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Ecological Study of the Weed Population of Eastern Nebraska

Elva L. Norris

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ECOLOGICAL STUDY OF THE WEED POPULATION OF EASTERN NEBRASKA *

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SCOPE OF THE STUDY

EXACT knowledge of the relations existing between weeds and cultivated crops is very limited. This is true also of the amount of viable weed seed present in arable soil. Impressions and observations have been recorded, but very few quantitative investigations have been made. The numerous circulars and bulletins about weeds, issued by many experiment stations, deal mostly with descriptions of species and methods of weed control.

The present research was undertaken primarily to determine the relationship which exists between weeds and cultivated crops, but also to obtain an estimation of the number of viable weed seeds present in the soil. A third objective was to provide a record of species which compose the weed flora of cultivated soils. Opportunity was also afforded to observe the effects of extreme drought upon the weed population.

A satisfactory definition of the term "weed" has never been given. A weed is frequently defined as "a plant out of place." This definition has been found unsatisfactory by Pieters (1935),[1] who suggests a weed is "a plant that does more harm than good and has the habit of intruding where not wanted." Muencher (1935) states that "weeds are those plants with harmful or objectionable habits or characteristics which grow where they are not wanted, usually in places where it is desired that something else should grow."

Only the weeds which occurred on arable land, as distinguished from meadow or grassland, were considered in this study. Even under constant cultivation certain weeds always appear among cultivated plants, and it is with these that this study is concerned.

* Contribution from the Department of Botany, No. 112.
[1] See bibliography, p. 90.

Rotation of crops in Nebraska consists of some systematic alternation of the three general classes of field crops, namely, small cereals (wheat, oats, and barley), legumes (sweet clover, red clover, and alfalfa), and cultivated row crops (usually maize). The fields studied included untilled fallow land, corn, oats, wheat, alfalfa, and sweet clover.

LITERATURE

Representative researches are those of Brenchley in England (1911, 1912, 1913, 1920), who carried on weed surveys for several years to obtain data on the association of weeds and crops. She determined that a definite relationship exists between crops and weeds, and states: "One of the chief factors in determining the abundance or scarcity of a particular weed is the degree of competition it is able to stand successfully, and furthermore, the aboveground struggle for light is as important as the underground struggle for food and water."

Brenchley & Warington (1930) made numerical estimations of the number of viable weed seeds in soil samples of known area taken from permanent wheat and barley fields at Rothamsted and Woburn experimental stations in England. They found that the actual number of living seeds per acre of some species is very large, poppies reaching an average of 113 million.

Researches by Korsmo (1930) in Norway include studies of weeds which occur under certain agricultural practices. He also deals with the content of living weed seed of arable soil. In 631 samples of cultivated soil investigated, there was found an average of 4,230,000 weed seeds per sample capable of germination. Samples represented .2471 acre and were taken to a depth of 25 centimeters. *Chenopodium album* L.,[2] *Spergula arvensis* L., and *Stellaria media* (L.) Cyrill. appeared in the greatest numbers. Buchli (1936), working in Switzerland, made a study of the ecology of weeds of fields in which he attempted to determine the extent to which the occurrence, range, and vigor of approximately 200 species depended upon the system of land use and upon climatic and soil conditions. Data are also given for the weed-seed content of various soils and the capacity of the seeds to germinate.

General information on weeds has been compiled by Muencher (1935), who states that "the common weeds of cultivated fields and gardens are relatively few, but very generally distributed throughout the northern United States." He finds that the most common weeds of American grain fields are annuals, but the few

[2] Authority for the name of the species is given only the first time the name is used.

perennials which do occur are among the most persistent and the most difficult to control. Soil samples taken in several counties in western New York contained 37 species of viable weed seeds.

Studies on competition of certain weeds and crops by Pavlychenko & Harrington (1934, 1935) were made in Canada. These workers conclude that success in competition depends on readiness and uniformity of germination under adverse moisture conditions, the ability to develop a large assimilating surface in the early seedling stage, and a root system with a large mass of fiber close to the surface but with its main roots penetrating deeply.

LOCATION AND EXTENT OF THE AREA

The studies were made in Lancaster county in eastern Nebraska, within a radius of 15 miles of Lincoln, and in southeastern Cedar county and adjoining portions of Wayne and Dixon counties in northeastern Nebraska. They extended over a period of three growing seasons, 1934 to 1936 inclusive. One hundred fields, about half of which were in Lancaster county, were selected and examined in 1934, and reexamined in 1935. In 1936, 40 of the same fields were studied for a third or fourth time. The fields varied in size from 30 to 80 acres. A total of approximately 5,000 acres of land was under observation during the three seasons.

PROCEDURE

Representative fields were selected for survey only after size, topography, type of soil, and the previous cropping system were considered. Extremely sandy or saline lands were avoided. A detailed study of each field was made to determine the importance of the species present. This was accomplished by traversing the area on foot and carefully studying the various slopes, ravines, or other parts, as well as the general area.

The importance of each species was estimated according to definitely outlined criteria. These included not only number, i.e., abundance, but also size, density, duration, gregariousness, and basal and foliage cover. The fruiting and seeding habits were also considered. The species encountered were placed in one of five classes which were designated as follows: (1) very abundant; (2) abundant; (3) common; (4) occasional; and (5) rare. An intimate knowledge of about 90 species was necessary in order to make accurate ranking. Although the classes were named according to the factor of abundance (which is usually the most important) yet it should be emphasized that all of the characters were considered in classifying a species in a particular field.

Species placed in class 1 were usually of large size, occupied considerable space, and were widely but not necessarily con-

tinously distributed throughout the field. Sunflower (*Helianthus annuus* L.) and cocklebur (*Xanthium commune* Britton) afford examples of this type, fig. 1. A species of small size, occupying little space, and having narrow leaves which cast only a small amount of shade and which probably used little water or nutrients, was present in extremely large numbers before it was placed

Fig. 1.—Edge of field of corn near Lincoln badly infested with *Helianthus annuus, Acnida tamariscina,* and other weeds. This general condition prevailed throughout the field. September 1934.

in class 1. Green foxtail (*Setaria viridis* (L.) Beauv.) was frequently an example of this type of weed. Those species which fell slightly below class 1 and yet well above the distribution designated as common were placed in the second class. Class 3 consisted of species rather evenly distributed throughout the entire field and which were almost constantly within view. Weeds that were widely scattered and so rare that they were found in only one or a few places were given a ranking of 5 for that particular field. Where they were of somewhat more frequent occurrence and importance, the ranking was raised to 4.

Each species was listed as soon as it was observed, but a ranking was not given until the survey was almost completed. The ranking of species into classes of relative importance is entirely

practicable, as was shown by Weaver & Fitzpatrick (1934) in their comprehensive survey of the prairies, but it requires experience and familiarity with the vegetation. It is believed that the estimates made in the extensive acreage studied give more accurate results on importance and distribution than if they had been obtained in greater detail from small areas.

The values were checked by having several trained workers investigate the same fields independently. Comparison of results showed that they were very similar and that the same relative rank was assigned to a particular species.

Intensive ecological studies were made of the most important species. Height at maturity, spread of foliage, size and number of leaves, time of flowering and fruiting, number of seeds, and presence or absence of seedlings were all determined. The condition of the habitat, whether mesic, hydric, or xeric, was observed. Presence or absence of plant disease, insect injury, and effect of drought were also noted.

SOILS

Soil, as conceived by the ecologist, is a dynamic natural body in equilibrium with its environment. This concept is in direct contrast to older ones which considered it as a static body, a sort of a storage bin of plant nutrients. Five chief factors are responsible for the development of soil: climate, vegetation, relief, age, and parent rock. Of these it is generally agreed that the two most important are climate and vegetation. Since the area studied has a fairly uniform climate and similar native vegetation (Weaver & Fitzpatrick 1934), the soil also has common characteristics. The region under study lies near the borderline between two zonal soil groups, Prairie and Chernozem, the first, in general, lying directly east of the second. The second difference between the two groups is the presence of a layer of calcium carbonate accumulation in the B horizon of the Chernozem. Its absence in the Prairie group is due to greater precipitation (Weaver & Clements 1938). Both soil groups are present in Lancaster county but only Chernozem in Cedar, Wayne, and Dixon counties.

Both of these zonal soil groups have developed under luxuriant prairie grasses during a period of thousands of years. The granular A horizon of the soil profile, usually 14 to 20 inches thick, is very dark brown in the Prairie soils and almost black in the Chernozem. The B horizon, of similar thickness, in the former grades into a lighter colored parent material, while in the latter it grades into a whitish calcareous horizon. At greater depths, the C horizon, into which roots of numerous native species often penetrate many feet, is found. It is usually many feet in thick-

ness, and only rarely is rock encountered. Kellogg (1936) states that "the high natural fertility of these [Prairie] soils combined with their favorable climate makes them among the most productive in the world for grains and grasses. . . . The group of Chernozem soils is one of the most important in the world."

Table 1.—Mean monthly and mean annual precipitation, and monthly precipitation during 1934 to 1936 inclusive, at Lincoln and Hartington, Nebraska.

	Average 56 years	1934	1935	1936
	Lincoln, Nebraska (Lancaster County)			
January	0.64	0.25	0.30	1.64
February	0.93	0.78	0.87	0.68
March	1.26	0.80	0.96	0.18
April	2.45	0.35	1.33	2.29
May	4.00	0.49	5.44	1.95
June	4.22	2.47	3.81	1.13
July	3.89	0.40	3.83	0.08
August	3.56	2.59	1.70	1.63
September	2.94	4.47	2.71	3.38
October	1.90	1.93	2.23	0.19
November	1.20	2.26	1.87	0.06
December	0.80	0.44	0.30	0.88
Total	*27.79*	*17.23*	*25.35*	*14.09*
	Hartington, Nebraska (Cedar County) (Average, 35 yrs.)			
January	0.69	0.40	0.99	2.90
February	1.10	0.40	1.08	2.42
March	1.24	2.58	0.93	1.23
April	2.53	0.73	4.69	1.26
May	4.54	0.81	2.85	3.26
June	4.32	6.52	3.68	1.79
July	3.18	2.60	1.92	0.09
August	3.51	0.92	4.70	1.03
September	3.08	4.13	1.28	5.44
October	1.80	0.34	0.46	0.32
November	1.12	1.40	1.00	0.47
December	0.77	0.85	1.02	1.72
Total	*27.88*	*21.68*	*24.60*	*21.93*

Various silt loams and clay loams were the chief soil types encountered.

PRECIPITATION AND SOIL MOISTURE

The mean annual precipitation at Lincoln, Nebraska, over a period of 56 years is 27.79 inches. That at Hartington, Nebraska, is 27.88 inches over a period of 35 years. Mean monthly precipitation and precipitation by months during 1934 to 1936 inclusive are given in table 1.

Precipitation at Lincoln during 1934 was 17.23 inches. This was 10.56 inches below normal. That at Hartington was 21.68, or 6.20 inches below normal. The year of 1934 was next to the driest in

the climatic history of the state. From April to August inclusive, drought was unprecedented; the precipitation at Lincoln totaled only 6.30 inches and that at Hartington 11.58 inches. During September more than 4 inches of rain fell at each station. October, November, and December were slightly above normal at Lincoln but 1.10 inches below at Hartington.

Soil samples were taken regularly in 1934 to a depth of 6 feet in a field of wheat at Lincoln (Noll 1938). Late in April no water was available for plant growth in the surface 4 inches except during two weeks in June. At 4 to 12 inches depth, the available water supply was also exhausted by April 24 and remained so until September 4. In the second foot, similar conditions developed by May 1, and the soil was continuously dry even during the following fall.

Precipitation for 1935 was 25.35 inches at Lincoln and 24.60 at Hartington. This was only 2.44 and 3.28 inches below normal at the two stations in the above sequence. January to March, inclusive, were abnormally dry at both stations, but during April, May, and June rainfall was normal. July rainfall was normal at Lincoln, but 1.26 inches below the mean at Hartington. During the remainder of the year, precipitation at the two stations was 1.59 and 1.82 inches below the mean.

Soil samples were taken regularly in 1935 to a depth of 6 feet in a field of alfalfa at Lincoln (Fredricksen 1938). During May, June, and July sufficient moisture for plant growth was present at all depths but by the latter part of August none was available to 6 feet. After September rains, moisture was available to the fourth foot.

The year 1936 was one of extreme drought. Precipitation was 14.09 and 21.93 inches, respectively, at the two stations, being 13.70 and 5.95 inches below the average. January and February were moderately moist at both stations, but drought began in May and continued until September. July and August were the driest that Nebraska had ever experienced. During September, precipitation was above normal at both stations.

Soil moisture in alfalfa fields was unavailable in the first 6 feet from July 8 to September 1, and only small amounts were present earlier in the season (Fredricksen 1938). Available water was generally low not only because of the deficient current precipitation but also because of low soil moisture, especially in the deeper soil, at the beginning of the sampling.

TEMPERATURE

Drought was accentuated by unusually high temperatures. The year 1934 was the warmest in the climatic history of the state.

Following a mild winter and warm spring, temperatures during May were the highest ever recorded for this month. This was true also for July which had 21 days when the average day temperatures (6 a.m. to 8 p.m. inclusive) were above 100° F (Weaver, Stoddart & Noll 1935). Temperatures became more moderate following the first week of August.

Fig. 2.—A recently plowed field on low ground with *Cannabis sativa*, 6 to 10 feet tall, invading from the margin.

Temperatures during 1935 averaged somewhat above normal, despite a cool moist spring and early summer. July was hot; the temperature averaged 8.5° F above the mean, and high temperatures continued until fall.

A notably hot summer followed the severe winter of 1935-6. July was the hottest month, with a maximum temperature above 100° F on 19 days. Temperatures during August were the highest ever recorded for this month. The remaining months also averaged above normal.

STUDIES DURING 1934

Weeds in Untilled Fallow Fields.—Many acres of agricultural land were allowed to lie idle in 1934, due to governmental regulations. Comparisons were made between the weed flora of untilled, fallow, arable land and that which was under cultivation.

Of the 27 fields of the former group examined, all had been cropped to corn the preceding year. Because of an excellent growth of weeds, fields observed early in June usually presented a complete foliage cover and at a distance were indistinguishable from a field of small grain. The cover of vegetation was broken only by the stalks of corn of the previous year. As the season advanced the vegetation was irregular in height, because of the growth forms of the various weeds which had been able to survive the severe competition. The large globular plants of Russian thistle (*Salsola pestifer* Nelson), often 3 feet in diameter, mingled with tall sunflowers (*Helianthus annuus* L.) and wild hemp (*Cannabis sativa* L.), fig. 2. Layering was sometimes marked, the tolerant wild buckwheat (*Polygonum convolvulus* L.) often forming a dense understory beneath taller weeds. Low-growing vegetation forming a continuous foliage cover usually proved to be small-flowered morning glory (*Convolvulus arvensis* L.). The vegetation in the moister soil was more luxuriant and often 8 to 10 inches taller than that on the steeper hillsides.

These weed-infested, untilled lands left undisturbed in nature's care, sometimes adjoining native prairie sod, compelled grave contemplation. Without vegetation, they would have been exposed to the unhindered erosive forces of both wind and runoff water. With the "shock troop" of weeds growing everywhere, sometimes in nearly pure stands but more frequently in varied mixtures, the soil was quite as well protected as though it had borne a crop. Conversely, water usage was undoubtedly even greater than among row crops such as sorghum or corn. The results of such circumstances were the depletion of soil moisture and an enormous increase in potential weed populations, to handicap the growth of crops for many years to come.

A summary of results obtained from the study of the untilled fallow fields is presented in table 2. The species of weeds commonly observed are arranged in order of importance as determined by their percentage of occurrence in the five classes, i.e., very abundant, abundant, common, occasional, and rare. The last column of table 2 gives the percentage of fields in which the species did not occur.

A total of 66 species was present, a larger number than in all types of cropped fields. A higher percentage of species, moreover, occurred in the very abundant and abundant classes. Nine annuals and one perennial composed the 10 most important weeds. Three of the annuals were grasses, viz., green foxtail (*Setaria viridis*), yellow foxtail (*Setaria lutescens*), and sandbur (*Cenchrus pauciflorus*). *Setaria viridis* ranked highest in importance of all species, being very abundant in 78 per cent of the fields but

Table 2.—Weeds of 27 untilled fallow fields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	1	2	3	4	5	0
			per cent			
Setaria viridis Beauv.	78	4	11	4	0	3
Salsola pestifer A. Nels.	37	15	26	11	0	11
Setaria lutescens Hubb.	37	4	19	0	0	40
Helianthus annuus L.	15	0	37	26	4	18
Rosa arkansana S. Wats.	7	26	48	7	4	8
Solanum rostratum Dunal	7	7	33	19	15	19
Xanthium commune Britton	7	4	37	15	11	26
Ambrosia elatior L.	7	4	26	44	15	4
Chenopodium album L.	4	15	59	15	0	7
Cenchrus pauciflorus Benth.	4	15	41	4	0	36
Polygonum pennsylvanicum L.	4	7	56	11	0	22
Amaranthus retroflexus L.	4	7	22	22	7	38
Convolvulus sepium L.	4	4	22	7	4	59
Digitaria sanguinalis (L.) Scop.	4	4	4	0	0	88
Lepidium virginicum L.	4	0	15	11	0	70
Ambrosia trifida L.	4	0	0	7	7	82
Rumex crispus L.	4	0	0	4	4	88
Euphorbia dentata Michx.	0	11	4	19	7	59
Salvia lanceolata Willd.	0	7	33	7	0	53
Echinochloa crusgalli Beauv.	0	7	15	7	4	67
Euphorbia maculata L.	0	4	56	22	4	14
Polygonum convolvulus L.	0	4	30	7	4	55
Apocynum sibiricum Jacq.	0	4	24	20	20	32
Oxalis stricta L.	0	4	19	7	7	63
Euphorbia marginata Pursh	0	4	11	11	7	67
Cannabis sativa L.	0	4	11	7	26	52
Acerates angustifolia (Nutt.) Dec.	0	4	4	4	0	88
Physalis lanceolata Michx.	0	0	78	11	0	11
Lygodesmia juncea D. Don.	0	0	37	7	4	52
Asclepias syriaca L.	0	0	22	33	0	45
Iva xanthifolia Nutt.	0	0	19	7	0	74
Erigeron canadensis L.	0	0	15	11	22	52
Amaranthus graecizans L.	0	0	15	7	4	74
Verbena bracteosa Michx.	0	0	15	0	7	78
Panicum capillare L.	0	0	11	19	11	59
Lactuca scariola L.	0	0	11	15	15	59
Polygonum aviculare L.	0	0	11	7	19	63
Euphorbia preslii Guss.	0	0	11	4	7	78
Polygonum muhlenbergii (Meisn.) Wats.	0	0	11	0	0	89
Physalis heterophylla Nees.	0	0	7	15	7	71
Kochia scoparia Schrad.	0	0	7	7	0	86
Silphium laciniatum L.	0	0	7	4	4	85
Portulaca oleracea L.	0	0	7	0	4	89
Brassica nigra Koch	0	0	4	11	7	78
Glycyrrhiza lepidota Pursh	0	0	4	0	11	85
Verbena stricta Vent.	0	0	0	11	11	78
Allionia nyctaginea Michx.	0	0	0	11	4	85

only 4, 11, and 4 per cent, respectively, in classes 2, 3, and 4. It was never recorded as rare, and was absent in only 3 per cent of the fields. Russian thistle (*Salsola pestifer*) was second in importance, being found in 89 per cent of the fields, ranking first in 37 and second in 15 per cent, respectively. The following are arranged in order of their importance: sunflower (*Helianthus annuus*), prairie rose (*Rosa arkansana*), buffalo bur (*Solanum rostratum*), cocklebur (*Xanthium commune*), annual ragweed (*Ambrosia elatior*), lamb's quarters (*Chenopodium album*), and

sandbur (*Cenchrus pauciflorus*). *Rosa arkansana* was the only perennial occurring among the 10 most important weeds. This half-shrub occurred in 92 per cent of fields but ranked in the first two classes in only 33 per cent.

Some species had a high percentage of occurrence yet rarely ever ranked in either of the two upper classes. Ground cherry (*Physalis lanceolata*) and milk purslane (*Euphorbia maculata*) were present in 89 and 86 per cent of the fields, respectively, but were never of sufficient importance to be placed in class 1. Giant ragweed (*Ambrosia trifida*) and curled dock (*Rumex crispus*) were more exacting in their habitat requirements. They did not occur in many fields but when present were sometimes of sufficient importance to be placed in class 1. Ten species which ranked highest in occurrence are listed in table 3.

Table 3.—Species of greatest occurrence in untilled fallow fields.

SPECIES	PER CENT OCCURRENCE	SPECIES	PER CENT OCCURRENCE
Setaria viridis	97	Physalis lanceolata	89
Ambrosia elatior	96	Euphorbia maculata	86
Chenopodium album	93	Helianthus annuus	82
Rosa arkansana	92	Solanum rostratum	81
Salsola pestifer	89	Polygonum pennsylvanicum	78

Species seldom occurring which are not recorded in table 2 follow. The annuals were *Amaranthus blitoides* S. Wats., *Aristida oligantha* Michx., *Boebera papposa* Rydb., *Bromus secalinus* L., *Chenopodium hybridum* L., *Hibiscus trionum* L., and *Solanum nigrum* L. Two winter annuals, *Sophia pinnata* (Walt.) Howell and *Thlaspi arvense* L., were observed, also two biennials, *Gaura parviflora* Dougl. and *Tragopogon pratensis* L. The largest number, however, were perennials: *Allionia hirsuta* Pursh, *Cirsium altissimum* (L.) Spreng., *Convolvulus arvensis* L., *Meibomia illinoensis* (A. Gray) Kuntze, *Silphium perfoliatum* L., *Teucrium canadense* L., *Taraxacum officinale* Weber, and *Vernonia baldwinii* Torr.

Among these weeds are those which are not commonly associated with cultivated crops, but are usually restricted to roadsides or overgrazed pastures. Their ability to occupy fields is due largely to their excellent means of seed dissemination, mostly by wind. Nearly all will disappear when the ground is again cultivated, and they are consequently of small importance. *Allionia hirsuta* and *Amaranthus blitoides* are usually found on arable soils but crop rotation holds them in check. Certain weeds, as *Convolvulus arvensis,* once introduced establish themselves with

great rapidity and become the dominant vegetation regardless of the type of cropping system employed.

Weeds in Fields of Corn.—Fields of corn in 1934 were not normally developed, since April and May had only about 25 per cent of the usual rainfall. The stands were very uneven. Because of the severe drought of July and August, the stalks were cut for fodder and very little grain was produced. Cornfields present

Table 4.—Weeds of 31 cornfields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	1	2	3	4	5	0
			per cent			
Convolvulus arvensis	19	0	13	0	0	68
Setaria viridis	10	10	58	0	0	22
Cenchrus pauciflorus	10	10	19	13	0	48
Rosa arkansana	3	16	38	13	3	27
Amaranthus retroflexus	3	10	51	13	10	13
Setaria lutescens	3	10	19	6	3	59
Apocynum sibiricum	3	6	29	29	13	20
Xanthium commune	3	3	29	16	16	33
Portulaca oleracea	3	0	10	16	10	61
Digitaria sanguinalis	3	0	3	3	0	91
Physalis lanceolata	0	6	83	3	0	8
Polygonum muhlenbergii	0	6	6	3	3	82
Convolvulus sepium	0	3	38	13	6	40
Asclepias syriaca	0	3	26	35	6	30
Salvia lanceolata	0	3	3	6	3	85
Euphorbia maculata	0	0	26	3	13	58
Salsola pestifer	0	0	6	26	6	62
Physalis heterophylla	0	0	19	19	3	59
Lygodesmia juncea	0	0	19	19	0	62
Echinochloa crusgalli	0	0	19	16	6	59
Amaranthus graecizans	0	0	16	13	6	65
Euphorbia dentata	0	0	10	6	0	84
Cirsium arvense (L.) Scop.	0	0	10	0	0	90
Ambrosia elatior	0	0	3	19	3	75
Solanum rostratum	0	0	6	42	13	39
Euphorbia preslii	0	0	6	6	0	88
Amaranthus blitoides	0	0	6	6	0	88
Helianthus annuus	0	0	6	3	6	85
Hibiscus trionum L.	0	0	6	3	3	88
Allionia nyctaginea	0	0	3	10	13	74
Silphium laciniatum L.	0	0	3	6	3	88
Panicum capillare	0	0	3	6	3	88
Allionia hirsuta	0	0	3	3	6	88
Chenopodium album	0	0	0	13	11	76
Polygonum pennsylvanicum	0	0	0	13	10	77
Acerates angustifolia	0	0	0	0	13	87

two types of habitats, the first during the preparation of the seedbed, followed by subsequent cultivations of the crop, and a second from the time of the last cultivation until the end of the growing season. The crop grew slowly but tasseling occurred unusually early. Leaves were abnormally small and few so that in most fields light was not a factor in competition. Many fields were brown and dry after July 15, due to severe damage by hot winds.

A study of 31 cornfields revealed a total of 55 species of weeds. The 36 which often occurred are arranged in the order of their

importance in table 4. Although *Convolvulus arvensis* ranked highest in importance, it occurred in only 32 per cent of the fields. It reproduces by means of seeds and vegetative parts, but dissemination is largely due to the activities of man. This species has a highly specialized root system which enables it to absorb at various levels to the exclusion of other vegetation (Kiltz 1930).

Fig. 3.—A field of corn on upland in Lancaster county where a rank growth of weeds, chiefly *Amaranthus retroflexus* and *Acnida tamariscina* 6 or more feet high, has greatly reduced the yield.

Observations made early in the season before the first cultivation of the crop disclosed numerous seedlings of annuals, *Amaranthus retroflexus* and *Setaria viridis* most often dominating. Fields observed immediately after cultivation appeared to be entirely free from weeds, but close examination showed that perennials such as *Rosa arkansana* and *Physalis lanceolata* were often present. Cultivation brings about the lifting and aerating of buried seeds and

usually places them under conditions suitable to germination. Sufficient time occurs between cultivations to permit germination and early growth so that the new crop of seedlings is largely destroyed by the subsequent cultivation. Because of drought, a late crop of seedlings did not appear during 1934 and the soil throughout the entire season appeared as if it had been recently cultivated. Deeply rooted perennials, however, continued to make almost normal growth.

Corn is not a good competitor of weeds. This fact was made evident by small areas accidentally left uncultivated. Maize growing under such conditions had spindling stems and the plants

Table 5.—Species of greatest occurrence in fields of corn.

SPECIES	PER CENT OCCURRENCE	SPECIES	PER CENT OCCURRENCE
Physalis lanceolata	92	Asclepias syriaca	70
Amaranthus retroflexus	87	Xanthium commune	67
Apocynum sibiricum	80	Solanum rostratum	61
Setaria viridis	78	Convolvulus sepium	60
Rosa arkansana	73	Cenchrus pauciflorus	52

were permanently stunted, although the weeds were later destroyed by cultivation. Mosier & Gustafson (1915), working in Illinois, found that corn averaged 46 bushels per acre where weeds were kept down by scraping the soil surface, but only 7 bushels where they were allowed to grow. A single plant of *Amaranthus retroflexus*, 6 feet tall, growing in a hill of corn, reduced the height of the corn to 5 feet, while surrounding stalks were 8.5 feet tall, fig. 3. *Convolvulus arvensis* and *C. sepium* twined around cornstalks and caused them to bend to the ground.

Annuals such as *Xanthium commune* and *Helianthus annuus*, which are very large and have exceedingly woody stems when mature, die readily if uprooted or covered with soil while in the seedling stage. Later they are destroyed only with difficulty. The 10 weeds of cornfields which had the highest percentage of occurrence are listed in table 5.

Because a weed had a high percentage of occurrence, it did not necessarily follow that it was of great importance. *Physalis lanceolata* and *Asclepias syriaca*, respectively, appeared in 92 and 70 per cent of the fields but they were rarely ranked in the two higher classes. Their importance was reduced because the stems were usually spaced singly on the underground parts.

A number of species were insignificant members of the weed flora of cornfields. The list included 10 annuals: *Abutilon theophrasti* Medic., *Ambrosia trifida, Eragrostis cilianensis* (All.)

Link., *Euphorbia marginata, Ipomoea hederacea* Jacq., *Iva xanthifolia, Lactuca scariola, Polygonum convolvulus, Cannabis sativa,* and *Verbena bracteosa.* Only one winter annual, *Lepidium virginicum,* and two biennials, *Arctium lappa* L., and *Gaura parviflora,* were present. The six minor perennials were *Cirsium altissimum, Glycyrrhiza lepidota, Helianthus tuberosus* L., *Polygala verticillata* L., *Kuhnia glutinosa* Ell., and *Verbena stricta.* In spite of their comparative scarcity, several of the plants may, under some conditions, prove troublesome.

Table 6.—Weeds of 20 oatfields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	1	2	3	4	5	0
			per cent			
Setaria viridis	60	20	5	0	0	15
Helianthus annuus	15	10	25	20	5	25
Setaria lutescens	15	5	30	0	5	45
Rosa arkansana	10	30	40	5	0	15
Salsola pestifer	10	20	20	15	10	25
Digitaria sanguinalis	10	5	5	0	0	80
Polygonum pennsylvanicum	5	5	55	25	0	10
Cenchrus pauciflorus	5	5	15	5	0	70
Polygonum convolvulus	5	0	30	5	5	55
Apocynum sibiricum	5	0	15	35	5	40
Convolvulus arvensis	5	0	10	0	0	85
Polygonum muhlenbergii	5	0	10	0	0	85
Brassica nigra	0	15	30	10	5	40
Xanthium commune	0	10	30	20	15	25
Solanum rostratum	0	10	30	20	5	35
Convolvulus sepium	0	10	20	25	0	45
Physalis lanceolata	0	5	85	0	0	10
Amaranthus retroflexus	0	5	45	10	5	35
Chenopodium album	0	0	60	25	0	15
Euphorbia maculata	0	0	50	15	5	30
Ambrosia elatior	0	0	35	35	15	15
Euphorbia dentata	0	0	35	5	0	60
Physalis heterophylla	0	0	30	15	5	50
Echinochloa crusgalli	0	0	25	20	5	50
Salvia lanceolata	0	0	20	20	10	50
Lygodesmia juncea	0	0	20	10	5	65
Oxalis stricta	0	0	20	5	5	70
Euphorbia preslii	0	0	20	0	10	70
Lepidium virginicum	0	0	15	5	0	80
Cannabis sativa	0	0	10	10	20	60
Ambrosia trifida	0	0	10	0	10	80
Asclepias syriaca	0	0	5	30	20	45
Euphorbia marginata	0	0	5	20	15	60
Polygonum aviculare	0	0	5	15	15	65
Portulaca oleracea	0	0	5	15	5	75
Amaranthus blitoides	0	0	5	10	5	80
Panicum capillare	0	0	5	10	0	85
Verbena bracteosa	0	0	5	5	10	80
Lactuca scariola	0	0	0	15	25	60
Silphium laciniatum	0	0	0	15	0	85
Amaranthus graecizans	0	0	0	10	5	85
Glycyrrhiza lepidota	0	0	0	5	25	70
Allionia nyctaginea	0	0	0	5	20	75
Rumex crispus	0	0	0	5	15	80

Weeds in Fields of Oats.—The spring of 1934 was unfavorable

to the germination of oats. Stands were poor and the plants tillered only slightly in the 20 representative fields selected for study. The average height of mature plants varied from 12 to 18 inches. Heading began about June 12, when the plants were only 12 inches tall. The grain in many fields was considered too poor to harvest. In six fields, sweet clover had been sown with the oats and it also germinated poorly. *Setaria viridis* was the dominant weed on badly eroded slopes where the soil was thin. When flowering it was often several inches taller than the oats. Thus, it showed a high degree of drought resistance. This is in accord with the findings of Rao (1937) on *Setaria italica*. *Apocynum sibiricum* and *Asclepias syriaca* sometimes overtopped the crop by 15 inches and were conspicuous even at a distance.

Table 7.—Species of greatest occurrence in fields of oats.

SPECIES	PER CENT OCCURRENCE	SPECIES	PER CENT OCCURRENCE
Physalis lanceolata	90	Chenopodium album	85
Polygonum pennsylvanicum	90	Helianthus annuus	75
Setaria viridis	85	Salsola pestifer	75
Rosa arkansana	85	Xanthium commune	75
Ambrosia elatior	85	Euphorbia maculata	70

Four of the fields had been harvested before examinations were completed, thus permitting a study of the effect of cutting on weeds. *Rosa arkansana* showed increased lateral branching on the remaining portions of the stems. *Salsola pestifer* made most of its growth rather rapidly after harvest, probably because of increased light, and large bushy plants were common in the stubble. *Polygonum pennsylvanicum, P. convolvulus,* and *Convolvulus sepium,* which were more abundant in the lower, more moist locations, were thriving. The stubble presented an abnormal appearance since the characteristic understory of annuals was lacking. Rains fell in late August and early September and the fields soon became green with seedlings.

Weeds listed in the 20 fields were 61 in number. The 44 which usually occurred are arranged in the order of their importance in table 6. Fields of oats had five fewer species than untilled fallow ground but six more than fields of corn. The great importance of *Setaria viridis* is shown by the fact that it ranked in class 1 in 60 per cent of the fields and held second in 20 and third rank in 5 per cent. *Helianthus annuus* occurred in all but 25 per cent of the fields. It held first rank in 15, second in 10, third in 25, fourth in 20, and fifth rank in 5 per cent of the fields. Ten species which ranked highest in occurrence are listed in table 7.

Minor weeds not recorded in table 6 follow. The annuals were represented by *Abutilon theophrasti, Amaranthus graecizans, Bromus secalinus, Eragrostis cilianensis, Erigeron canadensis, Hibiscus trionum, Iva xanthifolia, Kochia scoparia, Lactuca scariola,* and *Strophostyles pauciflora* (Benth.) Wats. Only one biennial, *Gaura parviflora,* was observed. Among the perennials of little significance were *Allionia hirsuta, Cirsium arvense* (L.) Scop., *C. altissimum, Rumex altissimus* Wood, *Silphium perfoliatum,* and *Urtica dioica* L.

Weeds in Fields of Wheat.—The weed flora of seven fields of fall wheat, representing 350 acres, consisted of 38 species, only

Table 8.—Weeds of seven wheat fields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	*1*	*2*	*3*	*4*	*5*	*0*
			per cent			
Apocynum sibiricum	14	0	14	29	14	29
Rosa arkansana	0	0	72	14	0	14
Physalis lanceolata	0	0	43	29	14	14
Helianthus annuus	0	0	29	0	29	42
Polygonum muhlenbergii	0	0	29	0	0	71
Euphorbia maculata	0	0	14	29	0	57
Lepidium virginicum	0	0	14	14	29	43
Polygonum pennsylvanicum	0	0	14	14	14	58
Chenopodium album	0	0	0	43	29	28
Salsola pestifer	0	0	0	43	14	43
Euphorbia dentata	0	0	0	29	14	57
Ambrosia elatior	0	0	0	14	43	43

12 of which were of general occurrence. With one exception, all fields were studied before harvest. Much variation occurred both in thickness of stand and height of plants; mature plants on hillsides were only 15 to 25 inches tall while in moister places their height was increased 5 to 10 inches. Because of drought and severe competition with foxtail, normal tillering also was often greatly decreased. Pavlychenko & Harrington (1935) found that during very dry seasons in Saskatchewan, Marquis wheat grown at ordinary rates of seeding had only one short culm while plants without competition produced as many as 27 well-developed tillers. In the present study, an understory of weeds was lacking where the stand was thick and in a thrifty condition. The majority of fields were harvested before many of the weeds had matured seed.

Important high-ranking perennials were *Apocynum sibiricum, Rosa arkansana,* and *Physalis lanceolata,* table 8. The first was found in 71 per cent of the fields, being very abundant in 14 per cent. It never occurred in class 2, but in classes 3, 4, and 5 it ranked 14, 29, and 14 per cent, respectively. Wild rose was second in importance, being represented in 86 per cent of the areas with

rankings of 72 per cent in the third class and 14 per cent in the fourth class. *Physalis lanceolata* occurred in 86 per cent of the fields but never ranked higher than the third class. Two annuals, *Helianthus annuus* and *Chenopodium album,* were frequent. The former was in class 3 in 29 per cent of the fields, while lamb's quarters occurred only occasionally.

Fewer weeds were found in fields of winter wheat than in corn and oats. Annual species particularly were reduced in number and were less important. Fall cultivation placed many seeds in a favorable environment for germination, and the resulting seedlings were killed by freezing. Most of the annual weed seedlings could not withstand the competition imposed by renewed spring growth of winter wheat. The rapid development and excellent branching of roots of winter wheat have been shown by Weaver, Kramer & Reed (1924). Numerous much-branched laterals ramify through the soil to a depth of 4 feet by December of the first year. Depth of penetration of mature plants in eastern Nebraska is 6 to 7 feet (Weaver 1926). Pavlychenko (1937) has shown a direct relationship between early and vigorous development of root systems and successful competition with weeds. The extent of the root system is remarkable. Even the relatively short-lived Marquis spring wheat produces a root system (in Saskatchewan) over one-half mile in total length.

The number of weeds which seldom occurred was unusually large; among these were 16 annuals: *Acnida tamariscina, Amaranthus retroflexus, A. graecizans, Cannabis sativa, Kochia scoparia, Lactuca scariola, Oxalis stricta, Polygonum aviculare, P. convolvulus, P. ramosissimum* Michx., *Portulaca oleracea, Setaria viridis, Solanum rostratum, Digitaria sanguinalis, Verbena bracteosa,* and *Xanthium commune.* It also included nine perennials, as follows: *Convolvulus arvensis, C. sepium, Distichlis spicata* (L.) Greene, *Lygodesmia juncea, Polygonum muhlenbergii, Rumex altissimus, R. crispus, Verbena stricta,* and *Vernonia baldwinii.*

Weeds in Fields of Small-Seeded Legumes.—Twelve fields of spring-planted legumes, comprising 10 of sweet clover and one each of alfalfa and red clover, were examined between June 14 and July 14, 1934. The soil had been cultivated before seeding but not as thoroughly as in making seedbeds for other crops. Seeds of legumes germinated poorly because of insufficient soil moisture. Hard seeds may also have contributed to poor germination. Germination occurred after fall rains, and the same fields had excellent stands in 1935. Notwithstanding unfavorable conditions, weed seeds were able to germinate and seedlings became established. Except for hillsides where the soil was thin, the

fields at a distance had the appearance of green meadows, although actually the foliage rarely covered more than two-thirds of the ground. A total of 60 species was present, 34 of which were of common occurrence.

The 10 most important weeds were *Setaria viridis, Rosa arkansana, Amaranthus retroflexus, Apocynum sibiricum, Setaria lutescens, Convolvulus arvensis, Oxalis stricta, Solanum rostratum, Polygonum convolvulus,* and *Salsola pestifer,* table 9. The first five were also important in untilled fallow fields.

Table 9.—Weeds in 12 fields of spring-planted legumes, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	1	2	3	4	5	0
			per cent			
Setaria viridis	50	8	33	0	0	9
Rosa arkansana	25	17	8	8	0	42
Amaranthus retroflexus	17	0	42	41	0	0
Apocynum sibiricum	17	0	17	17	8	41
Setaria lutescens	17	0	17	0	0	66
Convolvulus arvensis	17	0	8	0	0	75
Oxalis stricta	8	17	8	25	0	42
Solanum rostratum	8	17	8	17	25	25
Polygonum convolvulus	8	8	42	8	0	34
Salsola pestifer	8	8	17	25	25	17
Cenchrus pauciflorus	8	8	8	0	0	76
Chenopodium album	8	0	50	8	0	34
Polygonum pennsylvanicum	8	0	42	8	0	42
Xanthium commune	8	0	25	8	33	26
Physalis lanceolata	0	17	66	8	0	9
Euphorbia dentata	0	17	50	8	0	25
Euphorbia maculata	0	8	75	8	0	9
Salvia lanceolata	0	8	17	17	8	50
Ambrosia elatior	0	8	8	42	8	34
Helianthus annuus	0	0	66	0	17	17
Euphorbia preslii	0	0	58	0	8	34
Convolvulus sepium	0	0	33	0	0	67
Lepidium virginicum	0	0	33	0	0	67
Verbena bracteosa	0	0	8	17	17	58
Cannabis sativa	0	0	8	8	42	42
Euphorbia marginata	0	0	8	8	17	67
Lactuca scariola	0	0	0	58	17	25
Erigeron canadensis	0	0	0	25	42	33
Asclepias syriaca	0	0	0	17	58	25
Solanum nigrum	0	0	0	17	33	50
Abutilon theophrasti	0	0	0	17	8	75
Polygonum aviculare	0	0	0	9	25	66
Eragrostis cilianensis	0	0	0	8	25	67
Tragopogon pratensis	0	0	0	0	25	75

Setaria viridis was present in 91 per cent of the fields. Undisturbed plants reached a height of 3.5 to 4 feet by late July, fig. 4. Plants with as many as 40 tillers were often observed. The well developed stems sometimes had a basal spread of 3 to 4 inches, but a top spread of 18 inches. In dense stands, the fibrous roots thoroughly occupied the soil, forming a tough sod.

Amaranthus retroflexus was present in all fields. Its habits of

growth varied according to environmental conditions. If not crowded, it branched profusely, but under competition comparatively few branches appeared. Plants were sometimes 6.5 feet tall with a similar total spread of foliage. Secondary branches

Fig. 4.—A dense growth of *Digitaria sanguinalis* (left), *Setaria glauca* (center), and *S. viridis* (right), in an open spot in a cornfield, showing the rank, dense growth of these widely distributed weeds.

produced numerous tertiary ones, all of which bore seed spikes; thus, the possibilities for seed production were great. Even under conditions so unfavorable that the height is only 1.5 inches, this species often produces seed.

Solanum rostratum, which increases noticeably during dry years, grew in 75 per cent of the fields. Its numerous bright yellow

flowers and fresh appearance contrasted markedly with the surrounding drying vegetation. This weed is the original food of the Colorado potato beetle, and plants were rarely observed which were devoid of this insect.

Additional species which ranked high in importance and occurrence were *Physalis lanceolata, Euphorbia maculata,* and *Helianthus annuus.* Two species usually of low occurrence, *Lactuca scariola* and *Erigeron canadensis,* occurred in 75 and 67 per cent of the fields, respectively. The superficial cultivation had evidently placed the seeds at a depth favorable to germination.

Fig. 5.—*Polygonum pennsylvanicum* growing in low moist soil; the plants are about 3.5 feet tall and form a continuous cover.

Their very effective method of seed dissemination aids them in becoming successful migrants. Seed of legumes planted in the spring were of little value in reducing the importance of the weed flora under the conditions of drought which prevailed.

Annual species which were rarely observed comprised the following: *Amaranthus blitoides, A. graecizans, Ambrosia elatior, Bromus tectorum* L., *Echinochloa crusgalli, Kochia scoparia, Portulaca oleracea, Strophostyles pauciflora,* and *Digitaria sanguinalis.* All of these, under satisfactory habitat conditions, may become noxious weeds. One biennial, *Oenothera biennis,* was listed. Perennials rarely found were *Acerates angustifolia, Allionia nyctaginea, Cirsium altissimum, Glycyrrhiza lepidota, Kuhnia glutinosa, Lygodesmia juncea, Physalis heterophylla, Polygonum muhlenbergii, Psoralea floribunda* Nutt., *Rumex altissimus, R. crispus,*

Solanum carolinense, Taraxacum officinale, Verbena hastata, V. stricta, and *Vernonia baldwinii.*

Weeds in Fields of Barley.—The weed flora of approximately 150 acres of barley was studied during the first two weeks of August. It consisted of 44 species. The grain was not harvested because of its apparent light yield. The continuous cover of vegetation was about 25 inches in height and consisted largely of weeds, among which occurred the mature but much dwarfed barley. When growing under normal conditions, the roots of this cereal are well equipped for absorption (Weaver 1926). Pavlychenko & Harrington (1935) found that barley had the most extensive root system of any of the small-seeded cereal crops studied. Despite the scarcity of soil moisture, many weeds ecized.

Setaria viridis and *S. lutescens* were the two most important annuals. Their fibrous roots formed a tough sod near the surface of the soil. In addition to the foxtails, six other annuals, *Salsola pestifer, Ambrosia elatior, Polygonum pennsylvanicum, Amaranthus retroflexus, Chenopodium album,* and *Polygonum erectum,* were occupants of all fields, fig. 5. They grew generally throughout, excepting *Polygonum pennsylvanicum,* which was confined largely to low moist ground. *Polygonum erectum* appeared to prefer the hard trampled outer margins of the fields. *Physalis lanceolata* and *Rosa arkansana* were important perennials. The latter bore many mature fruits.

Weed-Seed Population of Arable Soil.—The annual weeds which appear with cultivated crops originate mostly from buried seeds of preceding weeds. Perennial weeds are also propagated by seeds, but their perpetuation is largely due to perennial underground parts. Since very little is known of the extent to which weed seeds infest the soil, studies were conducted to obtain numerical data on the weed-seed populations.

The soil samples were secured by means of a brass cylinder, 6 inches long and 4 inches in diameter, which was driven vertically into the soil to its full length. It was then carefully removed from the soil by means of a spade and its contents placed in a heavy manila paper bag. Each sample occupied a surface area of 12.6 square inches. Samples were taken from three locations in each field, i.e., one from higher ground, one from the lower places, and a third from an intermediate habitat. During September 1934, soil samples were taken from 45 fields before the soil had been disturbed by fall plowing. Of these fields, 35 were located in Cedar county and 10 in Lancaster county. Three samples were taken from each of 10 untilled fallow fields, 12 from fields of oats, 13 from corn, 3 from wheat, 2 from sweet clover, and 5 from alfalfa.

The samples were stored at room temperatures until April 1935, when they were transferred to pans 8 inches in diameter and 4 inches deep. The sample was sufficient to fill the pans approximately two-thirds full. The pans were placed in a specially constructed compartment in the greenhouse, which was enclosed by

Table 10.—Number of seedlings from 135 soil samples from high, low, and medium locations in fields.

SPECIES	GERMINATION DURING SPRING				GERMINATION DURING AUTUMN				TOTAL
	H	*L*	*M*	*T*	*H*	*L*	*M*	*T*	
Setaria viridis	780	671	1009	2460	42	11	13	66	2526
Amaranthus retroflexus	183	369	131	683	20	24	25	69	752
Setaria lutescens	90	283	169	542	2	4	1	7	549
Digitaria sanguinalis	115	63	72	250	23	10	43	76	326
Chenopodium album	1	11	72	84	2	0	23	25	109
Echinochloa crusgalli	15	58	19	92	3	0	0	3	95
Melilotus sp.	12	6	53	71	0	1	2	3	74
Eragrostis cilianensis	14	31	18	63	5	1	2	8	71
Euphorbia maculata	38	7	11	56	8	0	3	11	67
Portulaca oleracea	18	18	8	44	8	10	1	19	63
Lepidium virginicum	3	5	9	17	7	3	3	13	30
Cenchrus pauciflorus	1	6	13	20	0	1	3	4	24
Physalis sp.	7	2	4	13	1	0	0	1	14
Avena sativa	3	4	2	9	0	0	0	0	9
Oxalis stricta	1	0	1	2	2	1	2	5	7
Boebera papposa	6	0	0	6	1	0	0	1	7
Brassica nigra	0	7	0	7	0	0	0	0	7
Kochia scoparia	4	1	1	6	0	0	0	0	6
Poa pratensis	2	1	3	6	0	0	0	0	6
Panicum capillare	4	0	2	6	0	0	0	0	6
Salsola pestifer	2	1	0	3	0	0	1	1	4
Polygonum convolvulus	0	3	0	3	0	0	0	0	3
Euphorbia preslii	0	0	3	3	0	0	0	0	3
Solanum rostratum	3	0	0	3	0	0	0	0	3
Helianthus annuus	2	1	0	3	0	0	0	0	3
Xanthium commune	2	0	0	2	0	0	0	0	2
Taraxacum officinale	0	2	0	2	0	0	0	0	2
Amaranthus graecizans	0	0	1	1	0	0	0	0	1
Trifolium repens	0	0	1	1	0	0	0	0	1
Lactuca scariola	1	0	0	1	0	0	0	0	1
Convolvulus arvensis	1	0	0	1	0	0	0	0	1
Salvia lanceolata	1	0	0	1	0	0	0	0	1
TOTAL NO. SEEDLINGS	1309	1550	1602	4461	124	66	122	312	4773

fine muslin in order to avoid entry of wind-blown seeds. The soil was watered regularly, sometimes twice daily, by means of a hand sprinkler.

As the weed seedlings appeared, they were identified, counted, and removed from the soil. When the surface was clear of seedlings, the soil was stirred in order that all seed would be brought into a position favorable to germination. The number of seedlings of each species produced from each soil sample was determined and the date of their removal recorded. Identification of seedlings in an early stage of development was sometimes impossible, hence they were allowed to continue growth until identified. The grass

seedlings were quickly and accurately identified by the caryopses which remained attached to them.

When seedlings finally failed to appear, after a period of two weeks late in July, the soil was allowed to dry. It was then stored at room temperatures until September 15, when the samples were again moistened and placed under conditions favorable to growth. New seedlings were identified, counted, and removed as before. The two germinating periods are designated as spring (April 1 to July 30) and autumnal (September 15 to December 31).

The number of seedlings of each species produced from the 135 samples is given in table 10, where the totals are arranged in numerical sequence. Seedlings which appeared during each period as well as the number from the three locations are also recorded. The samples yielded 32 species, mostly annuals, five of which appeared only once. Only three perennials, *Physalis lanceolata, Convolvulus arvensis,* and *Poa pratensis,* were present, although field surveys showed that 35 per cent of the field weeds were perennials. This indicates that they are not propagated by seeds as readily as annuals.

The majority of species had a pronounced maximum germination in spring. Of the 4773 seedlings, 93 per cent appeared in the spring period. *Setaria viridis* ranked highest with 2526 seedlings. It was followed by *Amaranthus retroflexus* with 752 seedlings, *Setaria lutescens* with 549, *Digitaria sanguinalis* with 326, while *Chenopodium album* had 109.

The field soil at all times contained a mixed weed-seed population of different ages. Some seeds were in a period of natural dormancy, while others had completed this period but conditions were unfavorable to germination. At the termination of the studies, a small number of viable seeds may have been present which were still dormant. Brenchley & Warington (1930) constantly maintained soil samples under conditions favorable to germination during a period of four years. Seeds of several species continued to germinate, indicating that the period of dormancy for some may be of long duration. It is assumed that at the close of the first germination period all of the remaining seeds were dormant and that the autumnal period determined the number which had broken dormancy.

The controlled conditions in the greenhouse may account for the periods at which maximum germination occurred. Under field conditions, with fluctuations in both temperature and moisture, the time of germination might be hastened or delayed. Periodicity of germination is probably linked with various internal and external conditions, of which the temperature at any stage in

the life history of the seed presumably plays an important part (Warington 1936).

A clearer idea of the large number of viable seeds in soil is given by calculating the number per acre. A composite sample representing 37.8 square inches of surface soil was taken from a cornfield to the 6-inch depth. This area represents 1/166,387 part of an acre. A total of 90 seedlings representing 11 species, or 14,974,830 per acre, appeared. This does not include viable seeds which, because of dormancy, failed to germinate. Individual species and the calculated number per acre are as follows: *Setaria viridis,* 10,482,381; *Amaranthus retroflexus,* 1,663,870; *Digitaria sanguinalis* and *Setaria lutescens,* 499,161 each; *Portulaca oleracea, Xanthium commune, Eragrostis cilianensis,* and *Euphorbia malculata* were each represented by 332,774; and *Lepidium virginicum, Melilotus* sp., and *Helianthus annuus,* 166,387 each.

Table 11.—Average number of seedlings present per unit sample area and per acre from different types of fields.

TYPE OF FIELD	NO. SOIL SAMPLES	AVERAGE NO. SEEDLINGS PER UNIT AREA (12.6 sq. in.)	AVE. NO. SEEDLINGS PER ACRE
Untilled fallow	30	74	36,937,840
Oats	36	30	14,974,800
Corn	39	27	13,477,320
Wheat	9	34	16,971,440
Sweet Clover	6	19	9,484,040
Alfalfa	15	9	4,492,440

The locations from which soil samples were taken greatly influenced the number of weed seeds present, table 10. The greatest number of seedlings were present in samples taken at medium or low elevations. Weeds are more abundant in low moist places, where they usually grow larger and produce more seed. Seeds are also carried to low places by runoff water and with eroded soil. Certain weeds (as *Echinochloa crusgalli* and *Polygonum muhlenbergii*) are largely restricted to moister ground. The type of crop grown previous to the taking of soil samples also bore a relationship to the number of weed seeds, table 11.

Untilled fallow fields had a larger number of weed seeds than those which had received some type of cultivation. Field studies also supported this fact. Although competition in fallow fields is often severe, there is no disturbance by man. The suppressed weeds may die but the dominants complete their life cycles and fruit abundantly.

Green foxtail (*Setaria viridis*) ranked first in the number of seedlings, composing 57 per cent of the total. More than any other

species, it showed a tendency to germinate immediately when placed under favorable conditions. Almost all of the seedlings appeared during the spring germination period, thus indicating the presence of very few dormant seeds. Such seedlings immediately enter into competition with fall-planted cereals, but in the region studied they winterkill and crops compete only with plants from seeds which germinate in the spring. Seedlings of yellow foxtail (*S. lutescens*) were only one-fourth as abundant as those of the green foxtail (*S. viridis*). The foxtails were usually associated, and under favorable conditions both germinated immediately.

Rough pigweed (*Amaranthus retroflexus*) composed 16 per cent of the seedlings. A total of 752 was present, 683 appearing in the spring period. According to Muencher (1935), one plant of average size is capable of producing 196,405 seeds, hence the possibilities of soil contamination are great. Germination began April 19 and continued for three months. The period of dormancy was longer than for *Setaria viridis*. Crocker (1916) found that dormancy in this species resulted from the structure of the seed coat.

Crabgrass (*Digitaria sanguinalis*) was represented by 326 seedlings, 25 per cent of which appeared during the autumnal period. Germination was irregular, very few seedlings appearing during the first half of the spring period but gradually increasing as the season advanced. Field observations also showed that seed of crabgrass germinated late in spring. This grass was found only in a few samples from Cedar county, but it was abundant in soils from Lancaster county.

Seedlings of lamb's quarters (*Chenopodium album*) numbered 109. Seeds germinated throughout both periods, indicating that they were continually emerging from dormancy. They remain viable in the soil 40 years (Darlington 1922). Viability of these seeds is not affected by passage through the alimentary tract of domestic animals (Atkeson, Hulbert & Warren 1934). Korsmo (1930), after long-continued studies in Norway, reported *Chenopodium album* the most abundant weed in arable soils.

Approximately 57 and 30 per cent, respectively, of the seedlings of *Lepidium virginicum* and *Portulaca oleracea* appeared during the autumnal period. A higher percentage of seedlings of *Echinochloa crusgalli, Eragrostis cilianensis,* and *Euphorbia maculata* appeared in the spring period, as was also true of the remainder of the species in table 10.

STUDIES DURING 1935

The fields examined in 1934 were studied again in 1935. The number of each type selected the first year was altered because of crop rotation. During 1935 the following were examined: 49 corn-

Table 12.—Weeds of 49 cornfields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	*1*	*2*	*3*	*4*	*5*	*0*
			per cent			
Amaranthus retroflexus	22	14	32	20	0	12
Xanthium commune	14	10	26	14	2	34
Cenchrus pauciflorus	12	8	26	8	0	46
Rosa arkansana	10	10	42	16	0	22
Convolvulus sepium	10	6	22	8	0	54
Physalis lanceolata	8	4	80	4	0	4
Setaria viridis	6	8	62	8	0	16
Setaria lutescens	6	2	54	4	0	34
Convolvulus arvensis	6	0	8	0	0	86
Digitaria sanguinalis	6	0	0	2	0	92
Helianthus annuus	4	4	14	18	2	58
Polygonum muhlenbergii	4	4	8	2	0	82
Chenopodium album	2	14	16	34	4	30
Apocynum sibiricum	2	6	28	28	4	32
Salvia lanceolata	2	0	8	16	6	68
Polygonum pennsylvanicum	0	6	52	12	4	26
Portulaca oleracea	0	4	28	30	2	36
Lygodesmia juncea	0	4	18	6	2	70
Amaranthus graecizans	0	4	14	10	0	72
Echinochloa crusgalli	0	2	60	20	4	14
Solanum rostratum	0	2	22	24	6	46
Asclepias syriaca	0	2	20	30	8	40
Polygonum convolvulus	0	2	10	20	6	62
Euphorbia dentata	0	2	8	8	0	82
Hibiscus trionum	0	2	2	0	2	94
Amaranthus blitoides	0	2	0	6	6	86
Euphorbia maculata	0	0	62	10	0	28
Salsola pestifer	0	0	36	28	6	30
Physalis heterophylla	0	0	20	16	0	64
Lepidium virginicum	0	0	20	2	0	78
Ambrosia elatior	0	0	14	14	6	66
Kochia scoparia	0	0	8	6	0	86
Euphorbia marginata	0	0	6	6	0	88
Lactuca scariola	0	0	4	8	6	82
Melilotus sp.	0	0	4	6	0	90
Panicum capillare	0	0	2	26	2	70
Erigeron canadensis	0	0	2	10	0	88
Eragrostis cilianensis	0	0	2	8	2	88
Silphium perfoliatum	0	0	2	6	4	88
Cannabis sativa	0	0	2	4	2	92
Glycyrrhiza lepidota	0	0	2	4	0	94
Allionia nyctaginea	0	0	0	10	14	76
Brassica nigra	0	0	0	6	6	88
Abutilon theophrasti	0	0	0	6	0	94
Polygonum aviculare	0	0	0	4	10	86
Iva xanthifolia	0	0	0	4	4	92
Taraxacum officinale	0	0	0	2	6	92
Verbena bracteosa	0	0	0	2	4	94
Allionia hirsuta	0	0	0	2	4	94

fields, 21 fields of oats, 10 of small-seeded legumes, 8 of wheat, and 4 of barley. In addition 4 fields of sorghum and 3 untilled fallow fields were studied.

Weeds in Fields of Corn.—Among the 49 fields planted to corn, only 13 had borne this crop during 1934. Eighteen had been untilled and fallow, 11 planted to oats, 4 to wheat, 2 to sweet clover, and 1 to barley. The weed population was considerably affected

by the type of crop grown the preceding year. Fields uncultivated the previous season had an average of 20 species per field, 12 of which occupied places of importance in one or more of the first three classes. Those previously in oats averaged 19 species per

Fig. 6.—A single plant of *Amaranthus retroflexus* growing in a row of corn where it was not disturbed by the last cultivation. Its height is about 5.5 feet.

field, 10 ranking in the upper three classes, while those in corn averaged 15 weedy species with 9 in the classes 1 to 3.

The survey disclosed 64 species of weeds; the 49 most important are listed in table 12. Only 55 species, of which 36 were important, were found in cornfields the previous year. The fields in Lancaster county were studied during the four weeks following June 18 while those in Cedar county were examined after August 1.

Moisture was not a limiting factor to growth during June. Seedlings of *Setaria viridis* and *Amaranthus retroflexus* were abundant in fields which had not received the first cultivation. For example, a single square meter contained 1280 individuals of *Amaranthus*

Table 13.—Weeds of 21 oatfields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	*1*	*2*	*3*	*4*	*5*	*0*
			per cent			
Setaria viridis	29	10	43	10	0	8
Salsola pestifer	19	5	62	5	0	9
Rosa arkansana	14	14	38	10	0	24
Polygonum pennsylvanicum	14	10	43	14	0	19
Setaria lutescens	14	10	35	14	0	27
Ambrosia elatior	14	10	29	14	0	33
Salvia lanceolata	14	0	19	30	5	32
Cenchrus pauciflorus	14	0	14	0	0	72
Polygonum convolvulus	10	10	34	24	0	22
Oxalis stricta	10	10	10	10	10	50
Euphorbia dentata	10	5	24	10	0	51
Convolvulus arvensis	10	0	0	0	0	90
Apocynum sibiricum	5	5	24	14	0	52
Amaranthus retroflexus	5	0	53	29	0	13
Digitaria sanguinalis	5	0	14	0	0	81
Cannabis sativa	5	0	5	5	24	61
Xanthium commune	0	10	29	19	0	42
Lepidium virginicum	0	5	25	10	0	60
Convolvulus sepium	0	5	24	10	0	61
Helianthus annuus	0	5	19	29	24	23
Echinochloa crusgalli	0	5	14	19	0	62
Solanum rostratum	0	5	14	10	10	61
Strophostyles pauciflora	0	5	10	5	0	80
Ambrosia trifida	0	5	0	10	0	85
Chenopodium album	0	0	90	10	0	0
Physalis lanceolata	0	0	77	5	0	18
Euphorbia maculata	0	0	58	24	0	18
Asclepias syriaca	0	0	24	38	0	38
Brassica nigra	0	0	19	14	10	57
Physalis heterophylla	0	0	19	5	0	76
Lygodesmia juncea	0	0	14	10	0	76
Polygonum aviculare	0	0	14	10	0	76
Lactuca scariola	0	0	10	24	0	66
Kochia scoparia	0	0	10	5	0	85
Amaranthus graecizans	0	0	5	14	5	76
Portulaca oleracea	0	0	5	10	10	75
Erigeron canadense	0	0	5	10	10	75
Verbena stricta	0	0	5	5	5	85
Allionia nyctaginea	0	0	5	0	10	85
Panicum capillare	0	0	0	19	0	81
Verbena bracteosa	0	0	0	14	5	81
Tragopogon pratense	0	0	0	14	0	86
Eragrostis cilianensis	0	0	0	14	0	86
Euphorbia marginata	0	0	0	5	10	85

retroflexus 1.5 inches tall. A new growth of seedlings appeared immediately after each cultivation. Tillage retarded development of perennials (e.g., *Rosa arkansana* and *Apocynum sibiricum*), as was shown by their reduced size. *Physalis lanceolata* produced new plants from broken rhizomes, and its seedlings were also abundant.

Weeds of fields in Cedar county which were disturbed by the last cultivation had recovered, and a new stand of seedlings also developed. The moisture supply was adequate and all vegetation made excellent growth. Maize varied in height from 7.5 to 9.5 feet in August. The overlapping leaves produced considerable shade. *Amaranthus retroflexus* was often 5 feet tall and the complete spread of foliage equaled the height, fig. 6. A month later some of the larger plants were 6.5 feet tall and the spread of foliage was often 9.5 feet. Plants of *Convolvulus sepium* climbed upward 7 to 8 feet on cornstalks, causing them to bend to the ground. *Cenchrus pauciflorus* was more common on dry hillsides and in the thinner stands of corn. The prostrate stems of this xeric grass, which roots at the nodes, often formed growths 6.5 feet in diameter, and produced as many as 400 fruiting spikes. *Euphorbia maculata* is a tolerant species which formed prostrate mats frequently 2 feet in diameter. *Portulaca oleracea* had also made a rapid growth despite a reduced supply of light.

Only three of the annuals encountered, *Ambrosia trifida, Bidens frondosa* L., and *Boebera papposa* Rydb., were rarely observed. They were never dominant in any type of crop. The dried plants of two winter annuals, *Sisymbrium altissimum* L. and *Sophia pinnata,* were occasionally found. Ten perennials of little importance occurred: *Acerates angustifolia, Cirsium altissimum, Euphorbia cyparissias* L., *Grindelia squarrosa, Helianthus tuberosus, Kuhnia glutinosa, Medicago sativa, Rumex altissimus, Verbena stricta,* and *Vernonia baldwinii.* Of these, *Helianthus tuberosus* is often troublesome in moist places, but most of the species were those common to overgrazed pastures or found along roadsides.

Weeds in Fields of Oats.—The 21 fields of oats contained 57 species of weeds, 4 less than the preceding year. The five high-ranking weeds were: *Setaria viridis, Salsola pestifer, Rosa arkansana, Setaria lutescens,* and *Polygonum pennsylvanicum,* table 13. The 10 fields located in Lancaster county were studied before harvest, but the remaining 11 in Cedar county after the oats had been cut.

Oats in Lancaster county usually produced a complete foliage cover. Mature plants averaged 32 to 40 inches in height, being always 4 to 6 inches taller on low ground. An understory, 4 inches tall, of *Amaranthus retroflexus, Setaria viridis, S. glauca,* and *Oxalis stricta* was present where there was sufficient light. Numerous annuals and most of the perennials were able to thrive. Height growth of *Lactuca scariola, Helianthus annuus, Chenopodium album,* and *Polygonum pennsylvanicum* equaled that of the oats, and *Apocynum sibiricum* and *Asclepias syriaca* were often 4 to 6 inches taller. *Rosa arkansana* continued to develop normally.

Numerous seedlings of *Digitaria sanguinalis* were observed about the middle of July. Twining weeds were not retarded and areas of several square meters often consisted of tangled mats of *Convolvulus arvensis, C. sepium,* or *Polygonum convolvulus.*

The study of the harvested fields began August 1. Weeds had recovered from the effects of cutting and many were 10 to 16 inches high. Numerous annuals, normally 2 or more feet tall, were producing seeds, although reduced in height to only 4 to 6 inches. Plants of *Amaranthus retroflexus* only 1.5 inches tall were in fruit. *Salsola pestifer* had made a rapid growth on high, dry soil where it was not crowded. Its taproot supports numerous laterals which may attain a spread of 17 feet (Pavlychenko & Harrington 1935).

Rosa arkansana, because of its habit of branching from the base of the stem, was recovering, but the growth of *Asclepias syriaca* and *Apocynum sibiricum* was noticeably retarded. Rape had been sowed with the oats in four fields. It made a rapid growth after the oats were cut, and the shade produced by its broad leaves was distinctly detrimental to many annuals.

Of the 21 oatfields, 11 had previously been planted to corn, 6 to small-seeded legumes, and 4 to oats. Fields previously in corn had an average of 20 species of weeds, with only 12 in the three higher ranks. Those cropped to legumes and oats averaged 21 species with 15 in the three upper ranks. These data indicate that cultivated crops were of much value in decreasing both the number of species and the importance of the weed population.

The number of minor annuals, compared to those of 1934, was small, consisting only of *Abutilon theophrasti, Bidens frondosa, Hibiscus trionum,* and *Iva xanthifolia. Oenothera biennis,* the only biennial observed, usually was found near the margins of fields. This roadside weed produces many seeds which germinate moderately well (Blake 1935). Minor perennials seldom seen included *Allionia hirsuta, Convolvulus arvensis, Glycyrrhiza lepidota, Grindelia squarrosa, Polygonum muhlenbergii, Rumex crispus, Silphium laciniatum,* and *Solanum carolinense.* Three of these, *Convolvulus arvensis, Polygonum muhlenbergii,* and *Solanum carolinense,* reproduce vegetatively and are usually very noxious.

Weeds in Fields of Wheat.—Eight fields of fall wheat were studied before harvest. The stands were moderately heavy, and the mature plants varied in height from 33 to 44 inches. In small areas where wheat was absent, sunflowers and smartweeds were sometimes 42 inches tall, but where the crop was drilled few were able to survive. Heavy infestations of black stem-rust (*Puccinia graminis*) appeared during the latter part of the growing season.

These fields supported 54 species of weeds, compared to only 38 found in 1934. The five most important were *Convolvulus arvensis, Digitaria sanguinalis, Apocynum sibiricum, Xanthium commune,* and *Amaranthus retroflexus,* table 14. Weeds showing high percentages of occurrence were *Physalis lanceolata* and *Chenopodium album,* each common in 88 per cent of the fields, *Polygonum pennsylvanicum* in 77, and *Rosa arkansana* in 76 per cent.

Table 14.—Weeds of 8 wheat fields, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	*1*	*2*	*3*	*4*	*5*	*0*
			per cent			
Convolvulus arvensis	50	0	0	0	0	50
Digitaria sanguinalis	25	13	25	0	0	37
Apocynum sibiricum	25	0	38	13	0	24
Xanthium commune	25	0	0	0	0	75
Amaranthus retroflexus	13	13	50	0	0	24
Polygonum pennsylvanicum	13	13	38	13	0	23
Rosa arkansana	13	0	50	13	0	24
Helianthus annuus	13	0	38	0	13	36
Salsola pestifer	13	0	13	25	0	49
Asclepias syriaca	0	13	50	0	0	37
Polygonum convolvulus	0	13	38	13	0	36
Lepidium virginicum	0	13	38	0	0	49
Lactuca scariola	0	13	25	13	0	49
Physalis lanceolata	0	0	88	0	0	12
Chenopodium album	0	0	75	13	0	12
Euphorbia maculata	0	0	63	13	0	24
Setaria lutescens	0	0	50	0	0	50
Ambrosia elatior	0	0	38	38	0	24
Setaria viridis	0	0	38	0	0	62
Polygonum muhlenbergii	0	0	38	0	0	62
Oxalis stricta	0	0	25	38	13	24
Erigeron canadense	0	0	25	25	0	50
Kochia scoparia	0	0	25	13	0	62
Portulaca oleracea	0	0	13	38	0	49

Hail injured crops in two fields several weeks before they were studied. The weeds were recovering but most of the wheat had died. *Lactuca scariola* and *Kochia scoparia* branched profusely at the ground level. *Erigeron canadensis* was often 2 feet tall and frequently possessed 30 to 40 branches which had arisen near the base after the injury by hail.

An unusually large number of weeds occurred sparingly. Annuals comprised the following list: *Amaranthus graecizans, Ambrosia trifida, Atriplex hastata, Boebera papposa, Cannabis sativa, Cenchrus pauciflorus, Eragrostis cilianensis, Euphorbia dentata, E. marginata, E. preslii, Echinochloa crusgalli, Hibiscus trionum, Hordeum jubatum, Polygonum aviculare, Salvia lanceolata, Solanum rostratum, Strophostyles pauciflora,* and *Verbena bracteosa.* The winter annual, *Thlaspi arvense,* and a single biennial, *Melilotus* sp., were observed. Perennials seen occasionally were *Acer-*

ates angustifolia, Carex pennsylvanicum, Convolvulus sepium, Glycyrrhiza lepidota, Grindelia squarrosa, Rumex crispus, R. altissimum, Solanum carolinense, Taraxacum officinale, and *Verbena stricta.* Many of these appeared only at the margins of the fields. Most of them are ordinarily found in overgrazed pastures, fence rows, and along roadsides, and are unable to persist under

Table 15.—Weeds of 10 fields of small-seeded legumes, in order of their importance, are designated as percentages in classes 1, 2, 3, 4, 5, respectively. Column 0 gives the percentage of fields in which the species did not occur.

SPECIES	*1*	*2*	*3*	*4*	*5*	*0*
			per cent			
Chenopodium album	20	10	60	10	0	0
Salsola pestifer	20	10	20	30	0	20
Echinochloa crusgalli	10	40	0	0	0	50
Amaranthus retroflexus	10	30	30	0	0	30
Polygonum pennsylvanicum	10	10	80	0	0	0
Xanthium commune	10	10	40	10	0	30
Setaria viridis	10	0	50	10	0	30
Apocynum sibiricum	10	0	40	40	0	10
Verbena bracteosa	10	0	10	10	0	70
Helianthus annuus	0	20	20	20	0	40
Rosa arkansana	0	10	40	10	0	40
Polygonum convolvulus	0	10	30	30	0	30
Oxalis stricta	0	10	10	50	0	30
Cannabis sativa	0	10	0	10	10	70
Physalis lanceolata	0	0	80	10	0	10
Lepidium virginicum	0	0	80	0	0	20
Lactuca scariola	0	0	60	30	0	10
Ambrosia elatior	0	0	40	40	0	20
Eragrostis cilianensis	0	0	40	20	0	40
Euphorbia maculata	0	0	40	20	0	40
Erigeron canadensis	0	0	30	40	0	30
Asclepias syriaca	0	0	30	20	0	50
Abutilon theophrasti	0	0	20	20	10	50
Salvia lanceolata	0	0	20	20	0	60
Convolvulus sepium	0	0	20	10	0	70
Kochia scoparia	0	0	20	10	0	70
Tragopogon pratensis	0	0	10	40	0	50
Euphorbia dentata	0	0	10	20	0	70
Euphorbia marginata	0	0	10	20	0	70
Solanum rostratum	0	0	10	10	10	70
Polygonum aviculare	0	0	0	30	0	70

cultivation. *Hibiscus trionum* and *Strophostyles pauciflora* are rare in cultivated fields but once established are very persistent. The former belongs to the Malvaceae, a family noted for the longevity of its seed. The second is a member of Leguminosae, whose seed are often delayed in germination because of their impermeable seed coats.

Weeds in Fields of Small-Seeded Legumes.—Among 10 fields of small-seeded legumes 8 consisted of sweet clover, 2 of which had been grazed, and 1 each of alfalfa and red clover. All were planted in the spring of 1934, and the soil had not since been disturbed. Surveys disclosed 51 weedy species, 31 being often observed, table 15. The five most important weeds were annuals:

Chenopodium album, Salsola pestifer, Echinochloa crusgalli, Amaranthus retroflexus, and *Polygonum pennsylvanicum.*

In the ungrazed, sweet clover fields, the foliage cover was continuous, the plants often having 7 to 13 stalks 6 to 6.5 feet in height. The effect of insufficient light was evident, since stems had shed their leaves to a distance of 20 inches from the ground. *Chenopodium album,* when present, had narrow leaves and spindling stems. *Salsola pestifer* occurred sparingly. It lacked its usual vigor and dark green color. *Lactuca scariola* was suppressed where sweet clover had gained an early advantage. *Apocynum sibiricum,* because of rapid growth in early spring, was often 4.5 to 5 feet tall. The twining *Convolvulus sepium* had climbed high into the light and made an excellent growth. The ground was devoid of seedlings as well as the usual understory of weeds, although the very tolerant *Oxalis stricta* was common. Numerous dried plants of *Lepidium virginicum,* a winter annual, had made their growth before light became a limiting factor. The topsoil was loose and dry, making a habitat unsuitable to young plants.

A larger number of important weeds was found in sweet clover fields that were grazed. *Chenopodium album, Salsola pestifer,* and *Xanthium commune* were avoided by the livestock and occupied the first rank in importance. *Echinochloa crusgalli* and *Setaria viridis* were much grazed and were consequently of little importance as a weed factor.

Reduced stands of alfalfa and red clover were correlated with an abundance of weeds. The alfalfa field had 19 species, those of greatest importance being *Amaranthus retroflexus* and *Setaria viridis;* the field of red clover was infested with 22 species, of which *Chenopodium album* and *Polygonum pennsylvanicum* ranked highest.

Numerous minor species including many pioneer colonizers were present. The annuals comprised *Amaranthus blitoides, Ambrosia trifida, Boebera papposa, Euphorbia preslii, Hibiscus trionum, Iva xanthifolia, Polygonum aviculare, Portulaca oleracea, Setaria lutescens,* and *Digitaria sanguinalis.* The biennial *Oenothera biennis* was present as usual. Perennials were as follows: *Cirsium altissimum, C. lanceolata, Convolvulus arvensis, Grindelia squarrosa, Glycyrrhiza lepidota, Lygodesmia juncea, Polygonum muhlenbergii, Verbena stricta,* and *Vernonia baldwinii.*

Weeds in Fields of Barley.—During the first two weeks of August, four fields of barley, totaling 200 acres, were studied. Harvest had been completed three weeks prior to the surveys. In some places the vegetation was 10 to 14 inches tall. Data from the several fields were not considered collectively because of vary-

ing conditions under which the barley grew. One upland field, consisting of 80 acres, had been infested with *Convolvulus arvensis* six years or more. A second upland field was planted to both barley and rape. The two remaining were situated on low, moist ground.

Where *Convolvulus arvensis* was abundant, all other vegetation was reduced in importance. Morning-glories were so dense in some places as to exclude all other weeds as well as the barley, but in areas of less infestation dwarfed *Convolvulus sepium, Setaria viridis, S. glauca,* and *Polygonum convolvulus* sometimes grew, although poorly.

Where barley and rape occupied the same field, weeds were greatly reduced in importance, since the broad leaves of the dicotyledonous plant produced much shade. Only few weeds were present in the moister parts of the field where both crop plants had made vigorous growth. In the drier areas, *Setaria viridis* was the most abundant species. *Chenopodium album, Salsola pestifer,* and *Euphorbia maculata* were common annuals, while perennials consisted of *Apocynum sibiricum, Physalis lanceolata, Rosa arkansana,* and *Cirsium arvense.*

The two fields on low ground supported 31 species. *Amaranthus retroflexus* alone was very abundant, but the plants were small, having grown after harvest. Annuals ranking as common included *Ambrosia elatior, Amaranthus retroflexus, Brassica nigra,* and *Salsola pestifer.* Representative perennials were *Physalis lanceolata* and *Apocynum sibiricum,* but they occurred only occasionally. The vigorous barley plants reduced the importance of the weed flora.

Weeds in Other Types of Fields.—Four fields of sorghum, representing approximately 80 acres, were examined, one in July and three in August. The preparation of the seedbed and the methods of cultivation were the same as those used for corn. Weeds of 29 species were found. *Amaranthus retroflexus* was present in all fields, but it occupied only the third and fourth rank in importance. *Salsola pestifer, Polygonum pennsylvanicum, Setaria viridis,* and *Xanthium commune* were common in three. *Physalis lanceolata* and *Rosa arkansana* were the two high-ranking perennials. *Equisetum arvense* L. was present in one field; its rhizomes bearing sterile plants were often 40 inches long.

Sorghum is a better competitor of weeds than is corn, largely because of its more efficient root system. Although the depth (6 to 7 feet) and lateral spread (3 to 4 feet) are about the same as that of corn, the main roots have twice as many branches. These branches are also finer and have more laterals (Miller 1916). Sorghum had apparently so completely exhausted the water

supply of the surface soil that only few weeds could ecize. Annuals established early in the season were very large, as was shown by sunflowers which were 8 feet tall. The height of *Chenopodium album* was often 6.5 feet. These large individuals usually grew in the sorghum row and were consequently harmed but little by tillage.

A field of soybeans, comprising 20 acres, was studied late in August. The tangle of vegetation, about 22 inches tall, had almost obliterated the rows, but the large number of weeds between the rows indicated that cultivation had been neglected. *Setaria viridis* was very important, often being 10 inches taller than the surrounding vegetation. Other common annuals included *Salsola pestifer, Amaranthus retroflexus,* and *Cenchrus pauciflorus. Physalis lanceolata* was the only perennial of importance.

Three of the 27 uncultivated fallow fields of 1934, representing 120 acres, remained uncultivated the following season. Results of the studies were comparable since they were made at approximately the same time both seasons. The average numbers of species per field for 1934 and 1935, respectively, were 24 and 21. Important species for the two years were generally similar in their rankings, although several showed fluctuations. Those of greater importance the second year were *Helianthus annuus, Setaria viridis,* and *Chenopodium album.*

Helianthus annuus was an excellent competitor because of its large leaves and efficient root system. Its size and amount of branching depended upon environmental conditions (Peralta 1935). Late in August plants under favorable conditions were 8 feet tall and 35 to 40 primary branches originated within 15 inches of the base. These, in turn, produced secondary branches, each of which bore 7 to 10 flowers. Many of the leaves presented a photosynthetic area of a square foot. Where the weeds were thick they were greatly dwarfed (cf. Weaver & Clements 1938). In some untilled fallow fields, 260 plants were sometimes present per square meter. The strong taproot reaches a depth of 9 feet under favorable conditions, and the total spread of the numerous laterals may exceed 9 feet. The root system is very efficient, a vigorous plant using 75 gallons of water in producing a pound of dry matter (Kiesselbach 1916).

Setaria viridis made rapid growth early in the season, its fibrous roots absorbing much water from the upper few inches of soil and thus making it difficult for other seedlings to become established. *Chenopodium album* made rapid early growth and thus became largely independent of other species. Its ability to absorb large amounts of water and nutrients was detrimental to the surrounding vegetation (Ince 1915). *Solanum rostratum,*

Xanthium commune, Salsola pestifer, and *Amaranthus retroflexus* were slightly less abundant in 1935. *Rosa arkansana* and *Physalis lanceolata* showed no fluctuation. Several minor species observed more often during the second year included those with wind-disseminated seeds, such as *Lactuca scariola, Erigeron canadensis,* and *Tragopogon pratensis.*

COMPARISON OF STUDIES OF 1934 AND 1935

Comparison of results obtained during the two seasons indicated that important weeds for each type of field were similar. Variations often occurred among the less important species.

Weeds in Fields of Corn.—Comparison of corn fields of 1934 with those of 1935 showed that the species of weeds numbered

Table 16.—Comparison of occurrence and importance (in classes 1, 2, 3) of 10 important weeds of cornfields.

SPECIES	1934 (31 FIELDS)		1935 (49 FIELDS)	
	PER CENT OCCURRENCE	PER CENT IMPORTANCE	PER CENT OCCURRENCE	PER CENT IMPORTANCE
Physalis lanceolata	92	89	98	92
Amaranthus retroflexus	87	64	88	68
Apocynum sibiricum	80	38	68	36
Setaria viridis	78	78	84	76
Rosa arkansana	73	57	78	62
Asclepias syriaca	70	29	60	22
Xanthium commune	67	35	66	50
Solanum rostratum	61	6	54	24
Convolvulus sepium	60	41	46	38
Cenchrus pauciflorus	52	39	54	46

55 and 64, respectively. The additional ones of the second year were largely species whose seeds had been disseminated by wind; viz., *Cirsium lanceolatum, Erigeron canadensis, Sisymbrium altissimum, Bidens frondosa,* etc. The stability of important weeds in cornfields was shown by their similarity of occurrence and importance, table 16.

Several annuals, in addition to those included in table 16, were decidedly more abundant in 1935. *Chenopodium album* was of minor importance in one-fourth of the cornfields of the first year, but the following season it occupied classes 1 to 3 in 70 per cent of the fields. *Polygonum pennsylvanicum* ranked in the two lower classes in 23 per cent of the fields in 1934, but the ensuing year in 74 per cent. Two grasses, *Echinochloa crusgalli* and *Setaria lutescens,* responded to the favorable conditions, since their importance increased 50 per cent. Prostrate *Euphorbia maculata* occurred in 50 per cent more fields, usually ranking in the common class. *E. preslii,* common in all fields in 1934, was rarely found in 1935. Sporadic appearance of weeds may often be due to high winds (Bolley 1895).

Table 17.—Comparison of occurrence and importance (in classes 1, 2, 3) of 10 important weeds of oatfields.

SPECIES	1934 (20 FIELDS)		1935 (21 FIELDS)	
	PER CENT OCCURRENCE	PER CENT IMPORTANCE	PER CENT OCCURRENCE	PER CENT IMPORTANCE
Polygonum pennsylvanicum	90	65	81	67
Physalis lanceolata	90	90	82	77
Rosa arkansana	85	80	76	66
Ambrosia elatior	85	35	67	53
Chenopodium album	85	60	100	90
Setaria viridis	85	85	92	82
Helianthus annuus	75	50	67	24
Salsola pestifer	75	50	91	86
Polygonum convolvulus	45	35	78	54
Brassica nigra	60	45	43	19

Marked fluctuations were not noticeable among perennials; *Asclepias syriaca, Convolvulus sepium,* and *Apocynum sibiricum,* however, were slightly reduced in importance during the second year, due to the vigorous growth of the corn. Other species of approximately equal importance for the two years were *Convolvulus arvensis, Polygonum muhlenbergii,* and *Physalis heterophylla. Rosa arkansana,* in contrast to most of the perennials, showed a slight increase in occurrence and importance in 1935.

Weeds in Fields of Oats.—Fields of oats had 61 and 57 species, respectively, in 1934 and 1935. A comparison of 10 important species of the two seasons showed that they varied considerably both in occurrence and importance, table 17.

Annuals more important under the favorable conditions of 1935, which were listed in table 17, include *Chenopodium album, Setaria viridis, Salsola pestifer,* and *Polygonum convolvulus.* Additional species were *Salvia lanceolata* and *Oxalis stricta.* The first, ordinarily a species of small importance, occurred in 67 per cent of the oatfields where it was sometimes in class 1. Tolerant *Oxalis stricta* grew well, being present in one-half of the fields of 1935 in comparison to 30 per cent the previous year.

Despite conditions of drought in 1934, certain annuals were

Table 18.—Comparison of occurrence and importance (in classes 1, 2, 3) of 10 important weeds of wheat fields.

SPECIES	1934 (7 FIELDS)		1935 (8 FIELDS)	
	PER CENT OCCURRENCE	PER CENT IMPORTANCE	PER CENT OCCURRENCE	PER CENT IMPORTANCE
Physalis lanceolata	86	43	88	88
Rosa arkansana	86	72	76	63
Apocynum sibiricum	71	28	76	63
Salsola pestifer	57	0	51	26
Helianthus annuus	58	29	64	51
Polygonum muhlenbergii	29	29	38	38
Lepidium virginicum	57	14	51	51
Ambrosia elatior	57	0	76	38
Euphorbia maculata	43	14	76	63
Polygonum pennsylvanicum	42	14	77	64

more important than in 1935. *Helianthus annuus* occurred in 8 per cent more fields and was 26 per cent greater in importance. *Brassica nigra* made a decidedly better growth during the first season. *Xanthium commune* occurred in 75 per cent of the oat-fields of the first year, but during the second was considerably reduced by the competing cereal. *Ambrosia elatior* also occurred more often the first year, but it never ranked above class 3.

Fig. 7.—Characteristic growth of smartweed, *Polygonum pennsylvanicum,* in low moist soil, and *Acnida tamariscina* on slightly higher land in background. Such weeds produce millions of seed which may germinate the following year when the ground is planted to wheat.

Physalis lanceolata, Rosa arkansana, and most of the perennials were of less importance in 1935, since thicker stands of oats afforded more competition.

Weeds in Fields of Wheat.—Comparison of fields of fall wheat of the two years showed that the species of weeds numbered 38 and 54, respectively, table 18. Only 12 species were important the first year. Of these, one had ranking in the very abundant class, 7 ranked no higher than the third class, and 4 were always in the two lower classes. The weed flora of 1935 had 24 important species with 9 sometimes ranking in class 1. All other weeds were of sufficient importance to hold rankings in class 3.

In 1934, the fall-planted cereal so completely reduced the scanty soil moisture that was available for plant growth in the first 4

inches (Noll 1938) that weed seeds were unable to germinate. Under the more normal environment of 1935, almost all weeds and especially *Helianthus annuus, Ambrosia elatior, Euphorbia maculata,* and *Polygonum pennsylvanicum* increased in importance, fig. 7. Certain annuals, including *Oxalis stricta, Setaria viridis,* and *Portulaca oleracea,* which were infrequent the first season, sometimes grew in one-half the wheat fields of the next season, often occupying ranks in class 3.

Apocynum sibiricum, Physalis lanceolata, and *Polygonum muhlenbergii* occurred in approximately the same percentage of fields each year but their importance was more pronounced during 1935.

Table 19.—Comparison of occurrence and importance (in classes 1, 2, 3) of 10 important weeds of legume fields.

SPECIES	1934 (12 FIELDS)		1935 (10 FIELDS)	
	PER CENT OCCURRENCE	PER CENT IMPORTANCE	PER CENT OCCURRENCE	PER CENT IMPORTANCE
Amaranthus retroflexus	100	59	70	70
Setaria viridis	91	91	70	60
Physalis lanceolata	91	83	90	80
Euphorbia maculata	91	83	60	40
Salsola pestifer	83	33	80	50
Helianthus annuus	83	66	60	40
Lepidium virginicum	33	33	80	80
Xanthium commune	74	33	70	60
Lactuca scariola	75	0	90	60
Chenopodium album	66	58	100	90

One-half of the fields of the second year contained bindweed, which always ranked in class 1. Its almost complete absence during the first year resulted from seeds never having been introduced into the fields rather than from competition of the cereal.

The vigorous growth of vegetation of 1935 slightly decreased both percentage of occurrence and importance of *Rosa arkansana. Lepidium virginicum* occurred in approximately the same number of fields each year but its importance was greater during the second season.

Weeds in Fields of Small-Seeded Legumes.—Weeds in fields of legumes during the two seasons numbered 60 and 51 species, respectively. The species were similar but their importance varied. Although the fields for the two years were identical, growing conditions differed widely. In 1934 the soil was cultivated and planted, but many seeds did not germinate until after fall rains. Consequently, weeds suffered very little competition from the crop. The following spring, moisture was plentiful, the soil was not disturbed, and the established crop made an excellent growth. A comparison of the percentages of occurrence and importance of 10 important weeds of legume fields is given in table 19.

Annuals, with two exceptions, comprised the most important species. Several species declined in 1935. *Lactuca scariola* and *Chenopodium album,* however, were two very apparent exceptions, since these moderately tolerant plants had made a rapid growth early in the season before light became a limiting factor. Only one perennial, *Physalis lanceolata,* occupied a place among the 10 most important weeds. Its remarkable ability to adapt itself to all situations caused it to rank high in all types of fields. Most of the plants of *Lepidium virginicum* were dry and brown. They completed their growth before light and moisture became limiting factors.

WEEDS CLASSIFIED ACCORDING TO OCCURRENCE AND IMPORTANCE

The greater number of weeds of importance were found associated to some extent with all crops, yet many of them were especially stimulated or suppressed by one crop or another. An analysis of their percentages of occurrence and importance in the first three classes showed that weeds stimulated or suppressed by crops fall into the following distinct groups:

1. Weeds of equal importance in various crops
2. (a) Weeds especially associated with corn
   (b) Weeds suppressed by corn but of equal importance in other crops
3. (a) Weeds especally associated with wheat
   (b) Weeds suppressed by wheat but of equal importance in other crops
4. Weeds especially associated with oats
5. Weeds especially associated with legumes.

Weeds of Equal Importance in Various Crops.—Six species were of approximately equal importance in all crops. These were *Physalis lanceolata, Apocynum sibiricum, Rosa arkansana, Asclepias syriaca, Euphorbia maculata,* and *Convolvulus arvensis.* Five were perennials with extensive root systems which enabled them to grow in unfavorable environments. They were, therefore, not greatly affected by the type of crop, table 20.

Table 20.—Weeds that were of approximately equal importance in all crops. Column O percentage occurrence; I, percentage importance.

Species	Corn		Wheat		Oats		Legumes	
	O	I	O	I	O	I	O	I
Physalis lanceolata	90	94	87	66	86	83	91	82
Apocynum sibiricum	74	37	74	46	54	27	75	42
Rosa arkansana	76	60	81	67	81	73	59	50
Asclepias syriaca	65	26	46	37	59	15	63	15
Euphorbia maculata	57	44	60	39	76	54	76	62
Convolvulus arvensis	23	23	32	32	13	13	23	23

The common ground cherry (*Physalis lanceolata*) ranked highest of all in both occurrence and importance, while the second most ubiquitous species was *Rosa arkansana*. Its taproot penetrates to a depth of 15 to 21 feet (Weaver 1926); hence, only rarely was it affected by a deficiency of moisture. *Asclepias syriaca* and

Table 21.—Weeds especially associated with corn. Column O, percentage occurrence; I, percentage importance.

Species	Corn		Wheat		Oats		Legumes	
	O	I	O	I	O	I	O	I
Echinochloa crusgalli	64	41	15	13	44	22	33	25
Cenchrus pauciflorus	53	48	7	7	33	27	12	12
Portulaca oleracea	53	24	40	14	25	5	9	5
Convolvulus sepium	53	40	14	7	47	30	32	27

Apocynum sibiricum, because of their deep root systems, were also independent of cultivated crops. Their importance was less than that of *Rosa arkansana,* since they produce only a single stem from each node. *Euphorbia maculata,* in general, was indifferent to the type of crop, although it appeared to show a slight preference for oats and legumes. Its enormous seed production in conjunction with its tolerance accounted for its abundance.

Weeds Especially Associated with Corn.—Of the 64 weeds which occurred in corn, only three annuals and one perennial were especially significant. They were *Echinochloa crusgalli, Cenchrus pauciflorus, Portulaca oleracea,* and *Convolvulus sepium,* table 21. Their importance was more apparent after the last cultivation. Seeds of these species germinated later than those of most weeds. The number of seedlings, therefore, was not

Table 22.—Weeds suppressed by corn but of approximately equal importance in other crops. Column O, percentage occurrence; I, percentage importance.

Species	Corn		Wheat		Oats		Legumes	
	O	I	O	I	O	I	O	I
Chenopodium album	47	16	80	38	93	75	83	74
Helianthus annuus	29	14	61	40	71	37	72	53
Polygonum pennsylvanicum	48	29	60	39	86	66	79	75
Ambrosia elatior	30	9	67	19	76	44	73	28
Polygonum convolvulus	21	6	39	26	62	45	68	49
Lepidium virginicum	9	10	54	33	30	23	57	57
Oxalis stricta	0	0	45	13	40	25	64	27

reduced by cultivation. The soil is likely to contain many seeds of *Portulaca oleracea* since a single plant produces 52,300 seeds (Stevens 1932) which may retain their vitality 40 years (Darlington 1922). *Cenchrus pauciflorus* was more often present on the well drained uplands and especially slightly sandy soils, while *Echinochloa crusgalli* was largely confined to lower and

moister places. *Convolvulus sepium,* which propagates both vegetatively and by seed, was enabled by its twining habit to secure sufficient light and suffered little from competition for radiant energy.

WEEDS SUPPRESSED BY CORN BUT OF EQUAL IMPORTANCE IN OTHER CROPS.—Six annuals and one winter annual were reduced in importance in the presence of corn, table 22. They were *Chenopodium album, Helianthus annuus, Polygonum pennsylvanicum, Ambrosia elatior, Polygonum convolvulus, Lepidium virginicum,* and *Oxalis stricta. Chenopodium album* and *Polygonum pennsylvanicum* were dominant and important species associated with other crops, but with corn their occurrence was reduced to 47 and 48 per cent, respectively, and their importance to 16 and 29 per cent. *Helianthus annuus,* while rarely as important as the two preceding species, was reduced to a comparable degree. *Ambrosia elatior* exhibited occurrence and importance of 70 and 30 per cent, respectively, in all fields except corn, where it was 30 and 9. *Polygonum convolvulus* appeared less frequently and its percentage of importance was low. *Oxalis stricta* failed to appear, although it was well distributed through all other crops. *Lepidium*

Fig. 8.—Characteristic growth of a single plant of *Digitaria sanguinalis.* This clump, about 2 feet tall and 4 feet in diameter, has grown almost without competition. September 1934.

virginicum, a winter annual, had been largely destroyed during the preparation of the seedbed.

Weeds Especially Associated with Wheat.—Only two weeds, perennial smartweed (*Polygonum muhlenbergii*) and crabgrass (*Digitaria sanguinalis*), were especially associated with wheat, table 23. The former grows in habitats with excess moisture

Table 23.—Weeds especially associated with wheat. Column O, percentage occurrence; I, percentage importance.

SPECIES	CORN		WHEAT		OATS		LEGUMES	
	O	I	O	I	O	I	O	I
Polygonum muhlenbergii	18	15	34	34	13	10	13	9
Digitaria sanguinalis	6	6	46	39	20	20	18	8

either on low ground or poorly drained uplands. Reproduction occurs largely from rhizomes and few seeds are produced. Seedlings of *Digitaria sanguinalis* were first observed in abundance shortly before harvest. These were most abundant where stands of wheat were thin. In late August the purplish colored spike-like racemes were conspicuous in stubble fields about Lincoln but were rare in Cedar county, fig. 8.

WEEDS SUPPRESSED BY WHEAT BUT OF EQUAL IMPORTANCE IN OTHER CROPS.—Five species were especially suppressed by wheat. These were *Amaranthus retroflexus, Setaria viridis, Xanthium commune, Physalis heterophylla,* and *Convolvulus sepium,* table 24.

Table 24.—Weeds suppressed by wheat but of approximately equal importance in all other crops. Column O, percentage occurrence; I, percentage importance.

SPECIES	CORN		WHEAT		OATS		LEGUMES	
	O	I	O	I	O	I	O	I
Amaranthus retroflexus	88	66	45	45	76	54	85	65
Setaria viridis	81	77	26	26	89	84	81	76
Xanthium commune	67	43	20	13	66	40	72	47
Physalis heterophylla	38	19	0	0	38	25	8	0
Convolvulus sepium	53	40	14	7	47	30	32	27

Amaranthus retroflexus and *Setaria viridis,* which while very abundant in most crops, were greatly reduced, occurring in only 45 and 26 per cent of the wheat fields, compared with 88 and 81 per cent in fields of corn. *Xanthium commune* and *Convolvulus sepium,* although never as important as the two species previously mentioned, were proportionately reduced. *Physalis heterophylla,* comparatively unimportant in all other types of crops, was never observed in wheat.

Fall wheat and seeds of annual weeds germinated at the same time but most of the weeds were frozen. Annuals germinating

in the spring were unable to compete with the established wheat; hence, the number was much reduced.

Weeds Especially Associated with Oats.—The weed flora of oat fields contained representatives of almost all arable weeds. Fourteen species had an average importance of 57 per cent in 60 per cent of the fields. Four weeds, *Salsola pestifer, Brassica nigra, Setaria lutescens,* and *Salvia lanceolata,* were especially successful competitors of oats, table 25.

Table 25.—Weeds especially associated with oats. Column O, percentage occurrence; I, percentage importance.

Species	Corn		Wheat		Oats		Legumes	
	O	I	O	I	O	I	O	I
Salsola pestifer	54	21	54	13	83	68	82	42
Brassica nigra	6	0	0	0	52	32	0	0
Setaria lutescens	54	47	25	25	64	55	27	22
Salvia lanceolata	24	8	13	7	59	27	45	23

Since oats are planted in the spring immediately after the cultivation of the soil, the seeds of the weeds and the crop germinate simultaneously. If the oats become well established they grow rapidly and retard the weeds, but if the season is unfavorable, as in 1934, weeds gain control and greatly reduce the cereal. *Salsola pestifer* owes its success both to its ability to resist drought and to the production of large numbers of seeds which remain viable several years. It is a tumbleweed of large size, which scatters its seeds widely. Rapid growth after harvest soon increased its importance. *Brassica nigra* is a winter annual which makes a rapid growth in the early spring. It blossoms so early that in late June the infested fields were often a golden yellow. The crop of oats and the mustard seed mature at the same time, consequently threshed grain often contains a high percentage of seed of this weed. It is usually returned to the soil when oats are planted. Seed of black mustard retain their viability for a period of 40 years (Darlington 1922). Oats did not appear to suppress any particular weedy species, since those which were of small importance in oats were also unimportant in all crops.

Table 26.—Weeds especially associated with legumes. Column O, percentage occurrence; I, percentage importance.

Species	Corn		Wheat		Oats		Legumes	
	O	I	O	I	O	I	O	I
Oxalis stricta	0	0	45	13	40	25	64	27
Lactuca scariola	11	2	33	19	37	5	83	30
Erigeron canadensis	6	1	25	13	18	3	69	15
Verbena bracteosa	3	0	24	7	20	3	36	14

Weeds Especially Associated with Legumes.—Four species, seldom of much importance in any crop, were more often present among legumes, table 26. Here conditions were suitable for the tolerant *Oxalis stricta. Lactuca scariola* and *Erigeron canadensis* were often present especially in 1935, since their very light seeds, introduced by wind, had a chance to germinate in the undisturbed soil. The abundance of *Verbena bracteosa,* a common weed of undisturbed waste places and run-down pastures, is attributed to its enormous seed production and its drought resistance. A single plant of this prostrate annual may produce as many as 10,620 seeds (Stevens 1932).

Fig. 9.—A field of corn, on rather wet lowland, badly infested with almost a pure stand of *Acnida tamariscina.* The crop was scarcely worth harvesting although an adjoining native bluestem meadow yielded 3 to 4 tons of hay per acre. October 1935.

STUDIES DURING 1936

Effect of Drought upon Weed Population.—The most severe drought ever recorded in the middle west occurred in 1936. It provided an unparalleled opportunity to study the effect of a scanty water supply upon the weed flora. The effect of the drought of 1934 upon the native vegetation of the region has already been described by Weaver, Stoddart & Noll (1935). The early spring of 1936 was cold and dry, but May had unusually high temperatures and nearly normal rainfall. Small grains were in good condition and corn grew rapidly, but large numbers of weeds also appeared. Extremely high temperatures and very meager precipi-

tation during July retarded the growth of all vegetation and finally caused its deterioration. Reduction in yield of the small cereals was marked, in fact most crops were not worth the expense of harvesting. Since the ears did not fill, most of the corn was cut for fodder or ensilage, fig. 9. The vivid description given by Weaver of the midsummer drought of 1934 will serve also to picture conditions existing in 1936.

> No rain fell; clouds were rare, in fact during the latter half of the period they seldom formed. The light was intense, the dust-filled, yellow western sky in evening portending another day of drought. The hot southerly winds blew as from a desert; drought that had bleached the green hilltops to patches of brown alternating with white, now crept down the slopes. In pastures and fields great cracks had formed in the soil . . .

These studies were begun July 15 and continued until October. Forty fields comprising 21 cornfields, 8 of wheat, 7 of oats, 3 of sweet clover, and 1 of barley were fully examined during the most intense drought and again after fall rains.

Effect upon Weeds in Fields of Corn.—Corn plants on July 15 were generally dwarfed and lacked the usual dark green color. Many of the basal leaves were killed and dried by the heat. They were then torn by the wind from the parent plant and lodged in great numbers against fences. The small size of both corn and weeds greatly reduced the foliage cover. There were no weed seedlings; many fields were entirely devoid of annual plants, and the upper few inches of the soil were air dry, loose, and dusty. A survey of 21 fields disclosed only 37 weedy species, a small number in comparison with the 54 and 65 of the two previous years. Eleven of the 22 important species were perennials.

Five perennials ranked moderately high in occurrence in spite of the lack of moisture. *Physalis lanceolata* was present in 95 per cent of the fields, *Rosa arkansana* in 80, *Apocynum sibiricum* in 70, *Asclepias syriaca* in 55, and *Convolvulus sepium* in 50 per cent. *Physalis lanceolata* continued to grow in 95 per cent of the fields, where it ranked in the common class in 75 per cent. The two annuals ranking highest were *Setaria viridis* and *Salsola pestifer*. The former, although present in half of the fields, was of little importance. Because of its reduced stature and poor condition, it was usually ranked in class 4. *Salsola pestifer* occurred in 55 per cent of the fields but its importance warranted its placement in the two lower classes only, as was true of most of the annual weeds.

Three perennials, *Cirsium arvense, Glycyrrhiza lepidota,* and *Verbena hastata,* were of little importance. Only one biennial, *Melilotus* sp., was noted. The following dwarfed annuals were seen occasionally: *Abutilon theophrasti, Ambrosia elatior, Canna-*

bis sativa, Echinochloa crusgalli, Eragrostis cilianensis, Euphorbia preslii, Helianthus annuus, Hibiscus trionum, Kochia scoparia, Portulaca oleracea, and *Digitaria sanguinalis.*

Effect upon Weeds in Fields of Wheat.—The weeds present in eight fields totaled 23, but only six were of common occurrence. All of the fields were observed after harvest except two where, because of their apparent poor yield, the crops were considered worthless. The wheat stubble presented marked contrast to the normal. The fields were brown, and the soil was dry and cracked. Only occasionally were there small patches of green, usually colonies of *Physalis lanceolata* or *Rosa arkansana.* These perennials were in 90 per cent of the fields, securing their water not from the surface 2 or 3 feet, but from deeper soil and subsoil (Nedrow 1937). Living annuals were seldom seen, but the dried foxtails and lamb's quarters gave evidence of their presence earlier in the season.

Effect upon Weeds in Fields of Oats.—Seven drought-stricken fields of oats in Cedar county were examined. A total of 26 species of weeds were present but only 11 were important. The two high-ranking perennials, as in fields of wheat, were *Physalis lanceolata* and *Rosa arkansana. Salsola pestifer* occurred in all fields but usually ranked in class three in importance. Only rarely was a weed placed in the abundant class, more often being only common or occasional. Skeleton weed (*Lygodesmia juncea*) was unaffected by drought, since its vertical taproot, which produces very few branches, often attains a depth of 20 feet (Weaver 1919). Plants observed at midday had a fresh, turgid appearance, and the very abundant pink blossoms contrasted sharply with the surrounding vegetation. The dried understory was even more conspicuous in the oat fields than in the wheat stubble.

Effect upon Weeds in Fields of Small-Seeded Legumes.—The fields of sweet clover, all of which had been planted the previous year, were studied the latter part of July. Plants varied in height from 20 to 45 inches and were often entirely leafless. Sweet clover is not only deeply rooted, sometimes drying the soil to a depth of 13 feet, but has horizontal branch roots which absorb at various levels (Myers 1936). Of the 16 weeds present, only three were important. They comprised one perennial, *Physalis lanceolata,* a winter annual, *Lepidium virginicum,* and one xeric annual, *Salsola pestifer.* Half-dried and weakened plants of *Chenopodium album, Polygonum convolvulus,* and *Helianthus annuus* were occasionally present where crop plants were sparse.

Summary of Drought Effects upon Weeds.—Both annual and perennial species showed the effects of drought, but especially the former. A direct relationship has been shown between the

depth of rooting of prairie plants and resistance to drought (Weaver, Stoddart & Noll 1935). This was also true for deeply rooted perennial weeds. Some suffered more than others, this usually being manifested in the reduction of their size and in the reduced number or absence of flowers and fruits. *Physalis lanceolata,* which occurred (usually in class 3) in all but two of the 40 drought-striken fields, was the most resistant to drought of all perennials. The deeply rooted *Rosa arkansana* ranked second; its reduced stature and the scarcity of flowers and fruits and the shedding of the lower leaves indicated that it had been affected to some extent. *Asclepias syriaca* and *Apocynum sibiricum* survived, but a reduced number of stems appeared from underground parts. In stubble fields, *Convolvulus arvensis* became dry and brown but in fields of corn it remained green although the leaves were often dwarfed, fewer, and unusually narrow.

The usual number of annuals was present at the beginning of the season but nearly all died before they produced seed. The dry brown understory in fields of cereals indicated their former presence. Several xeric annuals, including *Salsola pestifer* and *Cenchrus pauciflorus,* were unaffected and made an unusually vigorous growth. *Solanum rostratum* and *Kochia scoparia,* when present, were usually thriving. It appeared that most of the annual weeds were quite as sensitive to drought as were cultivated crops.

After 4 to 5 inches of precipitation from August 28 to September 5, the fields were again studied. Except for a general freshness of appearance of perennials, they showed no change. *Convolvulus arvensis* and *C. sepium* were exceptions. Despite the lateness of the season, growth was renewed from underground parts, and seedlings also were commonly observed.

The majority of annuals ecized very rapidly. For example, a single square meter in a field of oats contained 4800 foxtail seedlings. Seedlings of the mustards, since they are winter annuals, made a rapid growth. Certain weeds, including *Amaranthus retroflexus* and the Setarias matured seed at a height of only 3 inches.

FLORA OF ARABLE LAND

The weed flora of cultivated soil originates from two sources, native and introduced species. Even in the climax flora of a region there is a fluctuation in the number of both individuals and species, a phenomenon called annuation, due to changes in climatic and edaphic factors. Certain native plants become adapted to conditions of tillage and acquire the weed habit when natural vegetation is destroyed. Many of these have always been

Table 27, part I.—List of the common weeds of cultivated soil, arranged in three general groups.

*** plants of great importance
** plants of intermediate value
* weeds of minor significance

EQUISETACEAE	
	* Equisetum arvense L.
GRAMINEAE	
*** Cenchrus pauciflorus Benth.	* *Bromus secalinus* L.
*** *Digitaria sanguinalis*[3] (L.) Scop.	* *Bromus tectorum* L.
*** *Echinochloa crusgalli* (L.) Beauv.	* Distichlis spicata (L.) Greene
*** *Setaria lutescens* (Weigel) F. T. Hubb.	* *Eragrostis cilianensis* (All.)
*** *Setaria viridis* (L.) Beauv.	* Hordeum jubatum L.
* Aristida oligantha Michx.	* Panicum capillare L.
CYPERACEAE	
* Carex pennsylvanica Lam.	
URTICACEAE	
** *Cannabis sativa* L.	* *Urtica dioica* L.
POLYGONACEAE	
*** Polygonum muhlenbergii (Meisn.) Wats.	* Polygonum erectum L.
*** Polygonum pennsylvanicum L.	* Polygonum ramosissimum Michx.
** *Polygonum convolvulus* L.	* Rumex altissimus Wood
* Polygonum aviculare L.	* *Rumex crispus* L.
CHENOPODIACEAE	
*** *Chenopodium album* L.	* Atriplex hastata L.
*** *Salsola pestifer* A. Nels.	* *Chenopodium hybridum* L.
** *Kochia scoparia* (L.) Schrad.	
AMARANTHACEAE	
*** *Amaranthus retroflexus* L.	** Amaranthus graecizans L.
** Acnida tamariscina (Nutt.) Wood	* *Amaranthus hybridus* L.
** Amaranthus blitoides S. Wats.	
NYCTAGINACEAE	
** Allionia hirsuta Pursh	** Allionia nyctaginea Michx.
PORTULACACEAE	
*** *Portulaca oleracea* L.	
CRUCIFERAE	
*** *Brassica nigra* (L.) Koch.	* Sophia pinnata (Walt.) Howell
** Lepidium virginicum L.	* *Thlaspi arvense* L.
* *Sisymbrium altissimum* L.	
ROSACEAE	
*** Rosa arkansana S. Wats.	
LEGUMINOSAE	
**Glycyrrhiza lepidota Nutt.	* Psoralea floribunda Nutt.
* Meibomia illinoensis (A. Gray) Kuntze	* Strophostyles pauciflora (Benth.) Wats.

[3] Only introduced species are italicized.

Table 27, part II.—List of the common weeds of cultivated soil, arranged in three general groups.

*** plants of great importance
** plants of intermediate value
* weeds of minor significance

OXALIDACEAE

** Oxalis stricta L.

POLYGALACEAE

* Polygala verticillata L.

EUPHORBIACEAE

*** Euphorbia maculata L.
** Euphorbia dentata Michx.
** Euphorbia marginata Pursh
** Euphorbia preslii Guss.
* *Euphorbia cyparissias* L.

MALVACEAE

** *Abutilon theophrasti* Medic.
* *Hibiscus trionum* L.

ONAGRACEAE

** Oenothera biennis L.
* Gaura biennis L.
* Gaura parviflora Dougl.

APOCYNACEAE

*** Apocynum sibiricum Jacq.
* Acerates angustifolia (Nutt.) Dec.

ASCLEPIADACEAE

*** Asclepias syriaca L.

CONVOLVULACEAE

*** *Convolvulus arvensis* L.
*** Convolvulus sepium L.
* *Ipomoea hederacea* Jacq.

VERBENACEAE

** Verbena bracteosa Michx.
* Verbena stricta Vent.

LABIATAE

** Salvia lanceolata Willd.
* Teucrium canadense L.

SOLANACEAE

*** Physalis lanceolata Michx.
*** Solanum rostratum Dunal
** Physalis heterophylla Nees.
** Solanum carolinense L.
* *Solanum nigrum* L.

COMPOSITAE

*** Ambrosia elatior L.
*** Helianthus annuus L.
*** Xanthium commune Britton
** Ambrosia trifida L.
** *Cirsium arvense* (L.) Scop.
** Erigeron canadensis L.
** Iva xanthifolia Nutt.
** Kuhnia glutinosa Ell.
** *Lactuca scariola* L.
** Lygodesmia juncea (Pursh) D. Don.
** *Tragopogon pratensis* L.
* *Arctium lappa* L.
* Bidens frondosa L.
* Boebera papposa Rydb.
* *Cirsium altissimum* (L.) Spreng.
* Grindelia squarrosa (Pursh) Dunal
* Helianthus tuberosus L.
* Lactuca sagittifolia Ell.
* Silphium laciniatum L.
* Silphium perfoliatum L.
* *Taraxacum officinale* Weber
* Vernonia baldwinii Torr.

ruderals even in the native prairie where they quickly took possession of disturbed or denuded surfaces such as gopher mounds, eroded areas or places of deposit, etc. Extreme conditions of drought of 1934 and 1936 provided striking examples of the effect of changes in climatic factors upon native plants (Weaver & Albertson 1936). Among prairie species which have become ruderals are *Rosa arkansana, Asclepias syriaca, Apocynum sibiricum, Physalis lanceolata, Erigeron canadensis,* and *Ambrosia elatior.*

The introduced weed flora of North America is largely of European origin. As early as 1672 such immigrant species as dandelions, shepherd's purse, quack grass, and many others were flourishing in New England (Josselyn 1672). Darlington (1859) states:

> Most of the weeds troublesome in our agriculture are immigrants, either from the Old World, or the warmer portions of this continent. As the aborigines disappeared with the advance of the whites, so do the native plants generally yield their possession as cultivation extends, and the majority of plants to be met with along the lanes and streets of villages, and upon farms, are naturalized strangers, who appear to be quite at home, and are with difficulty to be persuaded or driven away.

Even at this early date he urged that measures for eradication should be taken against *Convolvulus arvensis.*

Man in his various pastoral, agricultural and commercial relations is the chief agent in providing conditions suitable to weed growth. The Indians not only disturbed the prairie by burning, but also aided in the transportation of species (Gilmore 1914). Early white settlers introduced numerous foreign plants with garden and crop seed. Cratty (1929) states: "From an ecological standpoint our immigrant flora is closely associated with the cultivated plants of our fields, pastures and gardens . . ."

The foreign and native species mingled and have been distributed so widely that some confusion exists as to their source. Among these may be mentioned *Equisetum arvense, Hordeum jubatum, Amaranthus blitoides, Lepidium apetalum,* and *Erigeron canadensis* (Shimek 1931).

That the weed flora of any region fluctuates from year to year has been shown by Muencher (1930). Of the 96 species encountered in this study, Aughey reported approximately one-half were present in Nebraska as early as 1875. A record of the 96 species of weeds present in the 100 cultivated fields may be of value in determining possible future changes of the weed flora. The species are grouped by families in table 27.

Of the 96 weeds listed, 63 are native to North America. The duration of the species is as follows: annual 48, winter annual 7, biennial 8, and perennial 33. The weeds represent 23 families of

flowering plants and one of earlier, spore-bearing habit (*Equisetum arvense*). The following families contain the largest number of species: Compositae, 22; Gramineae, 12; Polygonaceae, 8; Euphorbiaceae, 5; Solanaceae, 5; and Chenopodiaceae, 5; thus accounting for 57 of the 96 species.

DISCUSSION

Deep, fertile, cultivated soils provide an excellent habitat for weeds, and if they are not suppressed their importance increases rapidly. The weed population of 27 untilled fallow fields was greater and more diversified than that of any other type of field, consequently more seeds were returned to the soil. A single year of their unhampered growth results in great expense and labor in future cultivation and loss in crop yield.

One of the chief factors determining the importance of a weed is the amount of competition it is able to withstand successfully. The habits of growth of the various crops and the systems of cultivation employed directly affect the composition and importance of the weed flora.

The seedbed for corn is free of weeds before the maize is planted in regular, well-spaced rows. The seed of the crop and the weeds germinate simultaneously and growth of the corn would be greatly retarded if it were not for frequent cultivations. Certain annuals, including *Cenchrus pauciflorus* and *Portulaca oleracea*, germinate after the last cultivation and develop seeds before frost. Fewer species with lower percentages of importance occur in corn than in any other type of crop, hence the importance of a cultivated crop in a rotation system should be emphasized. Brenchley (1915) states:

> The continuous growth of cereals year after year does not permit of thorough cleaning of the land, and the danger arises that some weed that is quite insignificant under rotation will gain such a footing that serious damage is caused. The Broadbalk field at Rothamsted has been under wheat for over seventy years and is now infested with black bent (*Alopecurus agrestis*) to such an extent that even hand-pulling at great expense does not serve to eradicate it, and fallowing has had to be resorted to in order that summer cultivation may be carried out. When a weed threatens to take command of the situation to this extent a change in the rotation, or some alteration in tillage will often provide circumstances that are less favorable to the spread of the weed . . .

The time when the crop is planted and the conditions existing during the growing season greatly affect the importance of weeds. Fall-planted wheat and weed seeds germinate almost simultaneously. The annuals are frozen and the wheat competes only with perennials and annuals which germinate in the spring. When adequate moisture is available the wheat develops numerous

tillers, producing a thick stand. Certain weeds, as *Amaranthus retroflexus* and *Setaria viridis,* are intolerant of shade and as a result are of little importance in the crop.

Barley and oats are spring-planted cereals. If moisture is plentiful the weeds make little growth among these vigorous crop plants. This was shown by a dwarfed understory of *Polygonum pennsylvanicum, Setaria viridis,* and *Ambrosia elatior.* If, because of drought, the cereals grow slowly and tiller but little, certain drought-resistant weeds, such as *Salsola pestifer, Cenchrus pauciflorus,* and *Solanum rostratum,* make a rapid growth and greatly retard the crop. These results are in accord with those of Brenchley (1920). "If the season be unfavorable and a long drought prevents the corn from growing away strongly the weeds have a much better chance."

The continuous foliage cover and efficient root systems of well established plants of small-seeded legumes reduce the importance of most weeds. Certain tolerant species and those which make a rapid growth early in the spring develop normally. Sweet clover and alfalfa are examples of "smother crops" useful in weed eradication. A thick stand of rapidly growing crop plants competes with the weeds for water and light to such an extent that the tops are weakened and the roots are correspondingly less efficient. If moisture is not plentiful, newly seeded legumes are of little value in suppressing the weed flora.

The greater number of important weeds are present in all types of fields, but some species appear to be stimulated or suppressed by certain crops. Brenchley (1920) after detailed investigation concludes: "Whilst most weeds of any importance are to be found associated to some extent with every crop, yet many of them are specially encouraged or discouraged by one crop or another."

That special weeds are common among certain crops conforms to the idea of Muencher, who states: "These weeds, of what might be termed special habitats, are among the most noxious and difficult to control as long as the grower insists on continuing to raise the same type of crop on the infested land."

The potential weed flora, as indicated by the number of seedlings which appeared in soil samples, is very large. This is in agreement with the findings of Korsmo (1935) and Brenchley & Warington (1930). The number of seedlings varied greatly according to the kind of crop that was grown the previous year. Soil from fields which were idle for a single season contained twice as many weed seeds as those which were cropped.

Fallowing is a method often employed for eradication of weeds. From an economic point of view such a method is of value if the

number of weeds remains at a low level for several years. Brenchley & Warington (1936) found that certain weeds are reduced by fallowing and they reestablish themselves very slowly. In direct contrast, some species reestablish themselves very rapidly, becoming more abundant than before the fallow. It appears that weed reduction by fallowing is only of temporary value for some species and not worth the cost involved.

The severe drought affected *Rosa arkansana, Convolvulus arvensis,* and *Lygodesmia juncea* very slightly, since their root systems penetrate 20 feet or more into the subsoil (Weaver 1919, Kiltz 1930). A more complete knowledge of root systems of weeds would be of great value in relation to methods of eradication (Pavlychenko 1937).

During the great drought (1934-37), most of the annuals wilted and died without producing seed. In fact, seedlings were rarely observed. Similar conditions existed in the prairie (Weaver, Stoddart & Noll 1935). After rains in early September, many annuals appeared but, with the exception of *Convolvulus arvensis* and *C. sepium,* few perennials showed further development.

With widespread erosion control measures in progress throughout the United States, it is desirable that the importance of weeds as plant cover be considered. That weeds are of value in preventing erosion was clearly demonstrated by Kramer & Weaver (1936). "All weeds are of some value as soil conservers, many are extremely efficient. Remaining on the ground after maturity, they function during life and after death."

Numerous investigations show outstanding differences in the amount of runoff water and eroded soil from different systems of cropping and cultural practices (Duley & Miller 1923, Bennett 1935, Miller 1936). Row crops, such as corn and soybeans, kept free of weeds are not as valuable in preventing erosion as are drilled crops or native vegetation.

For a balanced viewpoint of the nature of weeds, the following quotation of Seitz is worth careful consideration.

> Weeds are the wound dressers of the soil. Whenever man or nature makes a scar, the vigorous, coarse-fibered weeds find the spot and straightway mend the injury. Hated and much objurgated, the weed, of whatever breed, is one of the most useful forces in nature. The farmer regards it as a foe, the gardener as a nuisance. In truth, it is a friend that persists, regardless of ill treatment and attempts at extirpation. Soil, to preserve its strength, must be protected with some sort of covering, otherwise the rains leach it, or wash away the precious particles of mold that make it productive. Man neglects this factor in his dealings with the earth. Plowed fields are allowed to go uncovered after the crop is harvested. Washouts are left to take care of themselves. So is burned-over land. In all three instances great damage results, and much more would follow but for the energy of the weed family.

SUMMARY

The weed flora of 100 tilled fields of eastern Nebraska was studied during three growing seasons. Fifty were near Lincoln and the remainder near Hartington, 150 miles north. They varied in size from 30 to 80 acres and totaled 5000 acres.

Studies were made to determine the relationship between weeds and cultivated crops; to ascertain the weed-seed content of arable soil; to observe the effect of extreme drought on the weed flora; and to provide a complete record of weeds of cultivated soil.

The area studied lies near the borderline between Prairie and Cernozem soils and includes part of each zonal soil group. The soil is rich in organic matter and mineral nutrients and extends to great depths.

Precipitation averaged 8.9 inches below the 27.8-inch mean during the three-year period. Water content of soil was gradually depleted during both 1934 and 1936. Late in July no water to a depth of 4 feet was available for plant growth. During 1935, available moisture was present at all depths until the latter part of August.

Temperatures during the growing season were unusually high. Summers of 1934 and 1936 were the driest and hottest ever recorded in Nebraska. Average day temperatures of 100° F or more continued 19 to 21 successive days.

During 1934, 27 untilled fallow fields, 31 cornfields, 20 fields of oats, 7 of wheat, 12 of small-seeded legumes, and 3 of barley were studied.

Weeds of each field were grouped into five classes according to their importance, i.e., abundance, size, density, duration, gregariousness, basal and foliage cover, and fruiting and seeding habits. Species in each type of field were arranged in order of their importance as indicated by percentage occurrence in each of the five classes.

Untilled fallow land often presented a complete foliage cover of weeds. While weeds protected the soil from the erosive forces of wind and water they also depleted it of moisture and contaminated it with many seeds.

A total of 66 species grew in untilled fallow fields. More species were present and their importance ranked higher than in any other type of field. *Setaria viridis,* the most important weed, occurred in 97 per cent and was very abundant in 78 per cent of the fields. *Salsola pestifer* ranked second in importance, occurring in 89 per cent. Other species, in order of their importance, were *Setaria lutescens, Helianthus annuus, Rosa arkansana, Solanum*

rostratum, Xanthium commune, Ambrosia elatior, Chenopodium album, and *Cenchrus pauciflorus.*

Nineteen of the 66 species were observed only once or twice during the surveys of the fallow fields. Several are roadside weeds and will not persist under cultivation.

Fields of corn in 1934 were abnormal because of drought. Corn is not a good competitor of weeds even when moisture is abundant and frequent cultivations are necessary. Fifty-five species were present in 31 fields. The five most important were *Convolvulus arvensis, Setaria viridis, Cenchrus pauciflorus, Rosa arkansana,* and *Amaranthus retroflexus.*

Certain weeds did not occur often, but when present they usually ranked in the higher classes. *Convolvulus arvensis* was present in only 32 per cent of the cornfields, but was of great importance since it grew at the expense of all other vegetation.

Oats are normally good competitors of weeds but the stand was poor in 1934 and mature plants were only 12 to 18 inches tall. Sixty-one species of weeds were listed in the 20 fields. *Setaria viridis* was the most important, ranking in class 1 in 60 per cent of the oat fields; *Helianthus annuus* occurred in 75 per cent. Weeds with an unusually high percentage of occurrence were *Physalis lanceolata, Polygonum pennsylvanicum, Rosa arkansana, Ambrosia elatior,* and *Chenopodium album.*

Seven fields of fall wheat contained 38 species, only 12 of which were of general occurrence. Most important were *Apocynum sibiricum, Rosa arkansana,* and *Physalis lanceolata.* Only *Apocynum sibiricum* ranked in class 1. The root system of wheat is well adapted to successful competition with weeds.

Weeds of minor importance consisted of 16 annuals and 9 perennials. Many were important when associated with crops other than wheat.

Spring-planted legumes were of little value in reducing the weed flora under the conditions of drought which prevailed. Ten fields supported a total of 60 species, 34 being of common occurrence. *Setaria viridis* occurred in 91 per cent of the fields and was very abundant in 50 per cent.

The potential weed flora of the soil was indicated by the number of seedlings which grew from soil samples. Samples of 12.6 square inches were secured to a depth of 6 inches. The soil was placed under conditions favorable to growth during June to July and again in the fall. The samples were taken in September from fields which had been under different cropping systems.

A total of 135 soil samples yielded 32 species of seedlings, mostly annuals. *Setaria viridis* ranked highest with 2526 plants. *Amaranthus retroflexus* yielded 752, *Setaria lutescens* 549, *Digi-*

taria sanguinalis 326, and *Chenopodium album* 109. Only three perennials, *Physalis lanceolata, Convolvulus arvensis,* and *Poa pratensis,* were represented.

Seeds of a few species germinated freely throughout the year; most seeds showed a definite periodicity, the majority of seedlings appearing during the spring and autumn.

Cropping systems influenced the number of weed seed. Thirty-six samples taken from oat fields averaged almost 15 million seedlings per acre. Approximately an equal number from cornfields yielded 13.5 million, but samples from untilled fallow fields yielded about 37 million seedlings per acre.

Low or medium low ground yielded larger numbers of seedlings than steep hillsides or hilltops.

During 1935, 49 cornfields, 21 fields of oats, 10 of small-seeded legumes, 8 of wheat, 4 each of barley and sorghum, and 3 untilled fallow fields were studied.

Surveys of 49 cornfields of the second year disclosed 64 weedy species. As a result of adequate moisture, a greater percentage of weeds occupied higher rankings than in 1934.

The type of crop grown the previous year affected both occurrence and importance of weeds. Thirteen cornfields that had borne the same crop the preceding year averaged 15 species with 9 in classes 1 to 3. Fields uncultivated the previous year averaged 20 species, 12 of which were in the upper 3 classes.

Oat fields of 1935 contained 57 weedy species, 4 less than the preceding year. The five high-ranking weeds were *Setaria viridis, Salsola pestifer, Rosa arkansana, Setaria lutescens,* and *Polygonum pennsylvanicum.* Species of high occurrence, usually ranking in the common class, were *Chenopodium album,* present in all fields, and *Physalis lanceolata* and *Euphorbia maculata,* present in 82 per cent.

Eight fields of fall wheat were infested in 1935 with 54 weedy species, compared with 38 the previous year. *Convolulus arvensis, Digitaria sanguinalis, Apocynum sibiricum, Xanthium commune,* and *Amaranthus retroflexus* were the most important.

Ten fields of small-seeded legumes examined in 1935 contained 51 weedy species. The most important included *Chenopodium album, Salsola pestifer, Echinochloa crusgalli, Amaranthus retroflexus, and Polygonum pennsylvanicum.*

Ungrazed sweet clover fields presented a continuous foliage cover 6.5 feet in height and contained fewer weeds than grazed fields. Species which approximated the height of the legumes were able to persist, although they were often spindling and unbranched.

Weeds which were especially vigorous in grazed sweet clover,

since they were avoided by the livestock, were *Chenopodium album, Salsola pestifer,* and *Xanthium commune.* The grazed *Echinochloa crusgalli* and *Setaria viridis* were rare.

Barley is an excellent competitor of weeds when grown under favorable environment. Thirty-one species appeared in 1935, but none ranked higher than the common class. Where rape is grown with barley, weeds are even more greatly reduced.

Certain weeds, such as *Amaranthus retroflexus, Setaria viridis,* and *Convolvulus sepium,* are especially adapted to corn. Each year they showed marked similarity in both occurrence and importance. Fluctuations were due, directly or indirectly, to water content of soil.

Fields of oats were infested with 61 and 57 weedy species, respectively, during two seasons. The weeds were similar but their percentages of occurrence and importance varied considerably because of dissimilar growing conditions. Despite the drought of 1934, certain annuals were more important than in 1935.

Fields of fall wheat contained 38 and 54 species of weeds during 1934 and 1935, respectively. Annuals were of greater importance during the second year. Perennials, in general, did not fluctuate; a few, however, were slightly retarded during the second year because of the vigorous growth of the cereal.

Conditions for growth during the two years differed widely in fields of legumes, and the weed flora varied accordingly. The weeds numbered 60 and 51 species, respectively. Spring-planted legumes under conditions of drought were of little value as competitors; however, well established fields under favorable conditions greatly reduced the weed flora.

Important weeds were found to some extent in all crops, but some weeds were stimulated by certain crops and suppressed by others.

Species which were usually of equal importance regardless of the cropping system were largely perennials. They included *Physalis lanceolata, Apocynum sibiricum, Rosa arkansana, Asclepias syriaca, Euphorbia maculata,* and *Convolvulus arvensis.*

Weeds suppressed by corn but of equal importance in other crops included *Chenopodium album, Helianthus annuus, Polygonum pennsylvanicum, Ambrosia elatior, Polygonum convolvulus, Lepidium virginicum,* and *Oxalis stricta.*

Only two weeds, *Polygonum muhlenbergii* and *Digitaria sanguinalis,* were especially associated with wheat.

Fall wheat suppressed the following weeds: *Amaranthus retroflexus, Setaria viridis, Xanthium commune, Physalis heterophylla,* and *Convolvulus sepium.*

Oats contained representatives of almost all weeds. It did not

appear to suppress any particular species, since those which were of small importance here were also unimportant in all crops.

Four species which grew better in oats than in other crops were *Salsola pestifer, Brassica nigra, Setaria lutescens,* and *Salvia lanceolata.*

Severe conditions of drought during 1936 affected the annuals to a greater degree than perennials.

Twenty-one drought-seared cornfields in 1936 supported 37 weedy species in comparison with the 54 and 65, respectively, of the two previous years. Eleven of the 22 most important species of 1936 were perennials.

Fields of wheat in 1936 contained only 8 species which were of common occurrence, oat fields had 11, while in sweet clover they were reduced to 3.

The most drought-resistant perennials, all very deeply rooted, were *Physalis lanceolata, Rosa arkansana, Asclepias syriaca, Apocynum sibiricum,* and *Convolvulus arvensis.*

Salsola pestifer, Cenchrus pauciflorus, and *Solanum rostratum,* all xeric species, were not affected by drought. Their large size and frequent occurrence indicated unusual vigor.

Autumnal rains resulted in the appearance of many annuals, there being sometimes thousands of seedlings of foxtail per square meter. Certain species, including *Amaranthus retroflexus, Setaria viridis,* and *S. glauca,* matured seed, although only 2 to 3 inches tall. Winter annuals, including several species of mustard, made a rapid growth.

The weed flora of 100 arable fields consisted of 96 species of 23 families of flowering plants and 1 of spore-bearing habit.

Of the 96 weeds, 48 are annuals, 33 perennials, 8 biennials, and 7 winter annuals. Sixty-three species are native to North America.

All weeds are of some value in decreasing soil erosion. They appear immediately after the preparation of the seedbed or following cultivation, as well as after the grain is harvested, and completely populate untilled fields.

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