populated soils is a matter of conjecture. Moreover, whether the distinctive soil structure formed by the cicada nymphs may have an indirect effect on plant populations cannot be determined from available data. During the studies, it was frequently noted that plant roots followed faces of cicada krotovinas and that roots are abundant in unfilled nymph burrows. Roots are infrequently found within the cicada krotovinas themselves.

SUMMARY

The occurrence, subterranean activity, and effect on soil formation of western species of cicada were studied on natural relict rangelands. The structural characteristics of some Western soils are attributed to the burrowing of the nymphs of the cicada. The burrowing activity is shown to have occurred over long periods of time.

The term "cicada krotovinas" is used to denote the filled burrows of these insects. The burrows are filled with soil materials essentially from the host horizon with little mixing from other horizons. An additional term for blocky soil structure, "cylindrical blocky," is proposed to describe blocky soil peds which are definitely cylindrical in shape.

Cicada nymph distribution is influenced by kinds of soil. At the great soil group level, Brown and Sierozem soils are well suited to cicada nymph activity. There is an inverse relationship between the degree of development of textural B₂ horizon and of bulk density, and the abundance of cicada krotovinas.

Cicada activity is most common in well-drained, moderately permeable, silt loam and stony silt loam soils developed in loess parent materials that are more than 24 inches in depth. No single soil factor is a reliable indicator of suitable habitat of cicada nymphs.

Cicada activity is usually, but not exclusively, associated with the presence of shrubby plant species. Cicadas do not occur in any soils on which low sagebrush is dominant. The effect of cicada nymphs on plant growth is not known.

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