BURIED WEED SEEDS.

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THE seeds of many species of plants have a habit of germinating in unexpected places under various conditions, and the question of the vitality of seeds is one that has frequently engaged the attention of scientists. It has often been claimed that seeds obtained from old pyramids and sepulchres have germinated when placed in favourable circumstances, but Becquerel[1] states that strict enquiry and experiment show that authentic seeds of such origin will *not* germinate, but that the seeds so obtained which do germinate have proved to be frauds inserted by the fellaheen for the sake of gain. Various writers (quoted by Becquerel) have claimed the power of germination for seeds buried for very long periods. Michelet claimed that seeds of *Galium anglicum*, buried 3000 years ago in the valley of Doubs, had retained their power of growth; von Heldreich, that *Glaucium Serpieri* from land covered by excavated scoriae 1500 years ago, was still viable; much doubt, however, has been thrown on the authenticity of such seeds.

Information of this kind is of comparatively little value as evidence, as there is no definite proof of the time at which the seed actually reached its position or of the way in which it was transported. More satisfactory evidence has been obtained by the attempted germination of seeds of known age by various observers. Becquerel quotes experiments in which 500 species of seeds were sown, some of which were nearly 200 years old. Only four families gave any germination, *Leguminosae*, *Nelumbiaceae*, *Malvaceae*, *Labiatae*.

Leguminosae. 18 species germinated out of 90 sown. Ages 28–87 years.
Nelumbiaceae. 3 species germinated. Ages 18–56 years.
Malvaceae. 1 species (*Lavatera pseudo-olbia*) germinated out of 15 sown. Age 64 years.
Labiatae. 1 species (*Stachys nepetaefolia*) germinated out of 14 sown. Age 77 years.

[1] Becquerel, P., "Recherches sur la vie latente des graines" *Ann. des Sci. Nat., Bot.* 1907, 5, pp. 193–311.

From 1840 to 1857 germination experiments were carried on by a committee appointed by the British Association, and the results were summarised in a series of reports. 220 species were very fully tested with the following results[1]:

Limit of years during which germinating capacity was retained	Number of species
43	1 (Leguminosae)
42	1 ,,
27	7 (5 Leguminosae, 1 Malvaceae, 1 Tiliaceae)
26	4
25	4
21	4
18	1
15	2
14	1
13	5
12	2
10	4
9	2
8	70
6	3
5	3
4	9
3	97

The table indicates that the majority of seeds retain their germinating capacity for comparatively few years, three years and eight years being the critical time for a large number of species. The seeds were kept under ordinary conditions of dry storage, and were representative of 67 natural orders. A few typical farm weeds were included:

	Years		Years
Hypericum hirsutum	3	Arctium Lappa	8
Plantago media	3	Daucus Carota	8
Conium maculatum	5	Nepeta Cataria	8
Fedia dentata	5	Rumex obtusifolius	8
Aethusa cynapium	8	Silene inflata	8
Anagallis arvensis	8	Vicia sativa	8

The length of time that seeds retain their germinating capacity has a very practical bearing on agriculture in connection with the vitality of the weed seeds that are buried in the soil and that are brought to the surface by cultivation. The conditions under which seeds exist when buried in the soil are utterly different from those of dry storage, and while some seeds are probably enabled to retain their germinating capacity for much longer periods when buried, others succumb at an early stage. Seeds in the soil are subject to fluctuating conditions of temperature, moisture,

[1] *British Association Reports*, 1850, pp. 160–168; 1857, pp. 43–56.

oxygen supply, etc. Becquerel[1] states that the resistance of seeds to low temperature depends solely on the quantity of water and gas in their tissues. If this quantity is sufficient the cold disorganises the protoplasm and nucleus, so killing the seeds, but if the protoplasm has attained by desiccation its maximum concentration and consequently its minimum of activity it completely escapes the action of low temperature and does not freeze, so that the seed retains its power of germination. If this be the case, immature seeds are likely to lose their power of germination quite soon after burial from the effects of cold, whereas mature seeds of the same species may be able to withstand the low temperature of winter for long periods of years. Vines[2] considered that long continued exposure to a not very low temperature proves fatal, and he stated that under ordinary circumstances starchy seeds retain their power of germination much longer than oily seeds. This latter statement is at variance with the commonly accepted idea, as it is usually considered that the oil in the seeds is of special assistance in the retention of vitality.

Under certain conditions the seeds of many species of plants are able to remain dormant in the soil for long periods, and to start into growth when they are brought to the surface by the processes of cultivation. The popular imagination often runs riot in this connection and stories are told of great crops of charlock, poppy and other weeds which appear when "old pasture" or "land which has never grown charlock before" is broken up. Careful enquiry usually shows that the "old pasture" was under tillage at no very distant date, or that the land that was supposed to be free from charlock has been ploughed rather more deeply than usual. Nevertheless, some evidence cannot be explained away thus, and much enquiry and experiment will be necessary before a full and satisfactory explanation is forthcoming. Similar reports come from other countries than England. Brulalette d'Abbeville[3] stated that alders appeared on some excavated soil although none had been known in the district for two centuries. According to Maquin-Tandon[3] soil that was thrown up in digging a canal at Toulouse was covered in two years with *Polypogon monspieliensis*, a plant which is lacking in Toulouse. Trochu[3] cites an instance in which sarrasin and millet came up when the soil was disturbed in an orchard which had been established for 10 or 12 years, the species having been originally sown as crops. In the same orchard, when trenches were dug to root prune the trees, heath and furze came up from

[1] *Loc. cit.*
[2] Vines, *Physiology of Plants.*
[3] Quoted by Becquerel, *loc. cit.*

seeds which must have been buried for 45 years, as at the time the field was cleared it was covered with these plants. When some new trees were planted 14 years later the same species reappeared, after burial for 59 years.

Peter[1] took samples of soil in forests of known anterior conditions at depths of 8, 16, and 25 centimetres. He found that the number of seeds which germinated diminished with the depth, and that at 25 centimetres the seeds were very scarce. Old forests only gave wood species, recent forests which had originally been prairie and field furnished some seeds characteristic of these situations.

The most abundant species were:

(1) *Juncus bufonius, J. conglomeratus, Sagina procumbens, Hypericum perforatum, Ranunculus repens, Plantago major, Gnaphalium uliginosum.*

(2) *Chenopodium polyspermum, Rubus Idaeus, Potentilla Tormentilla, Linaria Elatine, Centunculus minimus.*

Peter concluded that many of the seeds could retain their vitality for half a century.

Passerini[2] carried on germination experiments in pots with seeds of *Orobanche crenata* for 14 years, and found that the seeds lost practically all power of germination after lying in the soil for eight years.

Dorph-Petersen[3] carried out germination experiments with weed seeds in order to find out how long they retained their power of germination when buried in soil. *Thlaspi arvense, Sinapis arvensis, Geranium molle,* and *Malva vulgaris* often lay dormant for 6–12 years before germinating. It appeared that the rapidity of germination was affected by the length of time seeds were kept before planting, and also that ripe seeds had a higher germinating capacity and retained it longer than unripe seeds.

Pots containing 100 seeds of each of *Plantago lanceolata* and *Sinapis arvensis* were placed 12 ins. below the surface of ground in 1899, and each year after one pot was dug up and the seeds were allowed to germinate.

With *Plantago lanceolata* two-thirds of the seeds were dead by 1900 but 8 % still retained their germinating capacity after 10 years. In dry torage a similar lot of seeds kept their viability well for a few years, but all were dead in 10 years. With *Sinapis arvensis* the germinating

[1] Quoted by Becquerel, *loc. cit.*

[2] "Duration of vitality of seeds of *Orobanche crenata*," *Atti R. Accad. Econ. Agr. Geogr. Firenze,* Series 7, 1910, 5, No. 1, pp. 1–7.

[3] *Jahresb. der Vereinigung für angewandte Botanik,* 1910. Summarised in *Journ. Board Agric.* 1911, pp. 599–600.

capacity was as high (87 %) after ten years as after one year, whereas in dry storage it was reduced to 82 % in one year and to 24 % in 10 years.

In these two cases it is evident that the conditions of burial are more conducive to the retention of germinating capacity than are those of dry storage. This provides a connecting link between the popular idea that charlock seeds can remain dormant in the soil for many years and the results obtained by the British Association Committee, in which species of Brassica kept in dry storage lost their power of germination in a very few years (*B. napus* eight years, *B. rapa* eight years, *B. oleracea* three years).

Dorph-Petersen also tested the effect of depth of burial by placing weed seeds 3 ins., 6 ins. and 12 ins. below the surface. The trials lasted for six years and showed that seeds placed at the greatest depths retained their germinating capacity best. The seeds of cultivated plants, especially grasses, died much more quickly in soil than did the related weed seeds.

Since August, 1915, experiments have been carried on at Rothamsted to test the power of germination of seeds buried in the soil under natural conditions at different depths, without any artificial placing or burial of seeds. To this end a number of samples were taken from different fields of known history by means of a sampling iron, 6 ins. by 6 ins. by 9 ins. This was driven into the ground, and the soil was carefully removed inch by inch, each inch being placed in a new paper bag and carefully labelled with the depth from which it was taken. The iron was driven far enough in to permit of sampling to a depth of 12 ins., and special precautions were taken that no crumbs of soil from the surrounding areas fell inside the sampling iron. The samples were then placed in clean sterilised pans or boxes in a greenhouse, kept watered, and left undisturbed for a time. The lower inches were chiefly heavy clay, which was broken up into small pieces by the fingers. After some months the sticky clay began to break down and disintegrate to some extent. Seeds soon began to germinate, and as soon as they were large enough to recognise they were noted and removed from the soil. Special care was taken that no plants were allowed to fruit and ripen seeds in the pans. Occasionally when the seedlings had been removed the soil was stirred and cut up with a knife. To avoid any danger of contaminating the samples, before the soil in any one box was interfered with all the surrounding boxes were covered with slates. As the boxes and pans were under cover in a greenhouse there was little danger of contamination by seeds carried on

the wind. As far as possible the ground in the immediate neighbourhood of the glasshouse was kept free from weeds and nothing was allowed to flower. After the experiment had been going on for some long time a fair number of *Senecio vulgaris* appeared in boxes in which they had not been evident in the early days of the test. Such seedlings were looked on with suspicion as being wind carried in all probability, and no account has been taken of them in the final results. After about 18 months a number of *Sonchus oleraceus* seedlings began to appear, and these also were considered as derived from wind carried seeds, as the species is so abundant in the immediate neighbourhood of the Laboratory. The conditions of the experiment, the types of the various seeds, and the distribution of the seedlings in the boxes render it highly improbable that any of the other seeds were of external origin, and it may be taken that the seedlings were derived from seed already in the soil when the samples were taken from the field.

Several samples were taken in each field selected for experiment and the fields were so chosen as to include land of as varied history as possible.

A. *Old Pasture* (never under arable as far as is known).
   (1) Harpenden Common. Sampled June 16th, 1916, 3 holes.
   (2) Park Grass. Sampled April 11th, 1916, 4 holes.

B. *Pasture, originally arable.*
   (1) Meadow at Laboratory house. Sampled April 28th, 1916, 4 holes.
   (2) Barn Field Grass. Sampled Oct. 19th, 1915, 4 holes.
   (3) Geescroft Field. Sampled about April 20th, 1916, 4 holes.
   (4) New Zealand Field (*a*). Sampled Aug. 24th, 1915, 4 holes.
   New Zealand Field (*b*). Sampled Sept. 24th, 1915, 4 holes.

C. *Arable Land.*
   (1) Long Hoos. Sampled April 25th, 1916, 2 holes.
   (2) Barn Field (8·0). Sampled April 6th, 1916, 2 holes.
   (3) Agdell (5). Sampled April 8th, 1916, 2 holes.

In the tables relating to each field the number of seeds which germinated at each inch are added together for all the holes sampled, except in the case of the totals, which are given for each individual hole for each species.

A. Old Pasture.

(1) *Harpenden Common.*

So far as is known this is genuine old pasture and has never been under tillage. The soil is of a fairly light nature and is deep, as the lowest inches

TABLE I. *Harpenden Common.* Holes 1, 2, 3.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Atriplex or Chenopodium	Orache or Fat Hen	.	1	.	.	.	.	.	.	.	.	.	.	0 + 0 +1	1
Polygonum aviculare	Knot-grass	.	.		.	.	.	.	1	.	.	.	.	0 + 1 +0	1
	Total	.	1	.	.	.	.	.	1	.	.	.	.	0 + 1 +1	2
Grassland plants															
Achillea Millefolium	Yarrow	2	.	.	.	.	.	.	.	.	.	.	.	0 + 2 +0	2
Bellis perennis	Daisy	1	.	.		.	.	.	.	.	.	.	.	0 + 1 +0	1
Galium verum	Ladies' Bedstraw	4	.	.	.	.	.	.	.	.	.	.	.	0 + 0 +4	4
Luzula campestris	Field Woodrush	*	1	1	.	1	.	.	.	.	.	.	.	3* + * +*	3*
Vicia sp.	Vetch sp.	.	.	1	.	.	.	.	.	.	.	.	.	0 + 0 +1	1
	Total	7*	1	2	.	1	.	.	.	.	.	.	.	3* + 3* +5*	11*
Grasses															
Grasses, various		*	*	*	2	.	2	*	1	1	.	.	.	* + 6* +*	6*
Lolium perenne	Perennial Rye-grass	.	.	.	4	.	.	.	.	.	.	.	.	0 + 2 +2	4
Agrostis sp.	Bent-grass	.	2	3	1	.	.	4	.	.	.	.	.	5 + 2 +3	10
	Total	*	2*	3*	7	.	2	4*	1	1	.	.	.	5* +10* +5*	20*
Suspected intruders															
Senecio vulgaris	Groundsel	.	1	1	.	.	.	1	.	.	.	1	.	0 + 1 +3	4
Sonchus oleraceus	Common Sowthistle	1	.	.	.	.	.	.	.	.	.	.	.	0 + 0 +1	1
	Total	1	1	1	.	.	.	1	.	.	.	1	.	0 + 1 +4	5

* indicates the presence of an indefinite number of plants at some periods.

sampled consist of good soil, and not of clay. A large number of grass and Luzula (species, probably = *campestris*) seedlings appeared in the top inches of soil and grass seedlings were also abundant in the second and third inches, but below this depth very few seeds germinated, except that in one hole a considerable number of grasses appeared seven inches down about a year after the beginning of experiment. Isolated grass seedlings occurred down to the ninth inch, probably derived from seeds that had been washed through the crannies or carried down by worms. During the 14 months of the experiment only 10 other seedlings appeared, inclusive of all species, with the exception of a few suspected groundsel and sowthistle plants. Eight of these were typical grassland plants, but the *Atriplex* or *Chenopodium* in the second inch and the *Polygonum aviculare* in the eighth inch were probably derived from seeds carried by birds or stock, as sheep and cattle have free run of the common. It is rather surprising that so few species occurred other than grasses and woodrush, but this may be due to the fact that the grazing is so close that only a very small proportion of plants have any chance to ripen and shed their seeds. The grasses that appeared were varied, but the greater number consisted of species of Agrostis, especially below the top inch of soil. Clovers were conspicuous by their absence, although plenty of leguminous plants occur on the Common. This is again attributed to the failure of the plants to form seed except in isolated cases.

(2) *Park Grass.*

There is no evidence available of this land being ploughed, and it is quite certain that it has been under grass for at least 300 years. The soil is fairly heavy and carries a good natural herbage, which has been allowed to develop undisturbed by stock for 40 years or more. Hay is cut every year, but as many of the plants have the opportunity of ripening their seeds one would naturally expect a much greater variety of species than was obtained from the close cropped Common soil. The difference proved to be most striking, for, apart from grasses, leguminous plants and possible intruders, 353 seedlings appeared between April, 1916, and August, 1917, compared with less than 20 from the Common soil. Practically all these were typical grassland plants[1], and the greater number occurred in the top six inches of soil. The maximum yield of seedlings was obtained from the second inch, and the number steadily

[1] *Centaurea nigra, Cerastium vulgatum, Ranunculus* sp. and *Stellaria media* have been separated out in the other tables as arable or grassland plants, but here they are so obviously present in their capacity of grassland plants that no division has been made in Table II.

TABLE II. *Park Grass.* Holes 1, 2, 3, 4.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Brassica alba	Charlock	.	.	.	1	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Atriplex patula	Orache	.	.	.	1	.	.	1	.	.	.	.	.	0 + 0 + 0 + 2	2
Atriplex *or* Chenopodium	Orache or Fat Hen	.	.	.	.	.	1	.	.	.	.	.	.	0 + 1 + 0 + 0	1
	Total	.	.	.	2	.	1	1	.	.	.	.	.	1 + 1 + 0 + 2	4
Grassland plants															
Achillea Millefolium	Yarrow	1	.	.	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Ajuga reptans	Bugle	5	56	40	17	12	4	3	5	1	5	.	.	8 + 15 + 103 + 22	148
Carex sp.	Sedge	.	.	.	.	.	.	.	1	.	.	.	.	0 + 0 + 0 + 1	1
Centaurea nigra	Hardhead	7	20	.	1	4	.	.	.	.	.	.	.	0 + 30 + 1 + 1	32
Cerastium vulgatum	Mouse-ear Chickweed	2	3	1	4	2	2	.	.	1	1	.	.	2 + 0 + 2 + 12	16
Conopodium denudatum	Pignut	1	16	5	3	.	.	.	.	.	.	.	.	2 + 5 + 15 + 3	25
Luzula campestris	Field Woodrush	.	4	10	3	6	2	.	.	.	1	.	.	0 + 19 + 6 + 1	26
Potentilla fragariastrum	Barren Strawberry	.	3	.	1	.	.	.	.	.	.	.	.	0 + 0 + 0 + 4	4
Prunella vulgaris	Selfheal	3	.	.	1	.	.	.	.	.	.	.	.	0 + 0 + 3 + 1	4
Ranunculus acris	Tall Buttercup	.	.	.	.	.	1	.	.	.	1	.	.	0 + 1 + 1 + 0	2
,, bulbosus	Bulbous Buttercup	.	.	.	.	1	.	1	.	.	.	.	.	0 + 0 + 0 + 2	2
Rumex acetosa	Sorrel	4	6	1	2	.	.	.	.	.	.	.	.	8 + 1 + 3 + 1	13
Stellaria graminea	Heath Stitchwort	1	.	5	1	.	.	.	.	.	.	.	.	0 + 1 + 1 + 5	7
,, media	Chickweed	.	.	1	.	.	.	.	.	.	.	.	.	0 + 1 + 0 + 0	1
Veronica Chamœdrys	Germander Speedwell	6	25	15	11	8	3	1	1	.	.	.	.	0 + 16 + 23 + 31	70
,, sp.	Speedwell sp.	.	.	.	.	.	.	.	.	1	.	.	.	0 + 0 + 0 + 1	1
Lotus corniculatus	Birdsfoot Trefoil	.	1	2	2	.	.	1	.	.	.	.	.	0 + 6 + 0 + 0	6
Trifolium pratense	Red Clover	.	.	.	1	1	.	.	.	.	.	.	.	0 + 1 + 1 + 0	2
,, repens	White Clover	1	1	.	.	2	1	.	.	1	1	.	1	5 + 2 + 1 + 0	8
,, (cut-leaved)	Clover sp.	.	1	.	.	.	.	1	.	.	1	.	.	1 + 2 + 0 + 0	3
	Total	31	136	80	47	36	13	7	7	4	10	.	1	26 + 100 + 161 + 85	372
														Less Leguminosae	353
Grasses															
Agrostis alba	Bent-grass	.	.	.	.	.	.	1	.	.	.	.	.	0 + 0 + 0 + 1	1
Anthoxanthum odoratum	Sweet Vernal-grass	2	2	1	1	.	.	.	.	.	.	.	1	2 + 3 + 2 + 0	7
Holcus lanatus	Yorkshire Fog	.	3	8	.	1	.	.	.	.	.	.	.	0 + 10 + 2 + 0	12
Lolium perenne	Perennial Rye-grass	1	1	.	.	.	.	.	.	.	.	.	.	1 + 1 + 0 + 0	2
Poa pratensis	Smooth-stalked Meadow-grass	1	.	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Grasses, various		3*	*	1*	*	.	1	1	.	.	.	.	.	1* + 1* + 4 + 0	6*
	Total	7*	6*	10*	1*	1	1	2	.	.	.	.	.	5* + 15* + 8 + 1	29*
Suspected Intruders															
Senecio vulgaris	Groundsel	1	1	.	.	2	.	1	.	.	1	.	.	1 + 2 + 1 + 2	6
Sonchus oleraceus	Common Sowthistle	1	.	.	1	.	.	.	.	1	.	.	.	2 + 1 + 0 + 0	3
	Total	2	1	.	1	2	.	1	.	1	1	.	.	3 + 3 + 1 + 2	9

declined to the sixth inch, below which depth very few seeds germinated, although individuals appeared right down to the stiff clay of the twelfth inch. Four arable seedlings put in an appearance, but it is possible that they had been carried by birds or had been brought in on the feet of men or horses and had then worked their way down into the soil. The distances from the sampled area to the nearest arable field is considerable, and neither charlock, fat hen nor orache have seeds that are at all well adapted for wind dispersal. Fat hen and charlock seeds are heavy and could not travel on the wind, and the orache remains enclosed in its envelope, while the weight of the seed is such as to render it improbable that the wind plays any effective part in dispersing this weed, as the envelope is not efficiently winged. The large number of *Ajuga* seedlings obtained from one hole six inches square is remarkable—103 plants of one species from such a small area being the second greatest number obtained during the investigation. It is obvious that the sample must have been taken from an area on which the plant is thoroughly well established as the seeds were found right down to the tenth inch. The same remark applies to *Veronica Chamaedrys*, though in this case the seeds were more evenly distributed over three holes, while the fourth hole was utterly barren of speedwell. *Conopodium* did not appear at all until the experiment had been running for nearly a year, and it was very difficult to be certain whether many of the tiny plants were genuine seedlings or whether they had arisen from very small tubers which were already in the soil. Even the smallest plants with obvious cotyledons developed their tubers at an early stage, but probably the 25 plants observed included both true seedlings and small older plants. The late appearance was probably due to the fact that *Conopodium* is naturally a very early plant and as it was later than the natural time of germination and growth when the experiment was set up the seeds lay dormant for a year till the usual growing period came round again. *Centaurea nigra*, again, gave rise to a certain amount of doubt at first, but it is probable that nearly, if not quite, all the 32 plants were true seedlings. In this case again nearly all the seedlings arose from one hole, indicating a local accumulation of seeds. The leguminous plants were not very well represented, as only 19 individuals appeared. This may be because the hay is usually cut before many of the clover seeds are ripe, so that the ultimate effect of haying on these species approximates somewhat to that of grazing, as seen on the Common.

B. PASTURE, ORIGINALLY ARABLE.

(1) *Laboratory House Meadow*[1].

The field was originally under arable cultivation, but in 1856 was fenced in and was sown with barley and grass. The grass seeds failed at first, and it was not until 1859 that a successful stand was obtained. Since that date the field has been kept as a meadow and mown for hay, no stock being run on it.

This field has been down to grass longer than any other area considered in this experiment, with the exception of the permanent pasture of the Park and Common. Although 58 years have elapsed since the land was under the plough a certain number of arable seedlings appeared from the soil samples, and the number is large enough to lead one to assume that a considerable proportion must have been buried in the soil from the time of grassing down. *Atriplex patula*, *Polygonum aviculare*, and *Veronica Tournefortii* occurred in two or three of the holes to a depth of several inches, and it is most improbable that so many well distributed seeds should have been introduced by external agency and have worked their way through the grass carpet down through the soil. It is more difficult to draw any conclusion with regard to those species which appeared in one single hole or as isolated individuals. *Arenaria serpyllifolia*, *Polygonum Convolvulus*, *Brassica* sp. and *Matricaria inodora* were represented by single plants, but as the seeds all occurred at a considerable depth, and as none of them are at all well adapted for dispersal over any considerable area, it is quite possible that they represent survivors from long buried seeds. On the other hand *Papaver* sp. and *Sonchus asper* appeared only in the first and second inches, and as both these species are easily carried by the wind, the seeds were almost certainly introduced in these cases. *Anagallis arvensis* and *Alchemilla arvensis* are doubtful species. *Anagallis* appeared from three holes from three to seven inches below the surface, which is an argument for the seeds being survivors of widely distributed long buried seeds, but as the species is most abundant in the allotments close by an element of doubt must be admitted. Four *Alchemilla arvensis* seedlings appeared from one hole, three of them being in the second inch, which suggests that by some accident a fruiting plant or a number of seeds were introduced at the spot, so that the seeds might be of more recent date.

[1] J. B. Lawes, "The history of a field newly laid down to permanent grass," *Journ. Roy. Agric. Soc. Eng.* 1889, **25**, pp. 1–24.

TABLE III. *Laboratory House Meadow.* Holes 1, 2, 3, 4.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable Weeds															
Alchemilla arvensis	Lady's Mantle	.	3	.	.	1	.	.	.	.	.	.	.	0 + 0 + 4 + 0	4
Anagallis arvensis	Poor Man's Weather-glass	.	.	2	1	.	.	1	.	.	.	.	.	2 + 0 + 1 + 1	4
Arenaria serpyllifolia	Thyme-leaved Sandwort	.	.	.	.	1	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Atriplex patula	Orache	.	.	2	3	5	.	.	.	.	.	.	.	6 + 2 + 0 + 2	10
Brassica sp.	Charlock	.	.	.	.	.	.	.	1	.	.	.	.	0 + 0 + 0 + 1	1
Matricaria inodora	Scentless Mayweed	.	.	.	.	1	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Papaver sp.	Poppy	1	.	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Polygonum aviculare	Irongrass, Knotweed, Knot-grass	.	1	1	1	.	.	.	.	.	.	.	.	0 + 1 + 2 + 0	3
,, Convolvulus	Black Bindweed	.	.	1	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Sonchus asper	Corn Sowthistle	1	1	.	.	.	.	.	.	.	.	.	.	0 + 2 + 0 + 0	2
Veronica Tournefortii	Large Field Speedwell	.	1	.	.	1	.	.	.	.	.	.	.	0 + 0 + 1 + 1	2
	Total	2	6	6	5	9	.	1	1	.	.	.	.	10 + 5 + 10 + 5	30
Arable or Grassland plants															
Capsella Bursa-pastoris	Shepherd's Purse	1	.	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Centaurea nigra	Hardhead	2	1	1	1	.	.	.	.	.	.	.	.	2 + 0 + 3 + 0	5
Cerastium vulgatum	Mouse-ear Chickweed	3	11	11	6	1	1	.	.	.	.	.	.	8 + 17 + 6 + 2	33
Geranium sp.	Geranium, Cranesbill	.	1	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Plantago lanceolata	Ribwort Plantain	1	.	.	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
,, major	Greater Plantain	.	1	1	1	.	.	.	.	.	.	.	.	2 + 0 + 0 + 1	3
Ranunculus bulbosus	Bulbous Buttercup	1	.	.	.	.	1	.	.	.	.	.	.	0 + 0 + 0 + 2	2
,, sp.	Buttercup sp.	.	.	.	1	.	.	.	.	.	.	.	.	0 + 1 + 0 + 0	1
Stellaria media	Chickweed	.	.	2	.	.	.	.	.	.	.	.	.	0 + 2 + 0 + 0	2
	Total	8	14	15	9	1	2	.	.	.	.	.	.	14 + 20 + 10 + 5	49
Grassland plants															
Bellis perennis	Daisy	2	3	.	.	.	.	.	.	.	.	.	.	5 + 0 + 0 + 0	5
Chrysanthemum leucanthemum	Ox-eye Daisy	.	.	2	.	.	.	.	.	.	.	.	.	2 + 0 + 0 + 0	2
Galium verum (not seedlings)	Ladies' Bedstraw	3*	9	.	.	.	.	.	.	.	.	.	.	12* + 0 + 0 + 0	12*
Prunella vulgaris	Selfheal	.	.	1	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Rumex Acetosa	Sorrel	1	.	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Trifolium repens	White Clover	6	6	8	6	.	.	.	.	.	.	.	.	12 + 7 + 5 + 2	26
,, (cut-leaved)	Clover sp.	2	.	4	.	.	.	.	.	.	.	.	.	4 + 2 + 0 + 0	6
Veronica serpyllifolia	Thyme-leaved Speedwell	13	9	5	6	2	.	.	.	.	.	.	.	26 + 1 + 0 + 8	35
,, sp.	Speedwell sp.	8	4	.	.	.	.	.	.	.	.	.	.	12 + 0 + 0 + 0	12
	Total	35*	31	20	12	2	.	.	.	.	.	.	.	75* + 10 + 5 + 10	100*
Grasses															
Agrostis sp.	Bent-grass	.	.	.	1	.	.	.	.	.	.	.	1	1 + 1 + 0 + 0	2
Lolium perenne	Perennial Rye-grass	1	1	4	6	1	.	5	.	.	1	.	.	1 + 3 + 10 + 5	19
Poa pratensis	Smooth-stalked Meadow-grass	7	12	32	17	.	2	.	1	.	2	.	1	27 + 22 + 23 + 2	74
Poa sp.	Meadow-grass sp.	.	17	6	1	.	4	1	.	.	.	.	.	0 + 0 + 14 + 15	29
Grasses, various		*	2*	1*	2	3	.	1	3	.	1	.	1	2* + 4* + 5* + 3*	14*
	Total	8*	32*	43*	27	4	6	7	4	.	4	.	3	31* + 30* + 52* + 25*	138*
Suspected intruders															
Lactuca sp.	Lettuce (garden)	.	.	.	.	.	.	.	1	.	.	.	.	0 + 0 + 0 + 1	1
Senecio vulgaris	Groundsel	3	4	2	1	2	.	3	1	.	.	.	.	3 + 4 + 2 + 7	16

The typical grassland plants and those common to arable or grassland occurred in some number, *Cerastium vulgatum*, *Trifolium repens* and *Veronica serpyllifolia* being the most abundant. All these seeds were segregated towards the surface, most of them being in the first three inches and none at all appearing below the sixth inch. Nearly all the true arable species were in the third, fourth and fifth inches with representatives in the seventh and eighth inches, which furnishes an additional proof that they are genuine buried seeds, as if aliens were introduced to any extent one would expect to find them in the upper inches as well in process of making their way down, as happened with *Papaver*, *Sonchus* and the doubtful *Alchemilla*. Grass seeds were abundant, chiefly in the top three inches, though viable seeds were found right down to and including the twelfth inch.

(2) *Barn Field Grass.*

This field was under ordinary farm cultivation till 1874, after which it was laid down to grass. As it was not an experimental field the earlier history is not very clear, but probably barley was the last crop carried prior to grassing down. Very few true arable weeds appeared in the pans, 12 seedlings of four species making up the entire crop. Clover and miscellaneous species characteristic of grassland were fairly abundant, but again very few species were represented, only 10 varieties appearing, of which three were clovers. Field observations showed that the herbage of the field now consists of grasses and clover with very few other species, so that it follows naturally that the species of buried weed seeds should be equally few in number. The fact that most of the arable seeds occur below the fifth inch of soil affords another proof that they were originally present and that they have not been gradually introduced by some external agency such as wind and animals. A few seeds may be introduced occasionally as the field is stocked with cattle, but the probability is that most of these die off before they have any chance of being washed down through the dense grass covering of the soil. If any contamination from outside sources were going on, one would expect a larger number of arable seeds to occur near the surface, as they would take some considerable time to be carried down five inches, but as a matter of fact only 1 such seedling appeared in the upper five inches. *Trifolium repens*, *Cerastium vulgatum* and *Ranunculus bulbosus* were present in large numbers and accounted for 91 % of the grassland plants. Nearly all these seeds occurred in the top six inches of soil, as was also seen in Geescroft, whereas all but one of the arable weeds appeared from six to eleven inches

TABLE IV. *Barn Field Grass.* Holes 1 E, 2 E, 1 W, 2 W.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Atriplex patula	Orache	.	.	.	.	.	.	3	.	4	.	.	.	0+ 0+ 5+ 2	7
Brassica alba	Charlock	.	.	.	.	.	2	.	.	.	.	1	.	0+ 0+ 3+ 0	3
Linaria minor	Small Toadflax	.	.	.	.	.	1	.	.	.	.	.	.	1+ 0+ 0+ 0	1
Papaver sp.	Poppy sp.	.	1	.	.	.	.	.	.	.	.	.	.	0+ 1+ 0+ 0	1
	Total	.	1	.	.	.	3	3	.	4	.	1	.	1+ 1+ 8+ 2	12
Arable or Grassland plants															
Cerastium vulgatum	Mouse-ear Chickweed	9	10	4	2	3	6	.	1	2	.	1	7	3+ 3+24+15	45
Myosotis arvensis	Field Forget-me-not	.	.	.	1	.	.	.	.	.	.	.	.	0+ 1+ 0+ 0	1
Ranunculus bulbosus	Bulbous Buttercup	1	5	19	7	4	2	4	.	.	3	.	1	8+24+ 3+11	46
Stellaria media	Chickweed	.	.	1	.	.	.	.	.	.	1	.	.	0+ 1+ 0+ 1	2
	Total	10	15	24	10	7	8	4	1	2	4	1	8	11+29+27+27	94
Grassland plants															
Bellis perennis	Daisy	3	.	3	1	.	.	2	.	.	.	.	.	6+ 3+ 0+ 0	9
Rubus sp.		1	.	1	.	.	.	.	.	.	.	.	.	1+ 1+ 0+ 0	2
Rumex sp.	Dock sp.	.	.	1	2	2	.	.	.	.	.	.	.	0+ 1+ 4+ 0	5
Trifolium pratense	Red Clover	.	.	.	1	.	.	.	.	.	.	.	.	0+ 1+ 0+ 0	1
,, repens	White Clover	47	29	27	12	3	5	4	2	1	.	1	.	43+14+31+43	131
,, (cut-leaved)	Clover sp.	1	.	.	.	.	.	.	.	.	.	.	.	0+ 0+ 1+ 0	1
	Total	52	29	32	16	5	5	6	2	1	.	1	.	50+20+36+43	149
														Less Leguminosae	16
Grasses															
Agrostis alba	Bent-grass	22	11	16	3	1	1	2	1	.	1	.	.	0+ 5+14+39	58
Alopecurus pratensis	Foxtail	4	1	.	.	.	.	.	.	.	.	.	.	0+ 0+ 0+ 5	5
Avena pubescens	Downy Oat	.	.	.	1	.	.	.	.	.	.	.	.	0+ 0+ 1+ 0	1
Festuca ovina	Sheep's Fescue	1	.	1	1	.	.	.	.	.	.	.	.	1+ 1+ 0+ 1	3
Holcus lanatus	Yorkshire Fog	5	10	6	1	.	1	.	.	.	.	.	.	0+ 1+ 9+13	23
Lolium perenne	Perennial Rye-grass	31	26	22	19	7	7	1	2	.	.	.	1	22+23+41+30	116
,, ,, *or* Poa annua	,, ,, *or* Annual Meadow-grass	13	4	6	2	.	.	.	.	.	.	.	.	0+25+ 0+ 0	25
Poa annua	Annual Meadow-grass	.	3	.	.	.	.	.	.	.	.	.	.	0+ 0+ 3+ 0	3
Triticum repens	Couch-grass	.	.	1	.	.	.	1	.	.	.	.	.	0+ 1+ 0+ 1	2
Grasses, various		4	3	2	1	.	.	2	1	.	.	.	1	6+ 3+ 3+ 2	14
	Total	80	58	54	28	8	9	6	4	.	1	.	2	29+59+71+91	250
Suspected intruders															
Senecio vulgaris	Groundsel	1	1	.	.	1	.	1	1	1	1	2	1	5+ 4+ 1+ 0	10
Sonchus oleraceus	Common Sowthistle	.	3	.	.	.	.	.	.	.	.	1	.	2+ 0+ 1+ 1	4
	Total	1	4	.	.	1	.	1	1	1	1	3	1	7+ 4+ 2+ 1	14

below the surface. The field is sometimes stocked with cattle and sometimes cut for hay, and the plants have opportunities of ripening their seeds, as cattle do not eat the herbage down so seriously as sheep. This helps to account for the comparatively large number of grasses and other grassland plants, the grasses being most abundant in the top four inches, the abundance being in sharp contrast to the paucity of arable weed seeds. The scarcity of arable plants may either be due to the length of time the seeds have been buried or to the fact that comparatively few seeds were left in the soil at the time of grassing down. This last suggestion is made because (as will be seen later) the adjoining arable field also yields remarkably few seeds, and the two fields were originally part of the same area. Certainly the 12 arable seedlings from this field compare very badly with the 75 plants obtained from a similar area in Geescroft. On the other hand Barn Field has been definitely under grass since 1874, while Geescroft was not finally thrown into the Park till 1885, and the extra eleven years would possibly account for the destruction of a large number of arable seeds that may have been originally present in the soil.

(3) *Geescroft Field.*

This area was originally under arable cultivation, and was used for various manurial experiments until 1878, but the land was very damp and difficult to work and frequently became waterlogged. It was left fallow for three years and in 1882 an unsuccessful attempt was made to seed it down to grass. Barley and clover were then cropped but in 1885 most of the field was thrown into the Park, so that the area has been under grass since that date. Geescroft is a very long way from any ploughed land and it is also protected to some extent by belts of trees, so that it is most improbable that it has been infected with arable seeds by means of wind carriage. It may safely be assumed that practically all the seedlings of arable weeds that came up in this experiment were derived from seeds that were lying dormant in 1885 or that were produced from plants that may have managed to survive for a year or two when the land was put down to grass. Arable weed plants very soon succumb to the conditions obtaining when land is under grass, and it is therefore unlikely that many of the seeds are of later date than 1885.

74 seedlings of typical arable weeds appeared in the soil of samples aggregating one foot in area, the number of each species varying from 1—6, except in the case of *Polygonum aviculare*, of which 52 plants appeared. These *Polygonum* seedlings occurred in every inch except the first, the largest numbers appearing from six to nine inches down. The

TABLE V. *Geescroft Grass.* Holes 1, 2, 3, 4.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Anagallis arvensis	Poor Man's Weather-glass	.	.	.	.	.	.	1	.	1	.	1	.	1 + 0 + 2 + 0	3
Arenaria serpyllifolia	Thyme-leaved Sandwort	.	.	.	.	1	.	.	.	.	.	.	1	0 + 0 + 0 + 2	2
Atriplex patula	Orache	.	.	.	.	3	.	2	.	.	.	.	.	0 + 1 + 1 + 3	3
Caucalis?		.	.	.	.	1	1	.	2	2	.	.	.	0 + 2 + 0 + 4	6
Papaver sp.	Poppy sp.	.	.	.	.	1	.	.	.	.	.	1	1	0 + 0 + 0 + 3	3
Polygonum aviculare	Knot-grass	.	2	3	4	3	13	9	6	6	2	3	1	9 + 18 + 6 + 19	52
,, Convolvulus	Black Bindweed	.	.	.	1	.	.	.	.	.	.	.	.	0 + 1 + 0 + 0	1
Veronica (agrestis?)	Field Speedwell	1	.	.	.	.	.	.	.	.	.	.	.	0 + 1 + 0 + 0	1
Viola tricolor	Wild Pansy	.	.	.	.	.	.	.	.	.	.	1	.	0 + 0 + 0 + 1	1
	Total	1	2	3	5	9	14	12	8	9	2	6	3	10 + 23 + 9 + 32	74
Grassland or arable plants															
Centaurea nigra	Hardhead	.	.	.	.	.	1	.	1	.	.	.	.	2 + 0 + 0 + 0	2
Cerastium vulgatum	Mouse-ear Chickweed	2	8	.	3	.	.	.	.	.	.	.	.	0 + 0 + 2 + 11	13
Myosotis arvensis	Field Forget-me-not	.	1	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Plantago major	Greater Plantain	7	7	5	2	2	2	1	2	.	.	.	.	2 + 4 + 9 + 13	28
Stellaria media	Chickweed	.	1	1	.	.	.	.	1	.	.	1	.	0 + 2 + 0 + 2	4
Taraxacum vulgare	Dandelion	.	1	.	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Viola sp.	Violet	.	.	1	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
	Total	9	18	7	5	2	3	1	4	.	.	1	.	6 + 6 + 12 + 26	50
Grassland plants															
Bellis perennis	Daisy	5	9	1	.	1	.	.	.	.	1	.	.	10 + 2 + 0 + 5	17
Conopodium?	Pignut?	.	.	.	.	1	.	.	.	.	.	.	.	0 + 0 + 0 + 1	1
Luzula campestris	Field Woodrush	2	1	2	.	.	.	.	.	.	.	.	.	1 + 4 + 0 + 0	5
Ranunculus acris	Tall Buttercup	3	.	.	.	.	.	1	.	.	.	.	.	0 + 0 + 2 + 2	4
,, ,, *or* R. repens	Tall *or* Creeping Buttercup	2	1	.	.	1	.	.	.	.	.	.	.	0 + 0 + 4 + 0	4
,, bulbosus	Bulbous Buttercup	.	1	1	.	1	.	.	1	.	.	.	.	1 + 1 + 1 + 1	4

Rubus sp.		1	.	1	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 1	2
Rumex Acetosa	Sorrel	.	1	1	.	.	.	.	.	.	.	.	.	2 + 0 + 0 + 0	2
Urtica dioica	Stinging-Nettle	.	.	1	.	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Veronica serpyllifolia	Thyme-leaved Speedwell	.	4	2	1	.	.	.	.	.	.	.	.	3 + 0 + 0 + 4	7
Trifolium pratense	Red Clover	1	.	.	.	.	1	.	.	.	1	.	.	2 + 1 + 0 + 0	3
,, repens	White Clover	8	26	37	15	1	4	6	8	2	3	2	2	25 + 39 + 27 + 23	114
,, (cut-leaved)	Clover sp.	2	9	12	.	3	1	1	2	2	1	1	.	12 + 11 + 2 + 9	34
	Total	24	52	58	16	8	6	8	11	4	6	3	2	56 + 58 + 38 + 46	198
														Less Leguminosae	47
Grasses															
Agrostis sp.	Bent-grass	21*	14	7	7	.	1	1	.	.	.	.	1	16 + 18 + 5 + 13*	52*
Arrhenatherum avenaceum?	False Oat?	.	1	.	.	.	.	.	.	.	.	.	.	0 + 0 + 0 + 1	1
Festuca ovina	Sheep's Fescue	.	.	1	.	.	.	.	.	.	.	.	.	0 + 1 + 0 + 0	1
Holcus lanatus	Yorkshire Fog	2	2	6	.	.	2	1	.	.	1	.	.	3 + 2 + 4 + 5	14
Lolium perenne	Perennial Rye-grass	1	2	4	1	.	1	2	.	1	.	1	.	1 + 2 + 7 + 3	13
Poa pratensis	Smooth-stalked Meadow-grass	2	4	2	.	.	.	.	.	.	.	.	.	1 + 0 + 7 + 0	8
Poa sp.	Meadow-grass sp.	.	.	3	1	1	1	.	.	.	.	.	.	0 + 4 + 2 + 0	6
Grasses various		8*	*	4	4	3	3	2	5	.	3	2	1	5* + 3 + 11* + 16	35*
	Total	34*	23*	27	13	4	8	6	5	1	4	3	2	26* + 30 + 36* + 38*	130*
Suspected intruders															
Senecio vulgaris	Groundsel	.	4	.	3	2	.	1	.	.	3	3	.	6 + 3 + 3 + 4	16
Sonchus oleraceus	Common Sowthistle	2	.	.	1	.	.	1	1	1	.	.	.	2 + 2 + 0 + 2	6
	Total	2	4	.	4	2	.	2	1	1	3	3	.	8 + 5 + 3 + 6	22

seedlings were well distributed in the soil from each of the four sampled holes, indicating that the mother plants were probably common over the field and were not localised in a few places. It is surprising that such a large number of seeds have retained their germinating capacity for over 30 years and the survival of so many suggests that *P. aviculare* was exceedingly plentiful when the area was cultivated. The old Rothamsted records show that this was actually the case and that knotgrass was one of the worst weeds occurring among the crops. *Plantago major* was also very characteristic at that time and a number of seedlings appeared during the present experiment, but as this species is common to both arable and grass land and still occurs in the field, it is not possible to ascertain the length of time the seeds had been buried in the soil. Those occurring in the upper layers of soil are nearly certain to be of comparatively recent date. None of the typical arable weeds that appeared in the soil samples are to be found in the surface vegetation of the field nowadays, whereas they were all recorded as being present among the crops in 1867, a fact which renders it still more probable that the seedlings obtained in the experiment grew from seeds which had been buried in the soil at least since the land was thrown into the Park in 1885.

A large number of typical grassland seedlings appeared and also a certain number of species that are common to both arable and grassland. The greater number (75 %) of the grassland seeds were present in the top four inches of soil, whereas most of the arable seeds (68 %) were found from five inches to nine inches below the surface. The stock of grassland seeds is replenished year by year as the plants on the surface ripen their fruits, so that it naturally happens that the bulk of the youngest and most viable seeds occur near the surface. As the seeds get carried down into lower depths in the course of time many of them lose their power of germination with increasing age, and the lowest inches contain very few seeds that are capable of growth when the soil is disturbed. On the other hand the long-buried arable seeds have apparently found some conditions of equilibrium in the middle depths which have enabled them to remain unharmed all these years. When the land first passed out of cultivation the greater number of arable weed seeds must have been in the top few inches. The conditions of aeration, temperature and moisture down to a depth of three or four inches at least, are such as to induce germination, which is effective or incipient according to the variety of seed concerned and the depth at which it is buried. Consequently in the course of the first few years most of the seeds towards the surface died off, either by germination or by rotting. The more deeply buried seeds,

however, did not find the conditions suitable for germination, and therefore lay dormant. Many of them must have died off, but some seeds were apparently at such a nice condition of maturity that they were able to establish equilibrium with their surroundings and so have survived in a condition of latent life or dormancy until the present time, 30 years after they were shed.

(4) *New Zealand Field.*

This field was under grass from 1906 till 1915. Prior to 1906 it was under arable cultivation and in the autumn of 1915 it was again ploughed up and is now cropped in the ordinary course of farm management. The soil samples were taken before the grass was disturbed and two separate sets of samples from four holes each were taken in August and September 1915. As the field is now cropped it has been possible to carry on observations of the arable weed flora as it appears in the field in order to make comparisons with what happens under glasshouse conditions.

The most striking feature of the New Zealand lists is the large number of arable seedlings that appeared in the greenhouse compared with those obtained from Geescroft and Barn Field soils, the numbers being 457 and 334 respectively from the two New Zealand samples against 74 from Geescroft and 12 from Barn Field grass. This is easily accounted for by the relatively short time that New Zealand field had been down to grass, as many seeds are known to be able easily to retain their vitality for over 10 years. On the other hand the number of true grassland plants was less than in the other two cases, because the shorter period during which the field was grassed over had not permitted such a large stock of ungerminated, living seeds to accumulate. When all the seedlings exclusive of grasses are considered together, it is seen that in the fields under consideration the total number decreases as the length of time under grass increases. This, however, must not be taken as a definite statement of general application, because so much depends upon the initial state of cultivation of the ground, the store of arable seeds originally in the soil, and the particular soil condition which determines how long the seeds are able to retain their vitality. Probably, however, the statement would approximately hold good under ordinary circumstances provided ample allowance were made for individual and local variations.

Altogether 16 arable species were derived from buried seeds, but 98 % of the total number of seedlings were referable to nine of these species. The number of seedlings of each individual species obtained from each separate hole varied within wide limits, as from 1 to 36 with *Papaver*

TABLE VI. *New Zealand Grass.* Holes 1 N, 2 N, 1 S, 2 S.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Alchemilla arvensis	Lady's Mantle	.	.	.	.	.	.	1	.	.	.	.	.	0+ 0+ 1+ 0	1
Arenaria serpyllifolia	Thyme-leaved Sandwort	.	.	.	.	1	.	.	.	.	.	.	.	1+ 0+ 0+ 0	1
Atriplex patula	Orache	.	2	8	5	6	7	3	8	9	24	8	26	24+ 6+ 41+ 35	106
Brassica sp.	Charlock	1	1	1	1	3	1	.	2	.	1	.	.	0+ 6+ 3+ 2	11
Euphorbia exigua	Dwarf Spurge	7	7	9	9	7	3	2	2	.	.	.	.	8+ 2+ 5+ 31	46
Lapsana communis	Nipplewort	.	.	.	.	.	1	.	.	.	.	.	.	0+ 0+ 1+ 0	1
Papaver sp.	Poppy sp.	7	11	6	16	16	12	4	2	.	.	.	.	8+43+ 15+ 8	74
Polygonum aviculare	Knot-grass	4	7	7	5	6	7	5	1	4	19	1	.	32+ 1+ 18+ 15	66
Sonchus asper	Corn Sowthistle	7	5	7	11	7	3	.	.	.	.	.	.	29+ 6+ 3+ 2	40
Veronica agrestis	Field Speedwell	12	9	1	7	2	.	1	1	.	.	.	.	3+ 1+ 18+ 11	33
,, hederaefolia	Ivy-leaved Speedwell	3	2	3	6	3	1	1	.	.	.	.	.	2+ 5+ 5+ 7	19
,, Tournefortii	Large Field Speedwell	26	7	15	7	1	1	.	.	.	.	.	.	23+ 6+ 15+ 13	57
,, sp.	Speedwell sp.	.	.	.	.	1	.	.	.	.	.	.	.	1+ 0+ 0+ 0	1
Viola tricolor	Wild Pansy	1	.	.	.	.	.	.	.	.	.	.	.	0+ 1+ 0+ 0	1
	Total	68	51	57	67	53	36	17	16	13	44	9	26	131+77+125+124	457
Arable or grassland plants															
Capsella Bursa-pastoris	Shepherd's Purse	.	.	.	1	1	.	.	.	.	.	.	.	0+ 0+ 0+ 2	2
Cerastium vulgatum	Mouse-ear Chickweed	5	.	.	1	1	.	.	.	.	.	.	.	0+ 0+ 0+ 7	7
Cirsium arvense	Creeping Thistle	.	.	1	1	.	.	.	.	.	.	.	.	1+ 1+ 0+ 0	2
Convolvulus arvensis	Bindweed	.	3	.	.	.	.	.	.	.	.	.	.	3+ 0+ 0+ 0	3
Myosotis arvensis	Field Forget-me-not	.	1	.	.	.	.	.	1	.	.	.	.	1+ 0+ 0+ 1	2
Plantago major	Greater Plantain	6	5	1	1	2	.	.	.	.	.	.	.	2+13+ 0+ 0	15
Ranunculus repens	Creeping Buttercup	.	1	2	.	.	.	.	.	.	.	.	.	0+ 0+ 0+ 3	3
,, sp.	Buttercup sp.	.	.	.	2	.	.	.	.	.	.	.	.	0+ 0+ 0+ 2	2
Rumex sp.	Dock sp.	1	.	.	.	.	.	.	.	.	.	.	.	0+ 0+ 1+ 0	1
Stellaria media	Chickweed	.	2	2	4	2	2	2	.	.	1	.	.	4+ 2+ 5+ 4	15
	Total	12	12	6	10	6	2	2	1	.	1	.	.	11+16+ 6+ 19	52

Grassland plants																	
Ajuga reptans	Bugle	1	.	.	.	.	.	.	.	.	.	.	.	.	0+ 1+ 0+ 0	1
Hypochaeris radicata	Cat's-ear	1	.	.	1	1	.	.	.	.	.	.	.	.	0+ 1+ 2+ 0	3
Rubus Idaeus	Raspberry	4	.	.	1	.	.	.	.	.	.	.	.	.	0+ 4+ 0+ 1	5
Trifolium pratense	Red Clover	11	3	6	7	3	.	1	.	.	.	.	.	.	22+ 8+ 0+ 1	31
,, repens	White Clover	53	6	.	.	1	4	.	1	.	.	.	.	.	32+19+ 10+ 4	65
,, ,, *or* pratense	,, ,, *or* Red Clover	13	.	.	.	.	.	.	.	.	.	.	.	.	13+ 0+ 0+ 0	13
,, sp.	Clover sp.	.	1	.	.	.	.	.	.	.	.	.	.	.	1+ 0+ 0+ 0	1
	Total	83	10	6	9	5	4	1	1	.	.	.	.	.	68+33+ 12+ 6	119
															Less Leguminosae	9
Grasses																
Agrostis alba	Bent-grass	2	6	.	5	11	13	5	.	2	.	.	.	.	14+ 8+ 11+ 11	44
,, vulgaris	,,	7	2	3	4	1	1	.	2	.	.	.	.	.	11+ 4+ 4+ 1	20
Dactylis glomerata	Cocksfoot	4	1	.	.	.	.	.	.	.	.	.	.	.	4+ 0+ 0+ 1	5
Festuca ovina	Sheep's Fescue	1	.	.	.	.	.	.	.	.	.	.	.	.	1+ 0+ 0+ 0	1
Lolium perenne	Perennial Rye-grass	30	2	1	6	.	.	1	.	1	.	.	.	.	4+19+ 14+ 4	41
Grasses, various		2	5	1	3	1	1	1	.	.	.	.	.	.	8+ 1+ 3+ 2	14
	Total	46	16	5	18	13	15	7	2	3	.	.	.	.	42+32+ 32+ 19	125
Suspected intruders																
Senecio vulgaris	Groundsel	.	1	1	.	.	.	.	.	.	.	.	.	.	1+ 0+ 1+ 0	2
Sonchus oleraceus	Common Sowthistle	1	.	.	2	.	.	1	.	.	.	.	.	2	1+ 1+ 2+ 2	6
	Total	2	1	.	2	.	.	1	.	.	.	.	.	2	2+ 1+ 3+ 2	8

TABLE VII. *New Zealand Grass.* Holes 1 BN, 2 BN, 1 BS, 2 BS.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Aethusa Cynapium?	Fool's Parsley?	.	.	.	.	.	1	.	.	.	.	.	.	0 + 0 + 0 + 1	1
Atriplex patula	Orache	1	4	10	5	9	6	10	11	4	16	12	.	12 + 35 + 26 + 15	88
Brassica sp.	Charlock	.	2	3	.	4	2	.	.	.	.	.	.	1 + 6 + 2 + 2	11
Euphorbia exigua	Dwarf Spurge	2	4	5	4	3	4	1	1	.	.	.	.	7 + 1 + 8 + 8	24
Papaver sp.	Poppy sp.	12	19	7	8	5	3	2	.	.	.	.	.	1 + 12 + 7 + 36	56
Polygonum aviculare	Knot-grass	8	4	10	7	9	8	1	4	3	.	1	.	5 + 13 + 31 + 6	55
Sonchus asper	Corn Sowthistle	.	1	2	3	5	2	.	.	.	.	.	.	2 + 5 + 4 + 2	13
Veronica agrestis	Field Speedwell	17	2	1	2	5	1	.	.	.	.	.	.	4 + 0 + 18 + 6	28
,, arvensis	Wall ,,	1	1	.	1	.	.	.	.	.	.	.	.	0 + 0 + 3 + 0	3
,, hederaefolia	Ivy-leaved Speedwell	3	1	8	3	4	3	.	.	.	.	.	.	2 + 2 + 10 + 8	22
,, Tournefortii	Large Field ,,	10	5	4	3	3	.	.	.	.	.	.	.	17 + 1 + 3 + 4	25
,, sp.	Speedwell sp.	3	3	.	.	.	.	.	.	.	.	.	.	3 + 0 + 1 + 2	6
Viola tricolor	Wild Pansy	.	.	1	.	1	.	.	.	.	.	.	.	0 + 1 + 1 + 0	2
	Total	57	46	51	36	48	30	14	16	7	16	13	.	54 + 76 + 114 + 90	334
Arable or grassland plants															
Capsella Bursa-pastoris	Shepherd's Purse	.	.	.	1	.	.	.	.	.	.	.	.	0 + 0 + 1 + 0	1
Cerastium vulgatum	Mouse-ear Chickweed	3	.	.	.	1	.	.	1	.	.	.	.	0 + 2 + 3 + 0	5
Myosotis arvensis	Field Forget-me-not	4	3	3	.	.	.	.	.	.	.	.	.	3 + 2 + 4 + 1	10
Plantago major	Greater Plantain	1	.	.	1	.	.	.	.	.	.	.	.	0 + 1 + 1 + 0	2
Rumex sp.	Dock sp.	8	2	2	1	1	1	1	1	1	.	.	.	1 + 5 + 12 + 0	18
Scabiosa arvensis	Field Scabious	.	.	.	.	.	.	.	.	.	1	.	.	0 + 0 + 1 + 0	1
Stellaria media	Chickweed	5	1	1	1	3	1	.	.	.	.	.	.	0 + 5 + 0 + 7	12
	Total	21	6	6	4	5	2	1	2	1	1	.	.	4 + 15 + 22 + 8	49
Grassland plants															
Trifolium pratense	Red Clover	20	2	1	1	2	2	1	.	.	.	.	.	10 + 9 + 0 + 10	29
,, repens	White ,,	21	4	1	.	2	.	.	.	.	.	.	.	7 + 6 + 13 + 2	28
	Total	41	6	2	1	4	2	1	.	.	.	.	.	17 + 15 + 13 + 12	57
Grasses															
Agrostis alba	Bent-grass	.	1	3	7	1	3	6	2	.	.	.	.	7 + 11 + 3 + 2	23
,, vulgaris et sp.	,,	8	2	1	3	.	1	1	.	.	.	.	.	1 + 7 + 5 + 3	16
Dactylis glomerata	Cocksfoot	.	1	.	.	.	.	.	.	.	.	.	.	1 + 0 + 0 + 0	1
Festuca ovina	Sheep's Fescue	.	.	.	.	.	.	.	2	.	.	.	.	1 + 1 + 0 + 0	2
Lolium perenne	Perennial Rye-grass	49	4	1	2	.	.	.	1	.	.	.	.	46 + 5 + 5 + 1	57
Grasses, various		2*	3	.	.	1	5	8	2	.	1	.	.	* + 10 + 1 + 11	22*
	Total	59*	11	5	12	2	9	15	7	.	1	.	.	56* + 34 + 14 + 17	121*
Suspected intruders															
Senecio vulgaris	Groundsel	1	4	.	1	1	.	1	.	.	.	.	1	0 + 4 + 2 + 3	9
Sonchus oleraceus	Common Sowthistle	1	.	1	.	1	.	.	1	.	.	.	.	2 + 1 + 0 + 1	4
	Total	2	4	1	1	2	.	1	1	.	.	.	1	2 + 5 + 2 + 4	13

sp., and from 6 to 41 with *Atriplex patula*, but with two single exceptions in the case of *Veronica agrestis* and *Brassica* sp. each of the main seedlings appeared from every one of the eight sampled holes in greater or less quantity. This shows that these species must have been very abundant in the field at the time of grassing down and also that the distribution was widespread and not localised in particular areas, as the sampled holes were taken from widely separated parts of the field and were not huddled together in one place. *Brassica* was well distributed, but the seedlings were not very plentiful in comparison to the other main species. The remaining less plentiful species all occurred as isolated individuals, indicating that they were either very local in distribution, or else that the seeds were less resistant to burial and had nearly all succumbed during the 10 years under grass. Information on these points was sought from the field itself during the first year after the land was ploughed. Ploughing took place in the autumn of 1915 and the weeds were examined in the following February, when the situation was as follows with regard to arable seedlings:

Veronica Tournefortii, „ hederaefolia, Brassica sp. } plentiful
Papaver sp., especially plentiful at one end of area
Veronica, probably agrestis, Sonchus asper, Senecio vulgaris } occasional
Matricaria inodora, Veronica arvensis, Scandix Pecten } scarce

In addition to the purely arable weeds the following were in evidence:

Rumex crispus, frequent
Stellaria media, Ranunculus repens } occasional
Senecio Jacobaea, Lamium purpureum, Chrysanthemum leucanthemum, Taraxacum vulgare, Capsella Bursa-pastoris, Convolvulus arvensis, Trifolium repens, Centaurea nigra (not seedlings) } scarce

It thus appears that during the winter months immediately succeeding the ploughing four of the species that appeared most plentifully from the seeds buried in the soil samples came up in quantity on the field and two other of the main species were present in less amount. It is impossible

TABLE VIII. *Long Hoos.* Holes 1, 2.

			Depth in inches												Total for each hole	Grand Total
			1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds																
Alchemilla arvensis	Lady's Mantle		9	14	21	21	13	15	19	11	5	.	.	.	60 + 68	128
Anagallis arvensis	Poor Man's Weather-glass		.	.	.	.	.	.	.	1	.	.	.	.	0 + 1	1
Arenaria serpyllifolia	Thyme-leaved Sandwort		22	34	52	16	44	14	15	9	4	1	1	.	158 + 54	212
Atriplex patula	Orache		1	3	2	3	4	1	4	3	.	8	1	.	30 + 0	30
,, ,, *or* Chenopodium	Orache or Fat Hen		.	.	.	.	.	.	2	.	.	17	1	3	20 + 3	23
Brassica sp.	Charlock		.	3	1	1	3	2	.	2	1	1	2	.	8 + 8	16
Caucalis sp.			.	.	.	.	.	.	.	.	1	.	.	1	2 + 0	2
Euphorbia exigua	Dwarf Spurge		1	1	.	.	1	5	1	1	2	.	.	.	6 + 6	12
Galium (Aparine *or* tricorne)	Bedstraw, Cleavers		.	.	.	.	.	.	.	.	.	.	.	1	1 + 0	1
Matricaria inodora	Scentless Mayweed		10	13	26	9	13	10	6	1	.	.	1	6	46 + 49	95
Papaver sp.	Poppy sp.		6	5	16	10	8	3	2	2	.	1	.	.	21 + 32	53
Polygonum aviculare	Knot-grass		.	1	5	2	1	8	2	2	1	1	.	.	9 + 14	23
,, Convolvulus	Black Bindweed		.	.	.	.	.	.	.	1	1	.	.	.	1 + 1	2
,, Persicaria	Willowweed		.	.	.	.	.	2	.	2	.	.	.	.	3 + 1	4
Sonchus asper	Corn Sowthistle		.	.	.	1	.	.	.	.	.	.	.	.	0 + 1	1
Veronica agrestis	Field Speedwell		3	5	2	1	4	5	.	.	.	.	.	.	10 + 10	20
,, hederaefolia	Ivy-leaved Speedwell		.	1	1	.	.	.	.	.	.	.	.	1	3 + 0	3
,, Tournefortii	Large Field Speedwell		4	9	25	32	24	3	8	.	.	.	.	.	79 + 26	105
,, sp.	Speedwell sp.		3	.	3	.	.	9	2	4	3	.	.	.	11 + 13	24
Viola tricolor	Wild Pansy		1	3	8	1	.	5	2	1	3	.	2	1	20 + 7	27
	Total		60	92	162	97	115	82	63	40	21	29	8	13	488 + 294	782
Arable or grassland plants																
Cerastium vulgatum	Mouse-ear Chickweed		3	2	4	2	.	1	.	2	.	.	.	.	2 + 12	14
Myosotis arvensis	Field Forget-me-not		2	.	3	.	1	1	2	.	.	.	.	.	0 + 9	9
Plantago major	Greater Plantain		2	.	.	2	1	1	1	.	.	.	.	.	4 + 3	7
Ranunculus sp.	Buttercup sp.		1	.	.	.	.	.	.	.	.	.	.	.	0 + 1	1
Scabiosa arvensis	Field Scabious		.	.	.	.	.	.	.	1	.	.	.	.	1 + 0	1
Stellaria media	Chickweed		.	.	1	.	.	.	.	2	.	.	.	.	3 + 0	3
	Total		8	2	8	4	2	3	3	5	.	.	.	.	10 + 25	35
Grassland plant, probably left from previous crop																
Trifolium pratense	Red Clover		.	.	.	.	.	.	.	.	1	.	.	1	2 + 0	2
Grasses																
Agrostis sp.	Bentgrass		3	5	7	3	3	4	6	3	5	1	2	1	22 + 21	43
Poa annua	Annual Meadow-grass		2	1	.	2	.	3	.	.	.	.	.	.	3 + 5	8
Grasses, various			.	.	.	2	1	2	1	.	.	.	.	.	6 + 0	6
	Total		5	6	7	7	4	9	7	3	5	1	2	1	31 + 26	57
Suspected intruders																
Senecio vulgaris	Groundsel		1	.	.	1	2	1	.	1	.	1	.	.	4 + 3	7
Sonchus oleraceus	Common Sowthistle		.	.	2	1	.	.	.	.	.	.	.	.	2 + 1	3
	Total		1	.	2	2	2	1	.	1	.	1	.	.	6 + 4	10

A certain number of weeds appeared that are common to arable and grass land, but they are evidently present here in their character of arable weeds. The true grassland plants were represented by one solitary species, *Trifolium pratense*, of which only two plants appeared. Few grasses occurred except for a number of *Agrostis* sp. which is a typical arable weed and should really be included in the list of arable seedlings, raising the grand total to 782 + 43 = 825.

(2) *Barn Field* (8·0).

Barn Field has carried root crops year after year for 61 years since 1856, and the plot 8·0 has received no manure of any kind during the whole period. As a result of this treatment the soil is now much impoverished and supports only a feeble type of vegetation, and in addition the continual hoeing and cultivating has reduced the weeds to a minimum, as few of them have any opportunity of forming seed before they are hoed up. This is well shown by the results obtained from the soil samples. Two holes were sampled, making up 24 pans. During the whole 16 months of the experiments only eight pans produced any seedlings, and three out of the eight were occupied solely by *Senecio vulgaris*, a possible intruder. *Senecio vulgaris* occurs rather frequently on Barn Field, and as most of the seedlings appeared in the pans during the first three months of the experiment it is quite likely that the seeds were really associated with the soil and were introduced with it, so that in this case they would not be intruders. Altogether seven arable seedlings and three arable or grassland plants appeared, the grand total of 20 seedlings from an area of $\frac{1}{2}$ sq. foot of soil being made up by 10 *Senecio vulgaris* seedlings. Every seedling appeared within the top six inches of soil, and furthermore, all the seedlings made very feeble growth, showing that the seeds were weak. The paucity in the number of species of arable weed seeds is probably more due to the continual cultivation for roots than to the starved condition of the soil, as even on the heavily manured plots in the same field only nine or 10 species of weeds occur, and these are present in very small quantity.

(3) *Agdell Field* (5).

This plot has been left unmanured since 1848 and has been worked under four course rotation experiments during the period of 69 years. In the third year of each course the plot has been left fallow, so that specially good opportunities have arisen of cleaning the land, as the seedlings that germinate during the fallow time are to a large extent

TABLE IX. *Barn Field Arable* (8·0). Holes 1, 2.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Euphorbia peplus	Petty Spurge		1	2	.	.	1	.	.	.	.	.	.	0+4	4
Sonchus asper	Corn Sowthistle	1	.	.	.	.	1	.	.	.	.	.	.	0+2	2
Veronica Tournefortii	Large Field Speedwell	.	.	.	.	.	1	.	.	.	.	.	.	1+0	1
	Total	1	1	2	.	.	3	.	.	.	.	.	.	1+6	7
Arable or Grassland plants															
Centaurea nigra	Hardhead	.	.	1	.	.	.	.	.	.	.	.	.	0+1	1
Stellaria media	Chickweed	.	.	1	.	.	.	.	.	.	.	.	.	0+1	1
	Total	.	.	2	.	.	.	.	.	.	.	.	.	0+2	2
Possible intruders															
Senecio vulgaris	Groundsel	7	2	.	.	1	.	.	.	.	.	.	.	5+5	10
Sonchus oleraceus	Common Sowthistle	1	.	.	.	.	.	.	.	.	.	.	.	0+1	1
	Total	8	2	.	.	1	.	.	.	.	.	.	.	5+6	11

TABLE X. *Agdell* (5). Holes 1, 2.

		Depth in inches												Total for each hole	Grand Total
		1	2	3	4	5	6	7	8	9	10	11	12		
Arable weeds															
Alchemilla arvensis	Lady's Mantle	.	.	1	.	.	.	.	.	.	1	.	.	1+1	2
Arenaria serpyllifolia	Thyme-leaved Sandwort	.	.	.	.	.	.	1	7	1	.	.	.	0+9	9
Atriplex patula	Orache	4	5	.	.	.	2	1	.	.	.	.	.	1+11	12
,, ,, or Chenopodium	,, or Fat Hen	.	.	.	2	2	.	3	.	.	.	.	.	0+7	7
Chenopodium album	Fat Hen	.	.	4	.	1	.	.	.	.	.	.	.	0+5	5
Euphorbia exigua	Dwarf Spurge	.	.	.	.	.	.	1	.	.	.	.	.	1+0	1
Galium sp.	Bedstraw sp.	.	.	.	1	.	.	.	.	.	.	.	.	1+0	1
Matricaria inodora	Scentless Mayweed	1	.	.	1	1	1	1	.	.	.	.	.	2+3	5
Polygonum aviculare	Knot-grass	.	.	.	.	1	.	.	.	.	.	.	.	1+0	1
	Total	5	5	5	4	5	3	7	7	1	1	.	.	7+36	43
Grassland plants															
Trifolium pratense	Red Clover	14	6	23	18	15	33	17	13	.	1	.	.	53+87	140
,, repens	White Clover	1	.	1	2	.	3	13	3	.	.	.	.	16+7	23
,, (cut-leaved)	Clover sp.	.	.	.	1	.	2	1	.	.	.	.	.	1+3	4
	Total	15	6	24	21	15	38	31	16	.	1	.	.	70+97	167
Died without developing	Total	3	6	.	17	5	4	.	4	.	.	.	.	24+15	39
Suspected intruder															
Senecio vulgaris	Groundsel	.	.	1	.	.	.	.	.	.	.	.	.	0+1	1

cultivated out and prevented from seeding. Also, as the field is experimental, an extra amount of weeding is done during the growing seasons, and this also tends to reduce the quantity of weeds. Added to this, the soil is now very poor owing to the long continued cropping without manure, and this impoverishment influences the growth of weeds as well as of crops and tends to reduce their vigour and abundance. All these limiting factors are reflected in the number of buried weed seeds which germinated in the soil samples.

From the two holes covering $\frac{1}{2}$ sq. foot only 43 arable weeds were identified, though probably some of the 39 seedlings which died in infancy without developing belonged to the same category. These numbers are in sharp contrast to those obtained from Long Hoos where no experimental interference took place and where the land received manure at intervals in the ordinary course of management.

During the first few months to Dec. 1916, *Atriplex patula* and *Chenopodium album* were the only weed seeds that germinated, and few even of these were present. In the spring of 1917 the number of these species increased considerably, and various other plants came up, bringing the total arable species to eight. Several plants of *Arenaria serpyllifolia* and *Matricaria inodora* appeared, but the other species only occurred in ones or twos. *Trifolium pratense* was present in far greater quantity than the weed seeds, but this is probably the result of an accidental error, as a few years ago clover seed was sown on the fallow half instead of on the clover half of the field, and it has not yet been possible to entirely eliminate the species. Both *Trifolium pratense* and *T. repens* were present in quantity from six to eight inches below the surface, and consequently it is probable that many of the seedlings were derived from seeds that had been buried for some considerable time and had been worked down by ploughing and cultivation.

GENERAL DISCUSSION OF THE RESULTS.

A survey of Tables I–X shows at a glance how closely the flora derived from buried seeds is associated with the history of the land. Permanent grassland is practically devoid of arable weeds, and also the number and variety of the species that do occur is greatly influenced by the fact of grazing or cutting, as the case may be. Continual close grazing, as on the Common, hinders seed production, and so reduces the number of viable seeds that become buried in the soil. Continual mowing, as on the

Park Grass, allows of the ripening of the seeds of many species in a differential degree, the earlier species having a better chance than those which flower later in the season. Consequently far more seeds become buried in this case, and the flora tends to remain very varied.

A striking difference exists between the buried seed flora of permanent grassland and of land that has at one time been under the plough, even though nearly 60 years have elapsed since grassing down. The permanent grassland is largely colonised by species of grasses and miscellaneous plants which are definitely associated with pasture and never with arable land, except for the one or two arable weeds which must be of accidental origin. On land that was originally arable however, a large number of plants occur, such as hardhead, mouse-ear chickweed, ribwort plantain, chickweed, etc., which are common to both arable and grassland, indicating that when once these species are established on an area they can persist, even when the type of cultivation is changed.

A fair number of true arable weeds appear even from soil that has been grassed over for 58 years (Laboratory House Meadow) and, as was shown in the special discussion above, many of these may almost certainly be regarded as survivors from seeds left in the soil from the time of arable cultivation. The proportion of grassland plants is large compared to that of the arable weeds, a result that is in complete accordance with expectations. Geescroft field has been under grass for a shorter period of time, and the number of arable seeds is greater, while the proportion of grassland plants has decreased. This trend of events becomes more marked as the time of grassing down gets less, and on New Zealand field, with only 10 years under grass, the arable weeds bear a heavy proportion to the grassland plants, particularly if the clovers (which might have been derived from buried seeds of a sown crop) are left out of consideration. The transition from the state of affairs on such temporary grassland to that on ordinary ploughed land is gradual and in the same sense, the number of arable weeds being greatly increased, the arable or grassland plants being sparsely represented, while the true grassland plants are almost absent.

The changes in the proportion of the arable and grassland plants derived from buried seeds are so consistent and so regularly associated with the history of the land that one is irresistibly forced to the conclusion that when arable land is grassed over a certain number of the seeds are able to retain their vitality for very many years. Many of the seeds die within a comparatively short time after burial, and as time goes on the number of living seeds gradually becomes less, though the evidence goes

to show that some seeds will survive burial for at least 58 years. Usually most of the older arable seeds survive in the lower depths of soil where the conditions are less variable, whereas the shorter the time that land has been under grass the greater the proportion of arable seeds that are found near the surface. While the stock of arable seeds is diminishing with the lapse of time, the supply of grassland seeds is being augmented by the fresh seeds that are ripened by the surface vegetation and are gradually carried down into the soil. Naturally enough, the greater number of these seeds are found in the upper inches of soil, comparatively few penetrating below the eighth inch.

Such fields as Barn Field Arable and Agdell show clearly how close is the connection between the methods of cultivation and the supply of weed seeds that become buried in the soil. Continual cultivation for roots, as on Barn Field, keeps most of the weeds from seeding and so prevents the accumulation of large stores of seeds in the soil. On the Agdell plot it is probable that many of the weeds have become starved out, or so impoverished that their seeds are not strong enough to survive for any length of time. Neither of these instances, however, is at all normal, as they are the result of experiment and not of ordinary farm management.

From consideration of the results of the above experiments it may be concluded that the case for large crops of charlock, poppies or other arable weeds appearing when real old pasture is ploughed up must still be regarded as not proven. These particular weeds were not obtained in the soil from old pastures, nor were they present when the land had been under grass for nearly sixty years. Nevertheless it is evident that under suitable conditions the seeds of some weeds are able to lie dormant at various depths in the soil over long periods, and to start into activity if and when the method of cultivation is so changed that they are brought nearer to the surface into the presence of the right combination of warmth, air and moisture. Consequently, the large crops of weeds that appear when temporary pasture is ploughed up must be regarded as being derived from seeds buried in the soil, and not from seeds transported from other areas by external agencies.

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