SOIL FERTILITY STUDIES IN AYRSHIRE.

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INTRODUCTION.

The importance of high fertility in soils for wartime cropping has become more and more apparent during the last three years. It has been obvious during seasons 1940, 1941 and 1942 that the soils in which fertility had been accumulated under pasture, properly manured and managed over many years, have been giving high crop yields, while neglected land has been yielding poorly, even with moderate manurial dressings. The fertile land has continued to yield heavy crops over these three years with little in the way of manurial treatment. The Land Fertility Scheme introduced under the Agriculture Act, 1937, was an endeavour by the Government to raise the fertility of arable and grass lands by encouraging farmers to apply dressings of lime and basic slag. Many farmers who had previously been advised that their soils were suffering seriously from lime and phosphate deficiencies took advantage of this Scheme, promoted in the interests of national security to meet the exigencies of war or other emergency. Others who, having recognised the serious needs of their soils in these respects, had adopted the practice of applying basic slag to the land under turnips, and lime to this land sown out with grass seeds in the following year, were induced to undertake more ambitious liming and slagging programmes. Thousands of samples of soils taken in Ayrshire by the writer before the outbreak of war, as well as by Mr. C. Louden and Dr. Whittles of the West of Scotlamd Agricultural College Chemistry Department during a soils survey in 1927 - 29, had demonstrated how deficient in lime and phosphate most of these soils were. The potato growing soils were the only ones in which satisfactory phosphate figures were found,

but their lime requirements were even greater than those where the land was cropped on a longer rotation system and less intensively manured. Most of the soils sampled by the writer had pH values of around 5.0, and a number were even under 4.0, especially on potato-growing and moor-edge soils. On one such potato soil, the 'good' section of the field had a pH value of 4.29, while those spots in this section where the potatoes had failed to meet in the rows showed a pH figure of 3.98, and the 'poor' section of the field returned 3.46: needless to say the potato yield on this field was poor. Previous to 1937, it was very seldom that a pH value as high as 6.0 was encountered even on recently-limed fields on those Ayrshire farms, which were generally acknowledged to be very well managed.

It was also found that the 'available phosphate' figure could only be raised in most Ayrshire soils by very heavy applications of phosphate, accompanied by liming, thus apparently indicating the tendency for phosphate-fixation to occur readily in Ayrshire soils. Serious deficiency of potash was not so widespread, though very high figures were seldom found. Low potash figures occurred most readily where increased production had resulted from applications of basic slag and lime, and higher yields of clovers and other plants containing higher percentages of potash, had drained away the potash reserves. For many years most of the manurial mixtures supplied by merchants to Ayrshire farmers for arable crops and grass contained only 3% potash (K_2O), which was only a fraction of what the crops were removing. As, owing to the high rainfall on the higher-lying farms of the County, the soils appeared heavy and difficult to work, the fertiliser manufacturers and manure-mixing firms had wrongly assumed that these soils were clay soils with potash reserves and that there was little need for potash applications. The chief need of neglected was, therefore, apparently phosphate, and the chief need of potato-growing soils and others under a short rotation seemed to be lime. These facts were impressed on the farmers of Ayrshire by the writer, as Agricultural Organiser for the County,

and between 1930 and 1939 many farmers had set about remedying the deficiencies of their soils in the interests of production, even although little financial benefit was apparent. This, combined with the use of large quantities of imported feeding stuffs, had resulted in many dairy farms being in high condition at the outbreak of war in September, 1939.

OBJECT OF STUDY.

In undertaking these studies, my object was to determine to what extent the application of certain chemical manures influenced the fertility of soils in the South-west of Scotland. It was obvious to the observant person that even on soils of similar origin and texture, the fertility (capacity for producing crops and/or pasture) varied greatly according to how these soils were treated with certain chemical substances used as manures in the growing of crops and pasture. Even although maps have been prepared by the Geological Survey showing the distribution of the various types of superficial deposits according to their origin, and soils have also been classified according to their texture, production has been found not to be closely related to type, but obviously was determined by the chemical substances added either for the nutrition of the plant or the improvement of the soil. It had also been established by Stapledon (1) and others that the type of herbage produced by a soil was an indicator of the fertility level. "To a very real extent grassland is singularly independent of the virginal character of the soil.... Good management and adequate manuring can lead to the development of tolerably good grassland on any soil which Great Britain has to offer..... Management or mismanagement has made our grasslands what they are." At the higher levels of fertility, ryegrass, cocksfoot, timothy and white clover were dominant, while at the lower levels nardus and agrostis predominated, holcus being intermediate. This conclusion was confirmed by the fact that the former types of pasture ploughed produced heavy crops, while the latter types of sward ploughed down gave poor crop yields. The main object of the

study was, therefore, to determine how good grass, the chief crop in normal times onthe dairy farms of South-west Scotland, can be secured and maintained, and to make observations on the crop yields preceding and following the establishment of such grass.

SOILS OF AYRSHIRE.

As pedology is only of recent development in this country, and so far no comprehensive study of this kind has taken place in Ayrshire, our knowledge of Ayrshire soils from that standpoint is limited. While on the hills and moors of the county the soil profile may be more or less developed, on the soils at lower altitudes (and of greater agricultural value, generally) cultivation at shorter or longer intervals interferes with the formation of the various soil profile horizons. While on inland farms much of the land lies for a long time under grass, grass cannot be regarded as natural to the area, as so little of the soil lies directly on limestone (or chalk), to which alone grass is deemed natural. In the middle ages, in common with other parts of Britain, large parts of Ayrshire were covered with woods, scrub and heath,(2) through which the cattle and pigs roamed (3). Under natural conditions many South-west Scotland inland soils were subject to impeded drainage, and their use for agricultural purposes only became possible under a system of artificial drainage. During the eighteenth century, before artificial drainage was introduced, the higher drier lands on the hills were cultivated, as the lower lands were swamp and bog (4). Many of our soils on the higher ground ground under natural conditions show podsolic characters with, in some cases, accumulations of masses of peat. Gley soils with impeded drainage due to an impervious stratum often within two feet of the surface are characteristic of much of the land which, owing to the development of artificial drainage, are normally under grass, but which originally were swamp, marsh or wet woodland, and which under unfavourable conditions (wet seasons, etc.) are still liable to revert and grow rushes. In the permanently waterlogged zone at the bottom

of the profile the iron compounds reduced to the ferrous condition give grey and bluish-grey soil colours. Brown earths constitute some of the better cropping soils of the county.

Soil properties are largely dependent on the properties of the constituents as well as on external factors, such as climate, slope, drainage conditions, etc. The largest soil particles, over 2 mm. in diameter, are mainly rock fragments, while those between 2 mm. and .002 mm. in diameter are generally composed of rock-forming minerals, the portion above .02 mm. being commonly termed sand, while that between .02 and .002 mm. is referred to as silt. The particles under .002 mm. constitute the clay fraction, of different composition and with special properties, largely due to the great development of specific surface, and its bearing on the retention of moisture and soluble plant nutrients and on the supply and movement of the soil air. In this connection the development and maintenance of 'crumb-structure' is of prime importance.

The humus or organic matter content, largely derived under natural conditions from plant residues by the action of micro-organisms in the soil, has also a marked effect on soil properties. The clay-humus association - the colloidal complex - reacting with bases, chiefly lime, profoundly affects the character of the soil - its moisture supply, aeration, structure, etc. - and its acidity, which is expressed as its pH, the negative logarithm of the hydrogen ion concentration of its aqueous suspension. As the exchangeable base content of a soil falls the lower the pH figure becomes. Since calcium accounts for approximately 80% of the reaction value of the exchangeable bases in normal soils, a close relation subsists generally between the pH and exchangeable calcium in soils with the same type of colloidal complex. The application of calcium carbonate or calcium hydrate is accordingly the most common and most satisfactory method of raising the base status and pH of a soil. Soils with high base status in which the principal saturating cation is calcium are generally most satisfactory from the agricultural standpoint, maintaining a granular structure with good aeration and free percolation of water, and avoiding differentiation into

horizons and losses of humus by leaching. Soils containing much clay must be kept well supplied with humus and lime, if the range in moisture content between the plastic wet condition and the dry cohesive condition is not to be too narrow. It is only within this range that clay soils can be satisfactorily cultivated. Excessive moisture is often present in such soils and interferes with the air supply therein and their working, which if performed under wet conditions expels the soil air and puddles the clay. Excess of moisture may be removed by underground tile drainage, much of the excess of soil water due to heavy rains moving along the surface of the undisturbed layer to sink through the disturbed layer overlying the drain tiles.

Plant growth is dependent on light, presence of carbon dioxide, a suitable temperature, a supply of moisture and oxygen, presence of the necessary plant nutrients, absence of injurious substances, a suitable soil reaction and base status (without excessive concentration of hydrogen-ions in the soil moisture) and a satisfactory roothold. The optimum temperature, water supply, plant nutrient concentration and soil reaction are different for different species of plants.

The lithological character of the parent material affects the soil composition and character, and the properties and vegetation of the resulting natural soils. Their conversion to agricultural purposes is dependent on how far their deficiencies for crop or pasture production can be eliminated by various measures, including the provision of artificial drainage, replacement of bases lost to the surface soil through leaching, and maintenance of soil structure, humus content and soil condition.

Though Ayrshire soils generally have not arisen directly from the underlying rocks, but have been greatly affected by glacial drift, raised beaches, alluvium and blown sand, the influence of the underlying geological formations and their lithological character is more marked in certain parts of the county.

A study of the geology of Ayrshire shows that the older sedimentary rocks occur in Carrick in the south of the County, south-east of the Southern Uplands Fault, and belong to the Ordovician and Silurian systems. North-west thereof and forming the

northern part of Carrick lies the Old Red Sandstone. The Carboniferous series occupies most of the Kyle division, apart from an Old Red Sandstone area between Muirkirk and Galston, and the area between Mauchline, Tarbolton, Trabboch and Ochiltree occupied by Red Sandstone of the Permian System. The Carboniferous series also occupies most of the Cunningham division, apart from the Igneous rocks in the North-west parishes and along the County boundary between Lugton and Darvel. Igneous intrusions also occur elsewhere throughout the County.

Geology, with consideration to lithological variations, topography and climate are all of importance in classification of soils, the relative importance of each varying with the country. Climate has been emphasised in Russia, but geology is of greatest importance in Britain (5). The sedimentary rocks of the Ordovician and Silurian systems give rise to brown earths in lowland areas: under high rainfall and drainage impedance, gley soil areas result. On uplands shallow truncated podsols, peat podsols, meadow soils and mountain peats are produced. The Old Red Sandstone and the New Red Sandstone series normally give rise to brown earths, from which have come the best agricultural soils in the county. The soils derived from the Carboniferous sedimentary rocks are generally heavier in texture and suffer from drainage impedance. The soils on the Carboniferous Limestone in Ayrshire have generally suffered calcium losses from the surface layers by leaching. As a rule, the soils overlying the Carboniferous series are heavier in texture than those overlying the other formations, and consequently the soils of Carrick are lighter in texture than those of Kyle and Cunningham.

Large areas of peat are found on the moors lying at the higher altitudes and towards the County boundaries; over much of Carrick they overlie granite. In the North peat generally overlies clay. Only small areas of such soils are well drained and under cultivation. Along certain parts of the coast, chiefly between Ayr and Ardrossan, the soils consist of coarse sand with poor retentive powers, and are of little agricultural value; elsewhere the constituent material of the sands is finer-

grained, and the soils are valuable for potato-growing. There is a soil range through light and heavy loams up to soils which, with an annual average rainfall of 45", may be termed clays, though not so intractable as the real clays of the South-eastern Counties of England, but which must be intelligently worked under dry conditions.

The soils of greatest agricultural value in Ayrshire, in common with other parts of Britain, have been largely affected by human interference. Owing to the heavy rainfall leaching of the surface layers continually takes place. Production of grass and arable crops can therefore only be maintained by replacing the bases eluviated from the surface. If the rate of replacement is too slow, arable crop and grass yields fall greatly, and grassland under extreme conditions may revert to rough grazing or even to heath. Soil fertility can be increased through providing artificial drainage, replacing bases leached out, and supplying the nutrients necessary for plant growth. The humus and nitrogen content of the soil can be improved by leaving land down in pasture for a period, whereby leaching of bases is also much reduced. The application of farmyard manure keeps up the humus content of soils while under crop and maintains soil structure, thus contributing to stability and thereby opposing the natural tendency of reversion to heath, forest and swamp.

Sufficient attention has not been given to this question by farmers, who have failed to appreciate the need for replacing losses through leaching by getting land down to grass, which will check further losses of bases and increase the humus and nitrogen content of the soil, the loss of bases and nutrients previously suffered being made good by the necessary suitable dressings. Neglect of such precautions, due to the lack of knowledge on the part of those managing the land, has resulted in consequent poor establishment and rapid deterioration of grasslands after sowing out on completion of the cropping period of such soils.

The fact that much land in Ayrshire (and other parts of West Scotland) was apparently producing less than its maximum both under pasture and arable crops was continually impressed on me as Agricultural Organiser for Ayrshire. After giving

full consideration to the matter, I concluded that on most South-west Scotland soils it should be possible to make arable cropping of the soil a preparation for good pasture and to establish and manage good pasture so that it would benefit arable crops grown later.

Though the soils varied in their origin and composition, so long as they suffered from drainage difficulties on account of various causes, including often the presence of an impervious layer within two feet of the surface and overlain by a soil with a low proportion of coarser particles, and a rainfall which generally exceeded (often considerably) 40 inches per annum, it was impossible by practicable methods, including tile drainage, to devote them continuously to arable crops. On the other hand, more freely draining soils of coarser texture can, under the humid western climatic conditions, be kept under continuous cultivation, so long as the humus content is maintained under skilful management. The soil texture of the first two feet and the rainfall and altitude have accordingly determined to a large extent whether a soil could be kept regularly under arable crops or if it should be chiefly devoted to grass. The following is a description of the soils in the various parts of Ayrshire from that standpoint.

In Ballantrae parish and the western part of Colmonell the arable land consists almost wholly of sandy soils and light loams, while in the eastern part of Colmonell parish more mixed soils with peat and occasionally clay prevail. Barr, the largest parish, and almost 94% rough grazings, also contains mostly lighter soils, with high organic matter and defective drainage. Girvan arable soils range from sands at sea-level to loams at 600 feet, the latter being naturally poor. The Dailly soils range from very light loams in the Girvan valley to heavy loams further inland on a few higher-lying farms adjoining the South Ayrshire Collieries. Kirkoswald parish shows a wide range of soils from blown sand near Turnberry to heavy loams on its south-eastern fringe. Maybole parish in its north-western corner has high ground comprising

both freely draining soils and peat overlying igneous rocks. The lower lands range from very light loams on the shore to heavier loams further inland. The Kirkmichael soils are similar, while the Straiton soils, still further inland, show light loams in the Girvan valley and on the lower slopes, and peat overlying granite on the higher hill land and moors, which occupy a large proportion of the parish.

On the north bank of the Doon, the soils are heavier, light loams being absent even in the valleys in Dalmellington parish, where the coal measures underlie most of the local soils. The soils of Dalrymple and Coylton and of the south-eastern portion of Ayr parish are also heavier loam types, apart from small areas of stonier land on the higher ground, chiefly near the Craigs of Kyle. Adjoining the town of Ayr, north-east thereof, and occupying the greater part of Monkton parish, are alluvial soils comprising heavy sands and loams. The soils of Stair parish range from free-draining loams near the river Ayr to heavy, poorly drained loams towards Ochiltree. Ochiltree and Cumnock soils are mostly heavier loams, except near the Lugar water, where light loams occur. In New Cumnock and Muirkirk parishes the soils are generally lighter than in Cumnock, with some peat on the higher ground. The Auchinleck and Sorn soils are mostly heavy loams, badly drained on many farms. The Mauchline and Tarbolton soils are mostly lighter loams, except where they border Sorn, Auchinleck and Craigie parishes, where they are heavier. Craigie, Symington, and the adjoining parts of Monkton, Dundonald and Riccarton consist of heavier loams. The greater part of Dundonald, Irvine and Stevenston parishes consists of sandy soils, with light loams on their eastern borders and extending eastwards up the Irvine valley through Dreghorn, Kilmaurs and Riccarton parishes. The Kilmarnock and Fenwick soils are mostly heavy loams, while the Loudoun and Galston soils, especially on the east side, are lighter loams and heavy sands, due to the effect of the Darvel raised beach. The Stewarton soils are heavy loams, while most of the Dunlop soils, due to igneous intrusions, are lighter in nature. Between Beith and Kilwinning lie the heaviest soils in the county with a very stiff clay subsoil and interspersed in places with peat, which extends

into Stewarton parish. Heavy loams are typical of the north-eastern portion of Ardrossan parish, and the north-western portion of Kilwinning parish. Westwards and northwards from Dalry the loams become lighter, due largely to the effect of the Old Red Sandstone formation and the igneous rocks which occur in the north-west corner of the County, including Largs, Kilbirnie, West Kilbride and parts of Ardrossan and Dalry parishes.

CLIMATE.

The climate and rainfall are favourable to the growth of arable crops on the lighter soils and militate against the cropping of the heavier soils, especially in a wetter-than-normal season. They also assist the establishment and maintenance of pastures even on the lighter soils, as even the drier districts have an annual average rainfall of almost 40 inches.

The average annual rainfall varies from 35 inches on the coast between Ayr and Irvine to over 80 inches on the heights on the Kirkcudbrightshire border, the cropping area being mostly included between the 35 and 45 inch isohyets. An annual rainfall of over 50 inches is experienced on the cropping areas on the upper reaches of the Girvan and Stinchar valleys, as well as in parts of Kilbirnie and Beith parishes, due to the proximity of the hills to the arable land of the narrow valleys. Even in the driest three-month period, April to June, 6 inches of rain can be expected near the coast, and more further inland, and accordingly neither arable crops nor grass are likely to be seriously affected by drought. The mean temperature near sea-level for the County varies between 39°F in January and 58°F in July, with an average of 48°F. for the year; at the 750 foot contour above which there is little cropping the mean temperature is approximately two degrees lower throughout the year. Generally speaking, the climate of Ayrshire is mild and moist, favourable to the growth of grass, and making the seeding and harvesting of arable crops difficult on the heavier loams, especially in the higher-lying districts.

SOILS AND AGRICULTURE.

In Ayrshire as a whole, if the coarse sands with poor retentive powers and forming a belt of varying width along certain parts of the coast, especially in North Ayrshire, and contributing to the golf courses and sand dunes, are excluded, the most valuable cropping soils are in the lighter texture groups. The heavy sands and light loams at a low elevation are the most productive soils and, when well farmed, commonly give yields of 15 tons potatoes or 2 tons oats (grain) per acre. The high fertility of such soils often results in yields of 2 tons wheat (grain) per acre, though wheat is normally regarded as a heavy land crop. The normal yields of all crops fall with a rise in elevation, even when the soil character remains unchanged. In the most upland parishes potato yields may not exceed 5 tons per acre, and oat grain yields may only slightly exceed 10 cwts per acre. This fall in yield is accentuated with the heavier-textured soils, and is apparently due to the lower temperatures, higher rainfall and wetter soil conditions prevailing at the greater altitudes. Arable farming ceases at a much lower altitude on the heavy soils in a wetter climate than on the free draining soils where the precipitation is less. There is very little cultivation beyond the 400 foot contour on the Beith-Kilwinning heavy soils of the Carboniferous series while cultivation is continued on the lighter New Cumnock and Irvine valley (raised beaches) soils up to almost 1000 feet. Conversely, the heavy soils lying only a short distance inland and at a low elevation in Kirkoswald parishes, and with a lower rainfall than prevails further inland, are more easily worked and give higher crop yields than similar more inland soils, subject to greater precipitation.

In field examination of soils it naturally takes less time to classify soils according to their behaviour under cultivation, and chiefly resulting from textural and structural differences, than according to the constituent materials, which can only be determined by microscopic examination and chemical analysis in the laboratory. It is probable that the chemical composition of the constituent particles may have a considerable influence on the agricultural behaviour of soils and a report (6) pub-

lished on such a study of South Ayrshire soils, shows that the Highland and Southern Upland Glacial Drifts have deposited soil particles of differing specific gravities and chemical constitution in the fine sand portion of various soils. The meeting point of these Drifts appears to be along a line extending from Girvan to Maybole, thence approximately two miles south of Dalrymple and similarly south of Cumnock to the Dumfriesshire border. It is reported that the ferromagnesian group percentage in the fine sand of the Northern Drift is 4.6 as against 2.1 in the Southern Drift. The apparent relationship of the incidence of raan, the result of boron deficiency in swedes, to the deposition of these Drifts has been discussed by Dennis and O'Brien (7). As already mentioned, factors also influencing greatly the behaviour of the soil are the depth of the cultivated area and the nature of the underlying layers as well as drainage conditions, both natural and man-provided. In the case of sandy and alluvial soils, differences in texture between soil and subsoil are slight, while in the case of heavier types such differences are often considerable, as shown by the following typical mechanical analyses figures obtained by the older method standardised (in 1926) by the Agricultural Education Association and quoted by Berry and others in the 'Soils and Agriculture' section of the Geology of North Ayrshire (8):-

Ref. No.	356		350		76		55		317		325	
Type	Light Sand;		Heavy Sand;		Light Loam;		Medium Loam;		Heavy Loam;		Clay.	
	Soil	Subsl.	Soil	Subsl.	Soil	Subsl.	Soil	Subsl.	Soil	Subsl.	Soil	Subsl.
Coarse sand	85.76	85.00	42.70	41.70	23.35	23.97	17.99	19.63	9.43	5.34	4.16	3.33
Fine sand	7.86	11.71	18.40	18.18	19.30	19.50	18.70	15.80	20.50	18.90	13.16	8.08
Silt	.19	.12	11.10	11.77	10.65	11.85	11.38	11.83	11.23	10.74	14.88	6.64
Fine silt	.17	.16	10.88	10.60	12,83	13.18	13.55	15.18	19.80	15.57	21.57	21.03
Clay	.08	.07	1.19	1.22	15.83	16.50	20.70	22.50	21.60	41.80	25.30	50.50
Moisture	.45	.34	3.62	1.47	5.28	4.72	5.25	5.12	4.40	4.60	5.65	4.69
Ignition loss	1.61	1.13	9.97	10.26	9.81	7.42	11.07	8.97	14.97	9.12	14.27	10.46

In the above table only nos. 317 and 325 show considerable difference between soil and subsoil; that such differences are occasionally less for heavy loams is shown by the figures which follow, most of which are from the same locality as nos. 317 and 325.

Ref. No.	314		320		323		211	
	Soil	Subsoil;	Soil	Subsoil;	Soil	Subsoil;	Soil	Subsoil.
Coarse Sand	11.99	9.08	3.42	8.36	6.58	6.31	7.27	5.84
Fine Sand	13.68	11.25	20.12	19.76	13.88	14.18	11.35	10.80
Silt	8.68	8.15	11.88	11.55	10.45	10.55	12.25	16.40
Fine Silt	19.49	21.05	23.70	19.50	23.35	22.08	19.95	23.60
Clay	26.84	39.35	20.00	31.40	29.03	34.35	25.30	24.05
Moisture	5.04	4.76	4.13	3.98	5.33	4.92	8.94	9.18
Loss on Ignition	16.97	10.97	10.84	8.82	15.02	11.20	11.97	10.15

In the case of no. 211 the differences in texture between soil and subsoil are small, and in the case of no. 320 the effect of additional clay in the subsoil is offset by additional coarse sand therein also.

Not only is the tractability of the soil to cultivation affected by the immediate subsoil, but it is also largely dependent upon the nature of the deeper layers and the facilities for drainage especially in the wetter districts. There are soils in the Beith and Symington districts which in the top 6" would be classified on account of the constituent particles as medium loams, but which, due to the shallow depth at which impermeable clay occurs and their drainage difficulties, behave like very heavy loams when under cultivation. On the other hand, the deep alluvial soils with little change in character to depths of three feet or more, behave like lighter soils than the top 9" would suggest. Where soils are shallow, the tendency is for them to remain under pasture, ploughing being only resorted to when there appears no other satisfactory method of improvement. This is especially the case at high altitudes and in wetter regions.

FARMING PRACTICE.

On the cropping parts of the coastal area early potatoes are grown, often continuously on the same land, with liberal applications (around 15 cwts. per acre) of mixed artificial manures in addition to dung or sea-weed dressings. The very light low-lying sands between Troon and Stevenston, liable to late frosts, are not suitable for early potatoes. The light loams in the Monkton - St. Quivox, Irvine valley and Girvan valley areas are most suited for continuous cropping and only lie a short time

in grass. A high proportion of potatoes is included, this crop being generally grown more than once per rotation, and good crops of oats and occasionally wheat are grown. A typical rotation is potatoes (after pasture or hay), wheat or oats, potatoes and roots, oats, hay or pasture; a dressing of dung is generally applied to the second potato crop. Around 12 cwts. artificial manures per acre are applied to the potatoes and roots, and 3 - 4 cwts. to grain crops and hay, a 20 - 30 cwts. per acre lime dressing being often now applied along with the grass and clover seeds. Typical manurial mixtures contain in normal times approximately 1 part sulphate of ammonia, 2 parts superphosphate, and 1 part potash salts. In the Carrick division as well as in Tarbolton, Mauchline, Largs and West Kilbride parishes, practically all the cultivated land is under a root or cleaning crop at least once per rotation. The typical rotation is roots, wheat or oats, hay, pasture for several years, oats. Manurial mixtures are similar to those already referred to, though the need for nitrogen after pasture is less. The hay crop is sometimes used for the production of ryegrass seed, especially at the lower elevations. In many of the inland parishes only small areas are put under turnips or kale as a cleaning crop, the remainder of the land being sown back to grass without the interposition of a cleaning crop. Though a crop of ryegrass seed is sometimes taken, crops in these districts are seldom grown for sale, but are limited to the area necessary to maintain a dairy herd. The proportion of land under arable crops in 1939 on such farms did not as a rule exceed 12% of the arable area, the land selected for ploughing having reached the stage at which ploughing appeared advisable for the purpose of renewing the grassland. Milk production on many such farms was only maintained at a high level through the purchase in normal times of large quantities of cheap imported feeding stuffs, which were less costly than oats or other feeding crops produced on the farm. Even although in North Ayrshire upland dairy farm rents were high in relation to the natural value of the land, many farmers were spending on purchased feeding stuffs for dairy cattle, sheep, pigs and poultry during the decade preceding 1939 an annual sum equal to several times their farm rentals. There were

many farmers whose daily milk production during the winter months was equal in gallons to the number of acres on the farm. Such high milk output could not have been achieved with the crop and pasture production of the farm alone. The residual values of purchased feeding stuffs were accordingly contributing to the fertility of many farms, the benefit being greatest where liming of the land had also been adopted as a routine procedure.

SOILS ON WHICH SPECIAL INVESTIGATIONS WERE CONDUCTED.

My studies have been chiefly conducted on soils which constitute the farm lands of Ayrshire. Here, as elsewhere in Britain (9), typical agricultural soils show disturbed profiles. Though strongly developed profiles are uncommon, the increase in clay content in passing from soil to subsoil is observed in most inland soils, which have not been derived from alluvium or raised beaches. All soils apart from those included under rough grazing, scrub, etc. are ploughed at shorter or longer intervals and occasionally receive manurial treatment while under pasture, with the result that the various natural soil horizons are not afforded an opportunity to develop. Nearer the coast the more freely draining soils, generally raised beaches or alluvium, which are almost continuously under arable crops with intensive manuring, and are well aerated to considerable depths, cannot develop horizons owing to the consequent mixing of surface and lower layers by deep cultivation.

The coarsest textured soil for which reports on experimental and investigational work are included later herein was at Hunterston, West Kilbride, which is typical of the lightest soils, derived from raised beaches, that can be maintained continuously under arable crops. Mechanical analysis of such a soil shows generally less than 15% clay and silt and under 15% fine sand, the remainder being coarse sand and larger material. The good cropping land, represented by the Morriston soil, shows around 20% clay and silt, 25% fine sand, and the balance as coarse sand. Differences in these groups between soil and subsoil are slight. Burn, Hill of Barnweil, Glenside,

Carbello, Knoweside and Genoch soils on mechanical analysis fractionate approximately as follows: 30% clay and silt, 40% fine sand and 30% coarse sand. Differences between soil and subsoil are more apparent. The remaining soils on which investigational work is later reported, Hunterston (Stair), Holehouse, Carston, Cairnston, Bardarroch, and Brackenhill show a higher proportion of the finer constituents, viz. approximately 40% clay and silt, 40% fine sand and under 20% coarse sand. The soils on these farms are typical of those of the majority of Ayrshire dairy farms.

The Brackenhill profile, which in common with others referred to is periodically disturbed by cultivation, shows a chocolate-coloured layer to a depth of 9", a more cohesive reddish-coloured 6" layer, followed by a bluish-grey cohesive 6" layer, underlain by at least 24" of a reddish-brown cohesive layer with various blue, green and red markings. The original tile drains have been mostly laid at a depth of 3½ feet. Though tile-drained such a soil tends to be wet in a wet climate, as the movement of water through such a soil is slow. During continued wet weather the various soil layers in turn approach saturation point. The surface layers first become saturated, and the excess water gradually sinks to the lower layers, a considerable period elapsing before the deeper layers are as wet as the surface. When drier conditions return in the spring, the surface first dries, often becoming very hard before the deeper layers are sufficiently dry for cultivation. It is very difficult therefore to establish and maintain good physical condition on such soils for the seeding and growth of arable crops, especially in a humid western climate, and in normal times arable cropping of such soils tends to be restricted to the minimum.

PHOSPHATE-FIXATION AND AVAILABILITY.

It has been found through numerous analyses of Ayrshire soils that the phosphate figure returned as 'available' to crops is generally low. The only soils on which high P_2O_5 figures are normally obtained are soils subjected to continued heavy manuring as on early potato soils. On these latter soils no response is obtained with

phosphatic manure as compared with no phosphate. On the other hand, there have been many experiments and experiences on Ayrshire farms where little or no response to phosphate has been obtained on soils returning low 'available' P_2O_5 figures under the standard methods of analysis. Applications of even 2 cwts. per acre P_2O_5 in the form of high soluble slag have failed to produce any result on the crop or pasture, and a soil analysis made, say, a year afterwards shows little or no change in the 'available' P_2O_5 figure. It would appear that this supply of phosphate, though not extracted from the soil by the routine analytical methods adopted, is available to meet, under normal conditions, the requirements of the pasture plants or the arable crops being grown. To determine the relative values and availabilities of basic slags and other phosphatic manures, many experiments have been conducted in Ayrshire on soils with low 'available' P_2O_5 figures. On some of these remarkable responses to phosphate have been secured, the swede crop proving almost a complete failure on the plots to which no phosphate was applied (10). Yet, in the following year, without any phosphate application, an oat crop has been grown on the 'no phosphate' plot practically equal in yield to that on the plots liberally dressed with phosphate. It would appear, therefore, that soil phosphate not available the previous year for the swede crop on the 'no phosphate' plot had become available for the oat crop. It may be that there is a supply of phosphate in many soils loosely fixed and more available to certain crops than others, and that this supply is due to previously applied phosphate, which has gone into some form of combination with certain soil constituents. In the soils with low 'available' P_2O_5 figures, where no response to phosphate on the swede crop was obtained, the 'no phosphate' plots giving normal yields, a loosely combined phosphate supply, which can be utilised by the swede crop, though not detectable by routine analysis, must necessarily be present.

The difficulty of recovering in the crop phosphate applied, even on definitely phosphate-deficient soils, is shown by the fact that even when limited dressings of high soluble basic slag were applied to the swede crop, the percentage recovery was

not appreciably higher than where liberal dressings of the same slag were given, and seldom exceeded 20%. The P_2O_5 recovery figure for low soluble slag seldom exceeded 10% on these same Ayrshire soils. These low recovery figures are common elsewhere in Britain, and are quoted in the reports of the Permanent Committee on Basic Slag (11). Hanley has also reported (12) on the low recovery figures at Cockle Park, Northumberland, and refers to the fact that heavy initial phosphate dressings appear necessary to produce results on grassland and that, in later years, periodic dressings are necessary to maintain the improvement though only 8% of the P_2O_5 applied has been recovered in the herbage, and the remainder is present in the surface soil layers.

A study of the 'available' P_2O_5 figures returned for certain Ayrshire soils where the previous treatment was known in addition to the pH value shows that the P_2O_5 figure tends to be higher where the pH approaches the neutrality figure of 7.0. This would suggest that phosphate fixation takes place most readily in acid soils. In addition to apparently reducing phosphate fixation, lime applications probably bring into the 'available' condition, as detected by routine analytical methods, P_2O_5 previously applied. This action of lime seems to have been expressed in the old couplet:

'Lime and lime without manure
Makes both farm and farmer poor'.

RESULTS OF PREVIOUS INVESTIGATIONS.

Over forty years ago the importance of phosphate in the form of slag for the improvement of old grassland had been demonstrated by the Cockle Park experiments in Northumberland (13). Stapledon also in his work "The Land Now and Tomorrow" continually stresses the importance of phosphate and lime in raising the soil to a higher fertility level. He also found under Welsh conditions that a "sensible" seeds mixture had a decided advantage over a haphazard mixture (14). The best seeds mixture was that consisting of special grazing strains bred at Aberystwyth. H.I. Moore found in Yorkshire (15) that phosphate and lime were important, but that a commercial seeds mixture was as efficient as a special pedigree mixture of grazing strains. John Orr's

results (16) in North-west England had demonstrated that ploughing down useless pasture and reseeding, supported by liberal phosphate and lime dressings, increased fertility several fold, and gave high returns for the financial outlays incurred. The Jealott's Hill demonstration plots, laid off and managed by Martin Jones (17), had shown that pasture type was influenced not only by chemical treatment, but also markedly by grazing management. Nearer home - the writer's experiments 1924 - 26 at Hunterston, West Kilbride (18) had demonstrated the importance of lime on soils with a very low pH value (under 4.0) for successful crops of all kinds, including potatoes - a crop which thrives best in a somewhat acid soil - but more especially for pasture. Pasture also benefitted from lime applications at Morriston, Maybole, where the pH value was under 5.0: under such conditions lime only slightly increased potato yields. Experiences on other demonstration areas and farms in higher-lying districts had suggested that applications of both phosphate and lime were required in order to secure and maintain good pasture. Good pastures seemed to prevail only on the few farms limed and well-phosphated: good areas in a field contrasting strongly with the remainder had generally been limed and/or dressed with basic slag. The scarcity of first-class pastures in a part of Ayrshire and the rapid deterioration of newly sown-out grassland is commented on by Sir R. George Stapledon (19), who had an examination made of 3,340 acres of Central Ayrshire dairy pastures with the following results:- 4% was in Molinia pasture, 51% was Agrostis (without ryegrass), 16% agrostis-dominant with ryegrass, and 3% ryegrass pasture; 6% contained considerable quantities of rushes. Yet 12% of the land was in arable crops and 6% in new seeds. He suggests this rapid deterioration as due to the non-use of grazing strains of ryegrass and the taking of heavy hay crops in the early years of the leys. My observations had suggested the phosphate and lime status as important factors. Under depressed conditions many farmers were unwilling to incur additional expenditure for phosphate and lime, and I had advised the use of 'basic' manures during the rotation. These comprising slag or mineral phosphate, calcium cyanamide or nitrochalk, plus potash salts bought separately cost less than

the merchants' mixed manure. These preliminary experiences referred to had suggested soil condition as the most important factor in securing good pasture. Seed mixture effects seemed to diminish with the age of the pasture, while liming and manurial effects became more evident. A.B. Stewart, Macaulay Research Institute, had found (20) that certain North of Scotland soils responded well to various forms of phosphate and lime for the various crops of the rotation, the lime effect on yield being specially marked. The effect of the different treatments on the percentages of phosphate, lime and potash in the crops was relatively slight, however. Experiments on the character of the sward of the effects of a complete manure containing lime, phosphate, potash and nitrogen, and of mixtures from which one constituent had been omitted, as well as from a control receiving no manure, were reported to the International Grassland Congress at Aberystwyth in 1937 by Heddle and Ogg(21). The effects of lime in checking agrostis was specially noted. The results of manuring on the botanical composition of continuous hay crops over a period of years was also reported at the same conference by Dr. Brenchley (22). Nisbet has also reported on the effects of lime on the establishment of perennial ryegrasses (23), and its influence on the composition of permanent pasture swards(24).

HUNTERSTON DEMONSTRATION AREA RESULTS.

On farms in the South-west of Scotland, where mixed manures containing a high proportion of sulphate of ammonia had been liberally used over many years for potatoes and other crops, and no lime applied, the pH value had fallen while, generally speaking, the available phosphate figure had risen considerably. Under such conditions soils, whose productivity had fallen especially in regard to root crops and grass, have had their production increased by the application of lime alone. On such farms grass seed mixtures have been observed to do badly when the pH value falls to under 5.0, while crop yields only fall to a slight extent. As the pH value drops further towards 4.0, all crops, even potatoes, suffer seriously in yield.

A very acute case of lime deficiency was encountered at Hunterston, West Kilbride, where a Demonstration Area of 7½ acres was maintained from 1923 to 1926. The pH value of the soil was 4.0, and no definite results were being obtained from manures, unmanured plots in 1923 equalling in yield those to which liberal manurial dressings had been applied. The cropping results have been given by the writer in a College bulletin (18), published in 1930. Lime was applied to five-eighths of the area in 1924 and to a further quarter in 1925. Liming (1 ton CaO per acre) in 1924 increased the yield of maincrop potatoes from 5.55 tons to 12.95 tons per acre; swedes were increased from 6.25 to 23 tons; and in 1925 the oat yield was raised from 9.5 to 14.25 cwts. grain per acre. In 1926 the hay yield on the unlimed areas averaged 16 cwts. per acre, and on the limed land 40.25 cwts. After the hay crop had been cut in 1926, the pH values were determined and found to average as follows:-

Unlimed.	1 ton CaO.	1¾ tons CaO.
3.86	4.59	5.43

A portion of the area hitherto unlimed was then limed, and a gradual improvement took place on this newly-limed section. The land lay under pasture till the end of 1932, when a number of botanical analyses were made with the following results on the various sections:-

	1¾tons CaO on roots;	1ton CaO on roots;	1ton CaO after hay;	Unlimed.	Mixture A 1ton CaO;	Mixture B 1ton CaO;	Mixture C 1ton CaO.
Lolium perenne	21	15	8	3	20	22	18
Dactylis glomerata	4	8	15	2	6	-	1
Phleum pratense	1	1	-	-	1	-	-
Festuca duriuscula	10	9	9	2	10	12	13
Cynosurus cristatus	21	19	16	7	22	23	25
Poa pratensis	12	11	11	4	12	12	9
Holcus lanatus	5	6	15	21	5	5	7
Agrostis spp.	5	6	10	58	2	4	5
Trifolium repens	19	22	10	1	20	19	20
Musci	1	3	4	-	2	3	2
Juncus effusus	-	-	2	2	-	-	-
Ranunculus spp. viz.	1	-	-	-	-	-	-
Useful plants	88	85	69	19	91	88	86
Inferior "	12	15	31	81	9	12	14

It is clear that the seed mixture effect is negligible in comparison with the

previous soil treatment. Particulars of the standard seed mixture used and of the other mixtures referred to are as follows (in lbs. per acre):-

	Standard;	A	B	C
Lolium perenne	14	8	26	6
Lolium italicum	6	4	10	18
Dactylis glomerata	8	8	3	6
Phleum pratense	2	3	1	2
Festuca elatior	3	4	1½	3
Avena elatior	-	5	2	-
Cynosurus cristatus	½	½	½	½
Poa pratensis	½	½	½	½
Festuca duriuscula	½	½	½	½
Trifolium pratense	3	3	3	2
" hybridum	1	1	1	1
" repens	1	1	1	1

On this land a potato crop was grown in 1933, followed by an oat crop in 1934 and potato crops in 1935, 1936 and 1937. On the unlimed strip each year the crop was much poorer than on the remainder of the land. Similar effects on crops of lime applied as much as 20 years earlier has been reported by Hanley (25). Oats were again grown at Hunterston in 1938 and grass seeds sown. The influence of the lime applied 14 years earlier was evident on the young seeds; the sward was much greener and had a higher clover content. In 1939 this lime effect on the hay was marked and certain observations and determinations were made on the hay aftermath in October, 1939. The results were as follows (lime treatment per acre in previous rotation indicated):-

Botanical Analyses.

	1¾ tons CaO roots	1 ton CaO roots	1 ton CaO seeds	1 ton CaO after hay	Unlimed.
Lolium perenne	38	25	36	38	10
Dactylis glomerata	30	32	35	32	17
Trifolium pratense	21	6	8	15	1
" hybridum	6	3	3	3	-
" repens	4	1	2	3	-
Holcus lanatus	1	8	4	-	8
Agrostis spp.	-	17	7	6	41
Rumex acetosa	-	8	5	3	23

Herbage Analyses (% in dry matter).

Nitrogen	2.24	1.52	1.82	2.03	1.51
P_2O_5	.910	1.07	1.07	1.07	1.11
CaO	1.04	.756	1.05	1.10	.445
Soil figures: pH	4.50	4.37	4.44	4.31	3.91
P_2O_5	41.4	34.5	31.3	42.3	33.3

The greatest residual value appears to be on the $1\frac{3}{4}$ tons CaO plot; 1 ton CaO after hay has produced a similar effect on the botanical and herbage analyses; the 1 ton CaO seeds is exerting more effect than the 1 ton CaO roots. The nitrogen and P_2O_5 content of the herbage on the unlimed plot is similar to that of the 1 ton CaO roots plot, but the CaO content is much lower, even although the CaO content of the 1 ton CaO roots plot is much lower than in the other limed plots. The herbage on the unlimed plot consists of a much higher percentage, viz. 72%, of inferior plants than on the limed plots, where the poorest plot is again the 1 ton CaO roots plot with 33% inferior plants. The pH value (3.91) of the unlimed plot is definitely lower than that of any of the limed plots.

MORRISTON DEMONSTRATION AREA.

The experience on Morriston, Maidens, where a College demonstration area was maintained by the writer during 1932- 36, is typical of those of many farmers, occupying similar cropping land. This soil was not so extremely acid as that on Hunterston, its pH value at the commencement of the trials in 1932 being 4.98. Lime applied at the rate of 1 ton CaO per acre increased the total potato yield in 1932 from 12.02 to 12.64 tons per acre, while the swede yield was raised from 17.35 to 29.15 tons, and the mangold yield was increased fourfold from 5.8 to 23.2 tons. In the following year this liming only increased the grain yield of the oat crop from 35.0 to 36.6 cwts. per acre. The average hay yield in 1934 was 55 cwts. per acre on the limed sections (from 53.9 to 58.8 cwts. for the various seed mixtures) compared with 37.2 cwts. on the unlimed sections. A botanical analysis made of the hays on the limed sections of the areas sown with certain seed mixtures, and on the unlimed portion, gave the following results in July, 1934, demonstrating that the proportion of ryegrass in the sward was higher and that of the holcus was lower where the larger seedings of ryegrass had been employed, and that the proportion of weeds was much higher and of the clovers lower, where the land had not been limed.

(S.M. = Seed Mixture: B.A. = Botanical Analysis)

	S.M. lbs.	B.A. %	S.M. lbs.	B.A. %	S.M. lbs.	B.A. %	S.M. lbs.	B.A. %	Unlimed S.M. lbs.	Unlimed B.A. %
Lolium perenne	14	31	8	19	20	40	26	57	14	35
" italicum	6	12	4	12	8	24	10	19	6	2
Dactylis glomerata	6	-	8	2	4	-	3	-	6	2
Phleum pratense	4	-	6	1	3	-	2	-	4	1
Cynosurus cristatus	1	7	1	2	1	1	1	5	1	1
Poa spp.	1	2	1	6	1	1	1	3	1	1
Trifolium spp.	4½	26	4½	13	4½	20	4½	14	4	1
Holcus spp.	-	21	-	41	-	14	-	2	-	35
Agrostis spp.	-	1	-	2	-	-	-	-	-	11
Rumex acetosa	-	-	-	-	-	-	-	-	-	11

A year later botanical analyses were again made with the following results for the various seed mixtures:-

	S.M. lbs.	B.A. %	S.M. lbs.	B.A. %	S.M. lbs.	B.A. %	6.M. lbs.	B.A. %	Unlimed S.M. lbs.	Unlimed B.A. %
Lolium perenne	14	29	8	20	20	27	26	27	14	-
" italicum	6	-	4	-	8	-	10	-	6	-
Dactylis glomerata	6	25	8	31	4	21	3	14	6	5
Phleum pratense	4	4	6	7	3	5	2	2	4	1
Cynosurus cristatus	1	3	1	4	1	2	1	2	1	-
Poa spp.	1	7	1	9	1	8	1	4	1	-
Trifolium pratense	3	5	3	1	3	4	3	5	3	2
" hybridum	1	-	1	-	1	-	1	-	1	-
" repens	½	22	½	23	½	25	½	27	½	4
Holcus spp.	-	5	-	4	-	6	-	15	-	9
Agrostis spp.	-	-	-	1	-	2	-	4	-	70
Rumex acetosa	-	-	-	-	-	-	-	-	-	9

The botanical analysis differences have become much less during the year, the only significant difference being the amount of cocksfoot present, which is approximately proportional to the amount of seed in the mixtures employed. Serious deterioration of the sward has taken place on the unlimed land, where weeds total 88% of the sward against 5% weeds on the limed portions sown with the same seed mixture.

Further observations and botanical analyses another year later, in September, 1936, showed no visible boundaries between plots sown with the various seed mixtures, and that all mixtures were giving almost identical swards where the treatments were the same; the percentage of ryegrass was around 28%, with the cocksfoot between 15 and 20%, on all the limed land. On the unlimed land the inferior plants had almost completely crowded out the useful types.

A section had been sown out with a seed mixture composed chiefly of grazing

strains of the various plants, but otherwise similar to the standard mixture already mentioned. The perennial ryegrass was Kent indigenous, the cocksfoot was Akaroa, and the timothy Aberystwyth S.50. The hay yield in 1934 had been identical with that of the standard seed mixture, in which Ayrshire perennial ryegrass, Danish cocksfoot and Scotch timothy had been included, and during 1935 and 1936 there appeared to be little difference in pasture yield between the two mixtures, though differences in appearance were visible at certain periods. It was accordingly decided that relative yields be ascertained by taking cuttings at intervals of four weeks during the summer of 1937. Three cuttings were made between May 14 and August 6 from sections of the grazing strains plot and two adjoining commercial strains plots, and the yields and chemical analyses of the herbage determined. Plots of 120 square feet were employed, and the following table gives the calculated herbage yields per acre and analytical results:-

	Commercial Strains A.		Grazing Strains.		Commercial Strains B.	
	%	Yield	%	Yield	%	Yield
Total crop	-	131.6 cwts.	-	130.0 cwts.	-	130.0 cwts.
Moisture	77.50	-	77.40	-	77.50	-
Ether extract	.81	1.07	.83	1.08	.85	1.17
Albuminoids	4.95	6.52	4.74	6.36	4.72	6.14
Crude fibre	4.20	5.53	4.05	5.27	4.12	5.36
Ash	2.05	2.70	2.10	2.73	2.09	2.72
Sol. carbohydrate	10.49	13.81	10.83	14.14	10.72	13.94
True protein	4.20	5.53	4.08	5.30	4.00	5.20

The results indicate that under the soil and climatic conditions prevailing, there has been no superiority either in yield or analysis of the special grazing strains over the ordinary commercial mixture. This is not in accordance with the results obtained by Stapledon (1) in many of his Welsh experiments (26), but it is in accordance with the experiences of Moore in Yorkshire (15), and of Findlay in the North of Scotland (27), and with the observations of most West of Scotland Agricultural Organisers and of other members of staff of the West of Scotland Agricultural College. At Morriston, as on numerous other Ayrshire farms, the most important grazing plant proved to be wild white clover, which thrives on soils well supplied with phosphate and potash and where the pH value of the soil is not too low. It is perhaps worth noting that the

ordinary commercial ryegrass was Ayrshire and the commercial timothy was Scotch, and that these strains being indigenous to West Scotland are likely to be at least as productive in Ayrshire as Kent or Aberystwyth-bred strains, introduced into the area.

BASIC SLAG TRIALS ON SWEDES.

The importance of phosphate for maintaining the fertility of Ayrshire soils has also been demonstrated by investigations conducted between 1934 and 1937 in conjunction with the Permanent Basic Slag Committee to compare the availabilities of low soluble and high soluble basic slags. Swedes, which are sensitive to lack of available phosphate, were the crop employed for these trials, and the layout was on the lines of the replicated randomized plots system. The following table gives the treatments and the mean yields in tons per acre under these treatments at the different centres:-

	Total P_2O_5 applied in cwts/acre.	Control.	Low soluble slag.	High soluble slag.	Standard error.	pH
Hill of Barnweil, Craigie.		4.0				5.2
	.125			9.5		
	.25			11.7		
	.50		10.0	11.5	±1.12	
	1.00		12.1	14.9		
Holehouse, Dalrymple.		20.3				5.1
	.125			25.3	-	
	.25			26.1		
	.50		23.0	26.3	±2.11	
	1.00		26.7	28.6		
Hunterston, Trabboch.		12.7				5.5
	.125			14.8		
	.25			20.0		
	.50		16.8	21.5	±1.05	
	1.00		21.1	23.4		
Morriston, Maidens.		18.0				5.3
	.50		17.4	25.5		
Limestone 17.4 20.8	1.00		20.8	25.2	±3.14	
Burn, Tarbolton.		3.9				4.5
	1.00		18.4	24.0	±0.42	

It is evident that results with various degrees of significance had been obtained at most centres. At Morriston, however, the low soluble slag and the limestone (containing equivalent quantities of CaO to those in the two rates of slag dressings)

applications have produced identical results and not significantly different from the yields on the control plots. The explanation of the less satisfactory response at this centre is probably that, owing to the fixation of phosphate, a comparatively low phosphate figure was obtained by the ordinary methods of analysis although in previous years potatoes had been grown with liberal manurial dressings containing much phosphate. At the other centres, phosphate and lime would be more required by the soil for maintenance of fertility, as a heavy manurial dressing for 'root' crops was only given at long intervals.

BASIC SLAG TRIALS ON GRASSLAND.

Improvement of the herbage by slag applications was secured on several central Ayrshire farms as a result of an investigation commenced in March, 1932, into the effect of two different rates of slag application. Both high and low soluble slags were applied at 10 cwts. and 30 cwts. per acre to various plots on four central Ayrshire farms. By October, 1933, considerable differences in botanical analyses were observed. Results were as follows:-

Abbreviations used - L = low soluble, H = high soluble, l = lighter dressing, h = heavier dressing, C = control.

	Carston					Cairnston					Glenside					Bardarroch				
	C	Ll	Lh	Hl	Hh	C	Ll	Lh	Hl	Hh	C	Ll	Lh	Hl	Hh	C	Ll	Lh	Hl	Hh
Lolium perenne	-	1	-	1	1	2	10	11	5	13	5	11	13	13	14	1	4	3	3	2
Phleum pratense	-	-	-	-	-	-	-	-	-	-	-	2	-	1	1	-	-	-	-	-
Cynosurus cristatus	7	12	14	15	16	8	15	10	13	14	13	19	16	20	17	10	15	18	23	20
Poa spp.	4	6	7	7	9	4	10	12	12	11	5	8	7	5	10	4	5	8	7	7
Trifolium repens	9	13	16	14	18	23	28	29	26	27	22	27	27	26	23	13	25	26	25	24
Lotus corniculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1
Agrostis spp.	42	29	22	23	21	19	5	8	11	7	13	10	6	4	6	39	16	16	9	15
Holcus spp.	25	21	27	26	26	26	24	20	23	20	26	16	19	20	22	22	19	20	18	20
Anthoxanthum odoratum	3	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Ranunculus spp.	6	6	6	7	3	9	3	4	2	5	6	3	3	6	5	5	7	5	6	7
Bellis perennis	.5	.5	1	1	-	.5	2	1	1	.5	1	1	1	1	-	-	1	1	1	1
Hieracium spp.	.5	.5	1	-	1	.5	.6	2	1	.5	-	1	1	-	-	-	-	-	1	-
Carex spp.	-	-	-	-	-	3	-	-	-	-	1	-	1	1	-	2	2	1	1	-
Rumex spp.	2	3	2	3	-	1	.7	-	-	-	-	-	-	1	-	-	-	-	-	-
Cnicus spp.	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plantago lanceolata	.5	-	1	2	3	-	.7	1	3	1	6	1	3	1	1	4	4	2	3	3
Musci	.5	2	1	1	1	2	1	2	3	1	2	1	3	1	1	-	1	-	1	-

Taking the average of the plots on the four farms:-

	C	Ll	Lh	Hl	Hh
Lolium perenne	2.0	6.5	6.8	5.5	7.5
Phleum pratense	-	.5	-	.2	.3
Cynosurus cristatus	9.5	15.3	14.5	17.8	16.8
Poa spp.	4.3	7.3	8.5	7.7	9.2
Trifolium repens	16.8	24.5	24.5	22.8	23.0
Lotus corniculatus	-	.2	-	.2	.2
Agrostis spp.	28.3	15.0	13.0	11.8	12.3
Holcus spp.	24.7	20.0	21.5	21.7	22.0
Anthoxanthum odoratum	1.0	-	-	.3	.2
Ranunculus spp.	6.5	4.8	4.5	5.3	5.0
Bellis perennis	.5	1.1	1.0	1.0	.4
Hieracium spp.	.3	.5	1.0	.5	.4
Carex spp.	1.5	.5	.5	.5	-
Rumex spp.	.7	.9	.5	1.0	-
Cnicus spp.	-	.3	.5	-	-
Plantago lanceolata	2.8	1.4	1.7	2.2	2.0
Musci	1.1	1.2	1.5	1.5	.7
viz.					
Useful grasses	15.8	29.6	29.8	31.2	33.8
Trifolium repens	16.8	24.7	24.5	23.0	23.2
Agrostis spp.	28.3	15.0	13.0	11.8	12.3
Other weeds, etc.	39.1	30.7	32.7	34.0	30.7

It is evident that the effect of the basic slag dressings has been to reduce the agrostis from 28.3% to generally less than half this figure, and the other weeds from 39.1 to approximately 32%, while increasing the useful grasses from 15.8% to around 31%, and Trifolium repens from 16.8% to approximately 24%. The beneficial effect has been rather greater with the high soluble slag and with the heavier rate of dressing for both slags. It is also apparent that perennial ryegrass has only contributed to a small extent to the improvement in the sward. It is a common experience in the South-west of Scotland for pastures laid down in a phosphate-deficient and lime-deficient condition to show very little ryegrass in a few years' time, and for manures and/or lime then applied to have very little apparent effect in restoring ryegrass, as so little had managed to survive beyond the first two years.

CARBELLO EXPERIMENTS.

The importance of basic slag in producing higher crop yields and improved herbage has also been demonstrated by results obtained by the writer on Carbello farm in the parish of Auchinleck. These randomised plots were laid off for a swede manuring

experiment in 1935, im order to test out the availabilities and effects of high soluble, medium soluble and low soluble slags. Along with $1\frac{1}{4}$ cwts. sulphate of ammonia and $2\frac{1}{2}$ cwts. potash salts per acre, the slags were applied at two rates, viz. to supply 56 lbs. P_2O_5 and 112 lbs. P_2O_5 respectively per acre. The proportion of the total contained P_2O_5 soluble in the standard citric acid solution was as follows:- low soluble 24%, medium soluble A 44%, medium soluble B 53%, and high soluble 89%. Yields of swedes in tons per acre were as follows:-

	Control.	Low.	Medium A.	Medium B.	High.	*Limestone.	Standard Error.	pH
56 lbs. P_2O_5	2.31	13.96	16.77	21.38	23.61	3.08	±1.13	5.2
112 " "		20.05	20.37	24.50	25.24	4.39		

* Equivalent to CaO in slags ($3\frac{1}{2}$ cwts. and 7 cwts.).

It was obvious from the turnip yields that the medium soluble slags were different in type, A being little superior to the low soluble, and B being little inferior to the high soluble. The importance of a higher dressing when the solubility is low is demonstrated by the above results, where the difference in yield between the two rates of dressing is only 1.63 tons with the high soluble slag, but is 6.09 tons with the low soluble.

The land was sown out to grass under an oat crop in 1936; hay was cut in 1937, and the land was grazed in 1938 and subsequent years. Even although a light dressing of ground mineral phosphate had been applied in 1938, the effects of the previous treatment on the sward were obvious, and in August, 1941, botanical analyses were made and soil samples were taken from the various control, limestone (equal to CaO content of 7 cwts. basic slag), low soluble and high soluble slag plots, at both rates of dressing, equivalent to 56 lbs. P_2O_5 and 112 lbs. P_2O_5 per acre. The mean botanical analyses of the plots under each treatment were as follows:-

	Control.	$CaCO_3$.	L 56.	L 112.	H 56.	H 112.
Lolium perenne	9.7	13.6	15.3	18.3	17.7	20.0
Dactylis glomerata	1.0	.3	2.3	1.3	4.0	3.7
Phleum pratense	-	-	.3	-	1.0	2.0
Cynosurus cristatus	3.3	1.7	5.7	4.0	8.3	7.3
Poa spp.	12,0	17.3	14.0	19.7	18.0	15.0
Trifolium repens	14.0	26.7	24.3	27.3	24.7	28.0
Holcus spp.	21.7	19.3	20.3	17.3	14.3	15.7
Agrostis spp.	24.7	12.0	9.0	5.0	4.3	2.0
Bellis perennis	4.0	4.7	3.7	3.3	3.0	4.3
Ranunculus spp.	5.3	4.3	4.0	3.0	3.7	2.0
Juncus spp.	4.3	.7	1.0	.7	1.0	-
viz.						
Superior species	40.0	59.0	62.0	70.7	73.7	76.0
Inferior "	60.0	41.0	38.0	29.3	26.3	24.0
Soil pH	5.30	5.30	5.45	5.35	5.35	5.54

In spite of the pH figure being only slightly lower on the control plots, there was still a strong contrast between the swards resulting from the 1935 treatments. The useful plants on the control plots only average 40%, while on the high soluble slag plots they approximate to 75%. There was still a greater difference between the two rates of application on the low soluble than on the high soluble slag plots. The few cwts. of limestone per acre have had a beneficial effect on the sward, though inferior to the slag dressings. No significant differences between plots were shown by the soil analyses, possibly due to removal of phosphate and lime by additional production on the slagged plots.

In 1935 also in the same field a calculated manurial and lime requirement dressing deduced from the soil analysis and consisting of 6½ cwts. (27% P_2O_5) ground mineral phosphate, 2¾ cwts. 30% potash salts, 2 cwts. nitrochalk and 9½ tons (85% $CaCO_3$) ground limestone, all per acre, was compared on the swede crop with the normal 10 cwts. per acre mixed manure employed in the district and analysing 3% nitrogen, 13% P_2O_5, and 3% K_2O. Growth was slow in the early stages with this special dressing, probably owing to the very slow availability of mineral phosphate on a soil made neutral by an abnormally heavy limestone dressing. Growth improved later and the yield was 19.9 tons per acre, compared with 22.5 tons with the ordinary manurial dressing. The oat crop in 1936, the hay crop in 1937, and the pasture in subsequent years were much

superior as a result of the special treatment. In August, 1941, botanical analyses and soil samples were taken on this plot and from the surrounding area treated in the ordinary way in 1935 with mixed turnip manure. Results were as follows:-

	'Requirement' Plot.	Adjoining Area.
Lolium perenne	35	11
Dactylis glomerate	2	1
Phleum pratense	2	1
Cynosurus cristatus	8	3
Poa spp.	11	12
Trifolium repens	33	30
Holcus spp.	1	18
Agrostis spp.	2	15
Ranunculus spp.	2	4
Bellis perennis	4	3
Juncus spp.	-	2
viz.		
Useful plants	91	58
Inferior "	9	42

	Soil.	Subsoil.	Soil.	Subsoil.
pH value	6.49	6.43	5.35	5.50
P_2O_5 mgm./100 gms. soil	13.4	6.40	11.0	5.4
K_2O " " "	trace	absent	trace	absent

The superiority of the sward is shown by the fact that only 9% inferior plants are present on the plot compared with over 40% on the adjoining land. Growth also starts earlier in the Spring and production is greater throughout the season. The pH value of the soil has fallen somewhat from the 7.0 figure obtained in 1935; a certain amount of loss of lime to the subsoil has taken place, as can be observed from the contrast between the two subsoil pH figures.

BRACKENHILL DEMONSTRATION AREA, 1936 - 39.

As previous demonstration areas in Ayrshire had been located in the West Kilbride, Ayr, Dunlop, Beith, and Kirkoswald districts, I decided in 1936 to try and secure land in the Sorn - Cumnock district. No extensive experiments had been done in this locality, and here, as elsewhere in the County, were fields, which, because they were grazing badly, were broken up and put through a course of cropping with a view to laying them down anew to pasture. Such attempts at improvement were often unsuccessful, as the farmers concerned failed to realise that the poor condition of the pastures was

due to soil deficiencies which they neglected to remedy before laying down anew.

A suitable field was obtained on the farm of Brackenhill, Catrine, in the South-west corner of Sorn parish and adjoining the main road, midway between Mauchline and Auchinleck. The soil had a pH value of 5.0, and the amount of available potash was satisfactory; the 'available' phosphate, as determined by the routine analytical methods, was extremely low. As good pasture cannot be expected when lime and phosphate are so deficient, and as the ordinary methods of manuring during the growing of arable crops involve the use of lime-depleting manures such as sulphate of ammonia and superphosphate, which give their best results in presence of lime, it was decided to compare the effects on both the various crops and the succeeding pasture, of these ordinary manures (later referred to as 'acid' manures), and of manures more suited to remedy the soil deficiencies in lime and phosphate (later termed 'basic' or 'non-acid' manures), without incurring much difference in expenditure over the rotation.

Season 1936.

An area of six acres, measuring 242 yards by 120 yards, was laid off and sub-divided so that four manurial strips crossed four variety strips. The oat varieties included were Early Miller, Castleton Potato, Star and Yielder. As many farmers in this county use for oats 3 cwts. per acre of 'XX Corn Manure' or 'Corn Manure', it was arranged to use each of these for 1½ acres. The former analysed 8% nitrogen, 7% soluble phosphoric acid, 2% insoluble phosphoric acid, and 3% potash; the latter had the same phosphoric acid content, but contained 5% nitrogen and 5½% potash. These were sown along with the oats, Agrosan dressed, on 6th April. The other half of the area received a fortnight before seeding 3 cwts. ground mineral phosphate and 1 cwt. 30% potash salts per acre. To one half of this section 1 cwt. per acre of calcium cyanamide was applied a week after the oats were sown, and to the other half nitrochalk was applied at the same rate after brairding. The nitrochalk supplied the same quantity of nitrogen as is contained in 3 cwts. of the 'Corn Manure', while the cyanamide supplied one-seventh less nitrogen than there is in 3 cwts. of the 'XX Corn Manure'.

The Castleton Potato oats were sown at the rate of 1 2/3 cwts. per acre and the other varieties at the rate of 2 cwts. per acre.

The weather during May and the first half of June was dry and cold, and the crop, especially the Yielder, grew slowly. This slow rate of growth was most marked on the half where mineral phosphate was used. The lack of sufficient moisture and nitrogen appeared to be the main cause of this slow progress at first, as, although this land is naturally retentive of moisture and some drains were out of order, this lea field had been late ploughed, and the crop was growing most vigorously on the damper land. As the weather still continued unfavourable for nitrification and growth, nitrochalk at the rate of ½ cwt. per acre was applied in the second week of June to all plots.

With the change to warmer and more moist conditions towards the end of June, all varieties showed an improvement; this was most marked in the case of Castleton Potato and least so with Yielder. All varieties came into ear early in July, Yielder being first and Castleton Potato last to shoot. The mineral phosphate section was about three days behind the 'Corn Manure' section. The crop was ripe early in September, the Yielder and Early Miller being several days ahead of the Castleton Potato and Star. The thinness on the ground of the Yielder and Star through their poor tillering power on this poor land, combined with the wet weather during August, resulted in a dense growth of grass on these plots. Fortunately the weather was favourable later in September and all plots were stacked in good condition.

The crop was threshed in March, and the yields of grain and straw ascertained. As the figures for straw included the grass also present, the straw weights for some Yielder and Star plots would be as much as 30% above the weight of pure straw present. On the other hand, this dried grass would be worth more than pure straw for cattle.

The yields in cwts. per acre for the various sections were as follows:-

(P.M.P. = potash salts + mineral phosphate).

		P.M.P. + cyanamide.	P.M.P. + nitrochalk.	Corn manure.	XX Corn manure.	Average.
		cwts.	cwts.	cwts.	cwts.	cwts.
Yielder:	grain (firsts)	11.1	13.1	14.0	14.9	13.3
	" (seconds)	.9	1.0	.9	.9	.9
	straw	23.0	23.0	19.2	17.9	20.8
Star:	grain (firsts)	17.5	17.0	16.5	20.0	17.7
	" (seconds)	.9	1.0	.9	.9	.9
	straw	24.0	24.5	23.5	24.3	24.1
Castleton Potato:	grain (firsts)	19.0	15.4	16.6	18.0	17.2
	" (seconds)	1.6	1.6	1.5	1.4	1.5
	straw	28.5	28.5	23.5	24.0	26.1
Early Miller:	grain (firsts)	16.4	15.3	16.7	19.2	16.9
	" (seconds)	1.2	.9	.9	1.0	1.0
	straw	22.7	20.5	20.0	21.3	21.1
Average of four varieties:						
	grain (firsts)	16.0	15.2	15.9	18.0	16.3
	" (seconds)	1.1	1.1	1.0	1.0	1.1
	straw	24.5	24.1	21.5	21.9	23.0

Though the Castleton Potato was thicker on the ground than the other varieties, its grain yield was practically identical with that of Star: in fact, the latter had a higher yield of large grain. The straw yield of the Castleton Potato was higher than that of the Star, which included a fair proportion of grass. The Early Miller was inferior to Castleton Potato in both grain and straw. The Yielder was poorest in both grain and straw (and the latter included much grass), and proved least suited for the soil and climatic conditions.

As regards the effects of the various manures, the XX corn manure supplying most nitrogen had done best; its grain yield exceeded by 2 cwts. per acre that of the corn manure. Similarly the potassic mineral phosphate section supplemented with 1 cwt. calcium cyanamide (20.6% nitrogen) yielded better than the section given 1 cwt. nitrochalk (15½% nitrogen). Contrasting the latter section with that receiving corn manure (and the same amount of nitrogen), we find that the substitution of the superphosphate of the corn manure by mineral phosphate reduced the grain yield by about ¾ cwt. per acre. Although the apparent 'straw' yield (due to grass) was higher, the actual straw yield would also be slightly less.

General Results of 1936 cropping.

The results obtained in 1936 indicate that, though land has been under pasture for several years, if the pasture has been poor, there may be a dearth of available nitrogen. In order to secure a grain yield of 20 cwts. per acre, 35 lbs. of nitrogen, the quantity supplied by 1½ cwts. sulphate of ammonia or 2 cwts. nitrochalk per acre proved necessary. This may have been partly due to late ploughing. The failure of 3 cwts. mineral phosphate per acre to replace effectively the superphosphate in 3 cwts. corn manure on this lime-deficient soil was probably due to the dry soil conditions consequent on the late ploughing and the continued dry, cold weather throughout May. Had the land been ploughed in January and the mineral phosphate applied before the end of February, results would probably have been different. Though the Castleton Potato appeared much superior to the other varieties under the conditions, its grain yield was only equal to that of Star which was much thinner on the ground. Yielder was too slow in brairding and too short of the straw for soil and climatic conditions.

Season 1937.

In 1937 with a view to ascertaining the effect of taking a root crop on the pasture later, half of the six acres was under turnips and swedes, and the remainder under oats, undersown with grass and clover seeds. As the previous year's cropping had shown the need for liberal nitrogen dressings, 4 cwts. per acre of the 'XX Corn Manure' was employed for the oat crop on the 'acid manure' section, and 4 cwts. high soluble basic slag (10% P_2O_5), 1 cwt. potash salts, and 2 cwts. nitrochalk per acre on the 'basic' manure section. Half of the nitrochalk was applied at seeding time and the remainder a month later. Three oat varieties, dressed with agrosan, were included; Castleton Potato at the rate of 1½ cwts. per acre, and Early Miller and Ascot at 2 cwts. per acre. Shell lime slaked supplying 1½ tons CaO per acre was applied to certain plots when sowing the oats, and three weeks later various mixtures of grass and clover seeds

were sown, suitable for producing a hay crop and several years' pasture.

All oats brairded well and maintained their vigour throughout the season, with little visible effect of lime and with no apparent difference between ordinary and 'basic' manuring. At the public demonstration held near the end of August and attended by the local farmers, the Early Miller was almost ripe, the Castleton Potato was well coloured, and the Ascot was still green, though well headed. Castleton Potato was the only variety showing much lodging, which had not occurred until ripening had commenced. Differences due to liming and manuring could not be detected by inspection. All varieties were cut during the following week and stacked on September 11th.

Threshing took place in the last week of February, and the following yields per acre were obtained for the various plots:-

Variety.	Unlimed Section. XX Manure.	Unlimed Section. Basic Manure.	Limed Section. XX Manure.	Limed Section. Basic Manure.	Average.
	cwts.	cwts.	cwts.	cwts.	cwts.
Early Miller: grain (firsts)	24.0	24.8	24.6	23.4	24.2
" (seconds)	1.8	2.1	2.0	1.9	2.0
straw	29.6	33.2	30.0	28.8	30.4
Castleton Potato: grain (firsts)	18.0	20.3	19.5	20.8	19.7
" (seconds)	3.4	3.4	3.0	3.1	3.2
straw	37.2	40.6	38.0	38.8	38.5
Ascot: grain (firsts)	28.3	29.7	30.9	28.8	29.4
" (seconds)	2.6	2.7	2.6	2.5	2.6
straw	36.0	37.6	37.6	36.8	37.0
Average of three varieties: grain (firsts)	23.4	24.9	25.0	24.3	24.4
" (seconds)	2.6	2.7	2.5	2.5	2.6
straw	34.3	36.9	35.2	34.8	35.3

Castleton Potato yielded less grain and more straw than the other two varieties. Early Miller, yielding 24% more grain and 21% less straw than Castleton Potato, failed to approach the grain and straw yields of Ascot, which, with almost 29½ cwts. firsts grain and 37 cwts. straw per acre, was almost a half better than Potato in grain and only slightly inferior in straw yield. Of the total yield of Potato 37% was grain and 63% straw, while the figures for the other two varieties were 46% grain and 54% straw.

The influence of lime on the oat crop was only slight, as might be expected where the acidity was not abnormal (pH = 5.0). With the ordinary XX manure the lime dressing had, on the average, increased the grain yield by 7% and the straw yield by 3%. On the limed parts of the slag, nitrochalk and potash section, there was 2% less grain and 5% less straw than where lime was not applied. On the whole, the 'basic' manure combination proved slightly superior to the XX manure derived from sulphate of ammonia, superphosphate and potash salts.

Half of the three acres under turnips and swedes was manured with a mixture of superphosphate, sulphate of ammonia, and potash salts, which are the main constituents of the common turnip manures sold to farmers. The other half had a dressing of slag, potash salts and either nitrochalk or potash nitrate. It was decided to test three levels of nitrogen, equivalent to $1\frac{1}{3}$, $1\frac{2}{3}$, and 2 cwts. sulphate of ammonia per acre, each along with 9 cwts. superphosphate (14% P_2O_5) and $1\frac{1}{4}$ cwts. potash salts (30%). The medium nitrogen mixture approximated in analysis to 12 cwts. of the common turnip fertiliser. On the other half of the turnip break the sulphate of ammonia was replaced by the equivalent amount of nitrochalk, and the 9 cwts. superphosphate was replaced by 15 cwts. high soluble 10% basic slag. The five varieties included throughout were Aberdeen Green Top Yellow turnip, and Locarno, Best of All, Picton and Monkwood swedes.

Owing to dry weather, brairding was slow and irregular. A few showers brought the plants to the singling stage, but three weeks' very wet weather followed, which on this retentive soil seriously affected the young plants, especially on the slagged portion, where the plants were more backward than where superphosphate had been used. The land remained so wet that further cultivation was impossible, and the lower-lying parts were so affected that strict comparison of individual plot yields was impossible.

The crop was lifted early in November and the yields ascertained. The average yields of the various varieties were as follows:-

	Yield per acre.	Total dry matter per acre.
Locarno	15 tons 19 cwts.	1.71 tons.
Best of All	14 " 18 "	1.77 "
Picton	14 " 18 "	1.60 "
Monkwood	14 " 13 "	1.72 "
Aberdeen Yellow	19.0" 0 "	1.93 "

Though of the swedes Locarno had given the highest yield, yet considered on the dry matter basis it was inferior to some of the other varieties. The Aberdeen Yellow gave both the highest yield and the highest dry matter yield. On the average the yields from the three levels of nitrogen in the manure were practically identical. There would seem to be no advantage in risking reduced disease-resistance by using more nitrogen than strictly necessary. The average yield with the more usual type of manure containing sulphate of ammonia, superphosphate and potash salts was 16 tons 15 cwts., while with slag, nitrochalk and potash salts the average yield was 15 tons. This difference would probably have been less had the early July weather been less unfavourable.

In coring swedes from the plots, it was observed that much 'Raan' - the effect of boron deficiency - was present. This, as a rule, is only expected to be serious on land regularly cropped, but on the plots it was present to the extent of 66% in Locarno, 24% in Best of All, 38% in Picton, and 52% in Monkwood.

General Results of 1937 Cropping.

The higher oat yields in 1937 than in 1936 would suggest that more nitrogen was liberated from the old sward in the second year. Though this is contrary to the experience with a white clover sward on land in good condition, it seems the normal experience for land carrying a sward with little white clover and much agrostis. In the circumstances, therefore, Castleton Potato proved the most suitable oat variety for the first year, but less suitable for the second year, when Ascot proved much superior. The high soluble basic slag has proved an efficient substitute for superphosphate on the oat crop, especially on the unlimed section. On the other hand it has been less efficient for the turnip crop, probably because the smaller plants on the slag plots

suffered more from the flooded drills in early July. Under the conditions the Aberdeen Green Top Yellow did better than any of the swedes. Increasing the nitrogen in the manure did not increase the crop. Although this land only grows swedes at long intervals, 'Raan' or 'Brownheart' was present in nearly half of the swedes cored.

Season 1938.

In 1938 the three acres, which had been sown out with various grass seed mixtures in 1937 with the oat crop, were in hay, while the other half, which had been under turnips and swedes in 1937, was devoted to oats, the same grass seed mixtures as in the previous year being sown therewith. The comparison of 'acid' and 'basic' manurial dressings was continued on both crops. The 'acid' section received 3 cwts. per acre for the hay of a mixture analysing 7½% nitrogen, 7% soluble P_2O_5, 2% insoluble P_2O_5 and 5½% K_2O, while the other section was given 1 cwt. calcium cyanamide, 12 cwts. basic slag and 1 cwt. 30% potash salts per acre.

When a public demonstration was held towards the end of July, it was easy to pick out the boundaries of the limed and unlimed sections, and of the 'acid' and 'basic' manure sections. Agrostis was profuse and red clover almost absent on the unlimed, acid-manured portion, while red clover was profuse and agrostis almost absent on the limed and slagged area. The limed, acid-manured, and unlimed, slagged areas were intermediate for clover and agrostis. The plots sown out with the seed mixtures containing least perennial ryegrass appeared rather thin to give a high yield of seed. The seed mixtures employed (in lbs. per acre) were as follows:-

	No.1.	No.2.	No.3.	No.4.	No.5.
Lolium perenne	20	30	40	20	26
Dactylis glomerata	6	4	3	6	8
Phleum pratense	4	3	2	4	4
Festuca pratensis	6	4	3	6	-
Cynosurus cristatus	1	1	1	1	-
Poa trivialis	1	1	1	1	2
Trifolium pratense	2	2	2	2	3
" hybridum	1	1	1	1	1
" repens	¾	¾	¾	¾	1

Mixture No.4 contained grazing strains, the Lolium perenne being Kent evergreen

and the Dactylis glomerata and Phleum pratense being Aberystwyth S.26 and S.50.

The hay crop was cut on August 4th and threshed on August 22nd. The yields of seed were low, especially on the plots with only 20 lbs. ryegrass per acre. Yields of seed and hay were higher on limed than on unlimed land, averaging as follows (per acre)

	Limed.	Unlimed.
Seed	4.5 cwts.	4.0 cwts.
Hay	40.8 "	37.5 "

The comparative yields with the mixtures containing respectively 20 lbs., 30 lbs. and 40 lbs. per acre ryegrass (Nos. 1, 2 and 3) were as follows (per acre):-

	20 lbs.	30 lbs.	40 lbs.
Seed	3. 6 cwts.	4.5 cwts.	5.3 cwts.
Hay	37.3 "	38.4 "	39.9 "

The mixture containing grazing strains of cocksfoot and timothy and Kent evergreen ryegrass gave the same yield of seed and 13% more hay than the corresponding commercial mixture. Its relatively high yield was possibly due to its escaping injury from the late frosts due to its later shooting. The highest hay yield was from mixture no. 5; this seemed to result from the larger amount of red clover present.

The aftermath grew most vigorously and contained more clover on the limed and slagged sections. The least aftermath was from the grazing strains.

Three oat varieties were included in this year's trials, viz. Early Miller, Ascot and Onward, all sown on 21st April. The manure on the 'acid manure' section was 4 cwts. of the same mixture as used on the hay, and on the other half 1½ cwts. calcium cyanamide, 1cwt. potash salts, and 8 cwts. slag per acre (10% P_2O_5) were employed. The latter manure seemed to be at a disadvantage with the late ploughing and late sowing, and growth was less vigorous on this half. The same grass seed mixtures were used for sowing out as in 1937, and shell lime (slaked) was applied to half of each section at the rate of 1½ tons CaO per acre.

The crop was cut on 8th september, Early Miller being dead ripe, Ascot normally ripe, and Onward green of the straw though well filled. The oats were thicker and taller on the 'acid manured' section. The comparative yields (in cwts. per acre)

for the manurial plots were as follows:-

	Ordinary Manure.		'Basic Manure'.	
	Limed.	Unlimed.	Limed.	Unlimed.
Grain (dressed)	22.2	21.2	18.6	19.4
" (seconds)	.7	.6	.7	.6
Straw	27.6	27.2	25.3	25.8

The relative yields of the three varieties were as follows (in cwts. per acre):-

	Early Miller.	Ascot.	Onward.
Grain (dressed)	17.0	20.0	24.1
" (seconds)	.6	.7	.7
Straw	24.6	27.6	27.8

The ordinary mixed manure had done better, especially on the limed portion. Onward gave the highest yield of grain and the highest ratio of grain to straw, viz. 47% and 53% of the crop respectively. Early Miller gave the lowest yield of both grain and straw, their proportions of the total crop being 42% and 58% respectively.

General Results of 1938 Cropping.

While in 1937 basic slag and nitrochalk proved an efficient substitute for superphosphate and sulphate of ammonia on this land for the oat crop, basic slag and calcium cyanamide failed to do so in 1938. This was probably due to the late ploughing and late application of the manures. The hay crop showed the benefit of slag and calcium cyanamide, as well as the benefit of a dressing of lime at the time of sowing out.

Season 1939.

In 1939, the fourth year of this demonstration area, the three acres, which had been sown out with the various grass seed mixtures in 1938 with the red land oats, was in hay, while the other half, in hay the previous year, was under first year's pasture. The comparison of 'acid' and 'basic' manures was continued on the hay crop and the influence of these treatments on the pasture observed.

As in the previous year the part of the 'seeds' limed before sowing out was much greener than the portion not limed, and the area on which slag and calcium cyanamide had been employed was better in colour than that on which superphosphate and sulphate of ammonia had been used. The latter section was dressed with the same mixed manure

(3 cwts. per acre) as used in the previous year, while the other section was given 1 cwt. calcium cyanamide and 1 cwt. potash salts per acre to supplement the slag which had been applied the previous year at the time of sowing out.

When a public demonstration was held towards the end of July, it was easy to pick out the boundaries of the limed and unlimed sections, and of the 'acid' and 'basic' manure sections. A considerable amount of holcus was present, and red clover was almost absent, on the unlimed, acid-manured portion, while red clover was profuse and holcus absent on the limed and slagged area. Though sown with the same grass seed mixtures as the part not green-cropped, the 1939 hay area was almost free from agrostis even where lime had not been used; the beneficial influence of the roots as a cleaning crop was evident. All plots had suffered considerably from the treading of stock during the wet winter, and the plots seeded with least ryegrass appeared too thin to give high seed yields.

The hay crop was cut for ryegrass seed on July 27th and threshed on August 17th. The seed yield was much lower with the grazing strains than with the ordinary mixture, being $3\frac{3}{4}$ cwts. per acre against $6\frac{1}{2}$ cwts; hay yields were similar at $23\frac{1}{2}$ cwts. per acre. The comparative yields with the mixtures containing respectively 20 lbs., 30 lbs. and 40 lbs. per acre of perennial ryegrass were as follows (in cwts. per acre):-

	Unlimed.		Limed.	
	Seed.	Hay.	Seed.	Hay.
20 lbs.	5.7	18.9	6.9	22.1
30 lbs.	6.9	23.2	8.5	28.0
40 lbs.	8.4	25.4	9.6	28.8
Average	7.0	22.5	8.3	26.3

On the average liming increased the yield of seed by 1.3 cwts. and of hay by 3.8 cwts. per acre. Seed yields were much higher and hay yields were considerably lower than on the corresponding plots in the previous year where the land had not been greencropped, and where more agrostis and holcus had competed with the ryegrass.

The aftermath showed the same contrasts on the various plots as the hay crop had shown. Botanical analyses showed on the unlimed, acid-manured section 30% holcus and

agrostis and 1% red clover, and on the limed and slagged section 15% red clover and 4% holcus.

The section under first year's pasture showed the same contrasts as the other half of the demonstration area, but more marked. It was evident at the demonstration in July that serious deterioration had set in on the section which had not received lime or slag, but throughout the rotation had only received the common mixed manures.

General Results of 1939 Cropping.

The influence of manurial treatment during the rotation on the hay and pasture in later years was strongly demonstrated on this experimental area, and the indications were that the differences would become more marked. The cost of the 'basic' manures had only slightly exceeded the cost of the commoner type of grain and grass fertiliser, and the yields of the ordinary rotation crops had only suffered slightly. On the other hand, the hay crop had been superior on the non-acid section, and the pasture was also very much better than with the ordinary manures. On this land, which in general agricultural characteristics is typical of much in Ayrshire and which is naturally deficient in lime and phosphate, it would appear that, if the ordinary 'acid' manures are used for the rotation crops, good pasture will only be obtained if lime is applied when sowing out. Much of this benefit, however, can evidently be secured by using manures such as basic slag and calcium cyanamide (with a liming value equal to almost half their weight) for the rotation crops. Further benefit accrues from using lime in addition. An increase in yield through liming amounting to 1¼ cwts. of ryegrass seed and 3¾ cwts. of hay per acre easily pays the present cost of lime. The use of special strains of the common grasses did not compensate for defective soil conditions. The cleaning of the land through taking a root crop was a benefit to the hay crop and the first year's pasture.

PROCEDURE IN RECENT INVESTIGATIONS.

In order to investigate further the relative effects of 'acid' and 'basic' manuring with, and without, liming, plots were laid down in October, 1939, and May, 1940 on the Latin Square principle at Brackenhill, Catrine, a typical Central Ayrshire dairy farm, where, in normal times, grass for hay and pasture is the most important crop, and where the preliminary results, related in the preceding pages, had been obtained with demonstration plots laid off for the benefit of Ayrshire farmers during a four years' course of cropping on an adjoining field. As already mentioned, the term 'basic' or 'non-acid' in this work is being employed in regard to manuring to such manurial combinations, as have the effect of raising the pH value of the soil owing to the lime supplied or conserved. The term 'acid' on the other hand is applied to the commonly practised system of manuring, where the manures employed, generally consisting chiefly of sulphate of ammonia and superphosphate, result in a lowering of the pH value, largely due to the lime-depleting action of the sulphate of ammonia. Rises in pH values in certain soils have been recorded by a number of investigators as a result of the use of superphosphate. Superphosphate does not have, however, the neutralising value of basic slag for an acid soil, and in Ayrshire the use of a normal mixture of sulphate of ammonia and superphosphate has been found to result in the lowering of the pH figure. It is therefore in that sense that the term 'acid' is being employed herein.

The October 1939 plots were laid down on land sown out to grass with a nurse crop in the previous Spring; the May 1940 plots were on land cropped with oats in 1939 and being sown with swedes in 1940, to be followed by oats in 1941, undersown with seeds for hay in 1942 and pasture in subsequent years. The determinations made included soil pH values, as well as herbage analyses and botanical analyses of the various plot swards at periods during the investigations.

Soil sample determinations were generally made in respect of the top 3" which is the region mainly affected by surface treatment and to which the grass roots are

chiefly confined in the early stages of their establishment, and for 3"-9", 9" being the depth to which soil samples are normally taken, and to which soils are usually cultivated. Ten cores were taken for each sample from each separate plot, the pH value being determined after drying, grinding and thorough mixing of the sample. To minimise seasonal (28) and soil dehydration (29) effects on pH values, sampling was as far as possible confined to the later part of September or the earlier part of October.

As the methods of soil phosphate determination employed in the West of Scotland do not seem to enable phosphate available for crops and pasture to be accurately assessed owing to the occurrence of 'phosphate-fixation' in most Ayrshire soils, it was decided that no useful phosphate comparisons could be made from the phosphate figures obtained by the analysis of the various plots after treatment with superphosphate or basic slag. It had been found that on soils similar to that at Brackenhill, where the pH value was around 5.0, dressings of even 1 ton basic slag (10% P_2O_5) per acre could be applied without appreciably affecting the 'available' phosphate figures, though response to further phosphate dressings would not be expected nor obtained.

Each herbage sample was composed of cuttings taken from ten points uniformly disposed over the plot. Determinations were made of moisture, nitrogen, phosphoric acid (P_2O_5) and lime (CaO) content by the ordinary analytical methods.

The botanical analyses were obtained by the ten point quadrat method, applied uniformly over the area of each plot, the readings at the various points being added to give the percentages of the various plants present in each plot under treatment.

The yields of arable crops were obtained where such were grown in the course of the investigations, and the necessary chemical analyses were made to obtain information on the effects of the various treatments. These included the determination of the P_2O_5 and CaO content of the dry matter. It has been established by Sir John B. Orr (30) and other investigators that pastures with high phosphorus and calcium content have a higher nutritional value for farm animals, and accordingly it can be concluded that, where P_2O_5 and CaO contents are high, pastures and crops are superior

for production purposes. A report on the superior value of certain Welsh pastures with naturally higher nitrogen and mineral contents, or managed and manured to give such higher analyses, has also been published (31).

BRACKENHILL DEMONSTRATION AREA STUDIES, 1939 - 42.

In view of the results obtained on the demonstration plots laid down for the benefit of the farmers, it was decided to make further detailed studies on the sward for the next three years, and its relation to the lime status of the soil. At the commencement of the experiments the pH value of the soil to a depth of 9" was practically uniform, only varying very slightly from 5.0. One series had been sown out to grass in 1937 with a second corn crop, the first oat crop in 1936 having been after pasture which had lain ten years. As already described, part of the land received for both oat crops and for the 1938 hay crop 'acid' manures in the form of superphosphate and sulphate of ammonia, and the remainder was dressed with 'basic' manures in the form of nitrochalk or calcium cyanamide and basic slag or mineral phosphate. Potash was applied in addition each year to all plots. In 1937 half of each section had received lime at the rate of 1½ tons CaO per acre. The liming gave a 5% increase in the oat yield on the 'acid' manure sections and a 3% decrease on the 'basic' manure sections. The hay yield in the following year was increased 10% by liming on the 'acid' manure plots, but was unaffected by liming on the 'basic' manure plots.

The second series was sown out to grass in 1938 with an oat crop, following swedes as the second crop of the rotation. Liming increased the oat yield by almost 5% on the 'acid' manure sections, but caused a slight reduction (about 3%) on the 'basic' manure sections. The haycrop under both treatments in 1939 was increased 14% by liming.

The land not devoted to a root crop was under first year's pasture in 1939, and the greencropped area was first under pasture in 1940. Botanical analyses were made of the various plots in the autumns of 1939, 1940, 1941 and 1942, and soil analyses were made in October, 1939, and September, 1942. Results were as follows:-
(Abbreviations used in following tables: A ='Acid' manure; B ='Basic' manure; L = Lime.)

A. Non-Greencropped Plots.

	September, 1939.				September, 1941.				September, 1942.			
	A	AL	BL	B	A	AL	BL	B	A	AL	BL	B
Lolium perenne	11	22	32	20	10	20	25	19	10	23	31	21
Dactylis glomerata	6	4	6	6	2	2	9	5	1	3	3	2
Phleum pratense	2	5	9	4	-	2	3	1	1	2	2	1
Cynosurus cristatus	-	1	4	2	-	2	3	7	2	9	13	16
Poa spp.	-	-	-	-	1	3	1	1	-	-	1	-
Trifolium pratense	2	6	5	6	-	-	-	-	-	-	-	-
" repens	3	16	19	10	12	25	29	22	11	17	23	21
Helcus spp.	30	22	9	19	25	24	15	24	25	23	14	17
Agrostis spp.	30	14	2	18	39	8	7	11	38	9	2	11
Anthoxanthum odoratum	-	-	1	2	-	-	-	-	-	-	-	-
Ranunculus spp.	14	8	12	13	9	12	8	9	10	13	9	11
Prunella vulgaris	2	2	1	-	-	-	-	-	-	-	-	-
Bellis perennis	-	-	-	-	-	2	-	-	2	1	2	-
Hieracium spp. viz.	-	-	-	-	2	-	-	1	-	-	-	-
Useful Plants	24	54	75	48	25	54	70	55	25	54	73	61
Inferior "	76	46	25	52	75	46	30	45	75	46	27	39
Soil pH, 0 - 3"	4.73	5.27	5.46	5.10					4.96	5.41	5.87	5.46
" " 3" - 9"	4.90	4.99	5.18	4.95					5.13	5.30	5.58	5.28

The above figures demonstrate that the soil reaction due to the treatment during the rotation has greatly affected the constitution of the sward. The higher the soil pH, the greater the proportion of useful plants in the sward. The botanical analyses of the various sections altered little during the three years. As a result of the 'acid manuring' during the rotation the sward contained three inferior plants to one useful plant; 'basic manuring' followed by liming has reversed these figures to three useful for every inferior plant. 'Basic manuring' without lime has given approximately equal numbers of useful and inferior plants: 'acid manuring' plus liming has given a similar result. Changes have been negligible during the three years apart from a gradual improvement in the 'basic manure' unlimed section.

Chemical analyses were made of the herbage from the various sections in October, 1939, and nitrogen, P_2O_5 and CaO contents determined. The results of the treatments averaged as follows (in percentages of the dry matter):-

	A	AL	BL	B
Nitrogen	2.37	2.30	2.62	2.40
P_2O_5	.638	.538	.684	.773
CaO	.726	1.169	1.685	1.120

The nitrogen content is slightly higher with the basic manure, with little differ-

ence between limed and unlimed sections. The phosphate content is rather higher in the herbage on the basic manure sections, and the herbage on the unlimed portions of both basic and acid manured areas has a higher P_2O_5 content than that on the limed portions. The CaO content is definitely highest in the herbage on the limed portions of the basic manure section, while it is lowest in the herbage on the unlimed portions of the acid manure section.

B. Greencropped Land.

	October, 1939.				September, 1940.			
	A	AL	BL	B	A	AL	BL	B
Lolium perenne	29	40	41	37	9	22	28	20
Dactylis glomerata	19	12	11	10	10	19	15	19
Phleum pratense	9	13	14	12	7	18	14	9
Cynosurus cristatus	-	-	-	-	-	2	2	2
Poa spp.	-	-	-	-	-	2	3	1
Trifolium pratense	1	11	15	11	1	4	9	7
" hybridum	-	1	1	3	-	-	-	-
" repens	-	3	5	5	1	6	9	13
Holcus spp.	18	6	4	9	27	13	8	14
Agrostis spp.	12	3	-	2	32	3	1	4
Ranunculus spp.	12	11	9	11	13	11	11	11
viz.								
Useful plants	58	80	87	78	28	73	80	71
Inferior "	42	20	13	22	72	27	20	29
Soil pH, 0 - 3"	4.93	5.44	5.80	5.39				
" " 3" - 9"	5.04	5.07	5.38	5.19				

	September, 1941.				September, 1942.			
Lolium perenne	10	18	24	20	12	27	30	21
Dactylis glomerata	6	14	12	8	3	4	6	1
Phleum pratense	-	7	3	2	1	1	2	2
Cynosurus cristatus	-	2	4	4	-	10	12	8
Poa spp.	-	-	1	-	1	-	-	-
Trifolium pratense	-	-	1	1	-	-	-	-
" repens	6	23	25	22	7	23	26	25
Holcus spp.	28	13	14	19	20	18	11	22
Agrostis spp.	42	14	5	13	44	2	-	11
Ranunculus spp.	8	9	10	10	11	9	10	9
Bellis perennis	-	-	1	1	1	6	3	1
viz.								
Useful Plants	22	64	70	57	24	65	76	57
Inferior "	78	36	30	43	76	35	24	43
Soil pH, 0 - 3"					5.09	5.66	5.97	5.53
" " 3" - 9"					5.06	5.31	5.61	5.46

The final results on these plots after three years in pasture are similar to those

On the plots where the land was sown back to grass without the interposition of a root crop. While the cleaning of the land with a root crop resulted in fewer weeds being apparent in the first eighteen months after the seeds were sown, deterioration took place later, chiefly on the land where neither slag nor lime had been applied during the rotation. By the end of a further eighteen months the swards had become stabilised, the only difference from the non-greencropped area being that the 'acid manure' section of the limed portion of the greencropped part, having a higher pH value, had fewer inferior plants, these being in the region of 35% of the sward.

On both greencropped and non-greencropped land only relatively slight benefit as shown below was obtained from using special grazing strains or additional quantities of ryegrass seed. The figure following the treatment symbol gives the number of lbs. of perennial ryegrass used per acre in the seed mixture for which the botanical analysis appears immediately below.

	Greencropped. Commercial;Grazing.				Non-Greencropped. Commercial;Grazing.				Greencropped. Commercial.				Non-Greencropped. Commercial.			
	A	AL	A	AL	A	AL	A	AL	B20;	BL20;	B30;	BL30.	B20;	BL20;	B30;	BL30.
Lolium perenne	12	27	12	37	10	23	13	28	21	30	25	36	21	31	30	35
Dactylis glomerata	3	4	3	1	1	3	3	3	1	6	1	2	2	3	3	3
Phleum pratense	1	1	5	4	1	2	2	2	2	2	2	1	1	2	1	1
Cynosurus cristatus	-	10	4	14	2	9	5	7	8	12	12	11	16	13	12	14
Poa spp.	1	-	-	1	-	-	1	2	-	-	-	1	-	1	1	-
Trifolium repens	7	23	5	22	11	17	7	20	25	26	22	27	21	23	23	25
Holcus spp.	20	18	18	10	25	23	24	20	22	11	19	10	17	14	16	12
Agrostis spp.	44	2	43	1	38	9	36	6	11	-	8	1	11	2	4	-
Ranunculus "	11	9	10	9	10	13	8	12	9	10	11	5	11	9	10	10
Bellis peren.	1	6	-	1	2	1	1	-	1	3	-	6	-	2	-	-
viz. Useful Plants	24	65	29	79	25	54	31	62	57	76	62	78	61	73	70	78
Inferior "	76	35	71	21	75	46	69	38	43	24	38	22	39	27	30	22

The foregoing tables show that, while on the average the swards from the grazing strains seed mixture contains 8% more useful plants and hence 8% fewer weeds, the sward improvement resulting from liming on these 'acid manured' plots with both mixtures is several times greater, showing on the average an increase from 27% useful plants in

Background: 'Acid' Manured & Limed.
Foreground: 'Acid' Manured & Unlimed.

Background: 'Acid' Manured (Unlimed).
Foreground: 'Basic' Manured (Unlimed).

Left: 'Acid' Manured (Unlimed).
Right: 'Acid' Manured (Limed).

Left Background: Limed.
Foreground & Right Background: Unlimed.

Left: 'Acid' Manured (Unlimed).
Right: 'Acid' Manured (Limed).

Left: 'Basic' Manured (Unlimed).
Right: 'Acid' Manured (Unlimed).

the sward to 65%, and accordingly a reduction in weeds from 73% to 35%, the improvement being greatest on the land which had been previously cleaned with a root crop. The use of 30 lbs. of perennial ryegrass in the seeds mixture in place of 20 lbs. has given a sward with 5% fewer weeds on the average, but even on the 'basic manured' plots the difference due to liming averages 1[illegible]%, an improvement almost three times greater.

The contrasts in appearance between the various treatments plots became more marked with the passage of time, especially where the land had been cleaned with a root crop during the rotation. The plots which had received only the commonly-used manures for the various crops and hay (and consisting of superphosphate, sulphate of ammonia and potash salts) without a lime dressing at the end of the rotation were always poor in colour, and being less palatable to stock were also always rougher, contrasting strongly with the areas where lime had been used in addition, or basic manures such as slag and nitrochalk employed. They displayed a 'whiteness' and lack of vigour throughout the season, the contrasts being greater each succeeding year, and are shown by the accompanying photographs taken on the plot boundaries. There has always been little visible difference between the 'acid manure' plus lime and the 'basic' manure sections, both being equally well eaten and similar in colour and appearance. The 'basic manure' plus lime sections have also been well grazed and slightly superior in colour, showing the greatest vigour of growth throughout the year.

The quality of the pasture has accordingly been chiefly influenced by the manures (including lime) and their effects on the surface soil reaction. The higher the pH the lower the proportion of inferior pasture plants. The only soils to which grass is natural are calcium soils with high base status, and in order to obtain good pasture on Ayrshire soils the creation of calcium soil conditions should be aimed at.

BRACKENHILL RESEEDING RESULTS.

On an adjoining field at Brackenhill, which was undrained and had been under pasture for twenty years, having become very rough with rushes, certain trials were

laid down in April, 1938. The soil was in poor condition, the pH value being 4.8, the 'available P_2O_5' figure being nil and the 'available K_2O' being 10.8 mgm. per 100 gms. soil. Certain plots were ploughed and directly reseeded with a commercial seeds mixture composed of 20 lbs. Lolium perenne, 8 lbs. Lolium italicum, 4 lbs. Phleum pratense, 6 lbs. Dactylis glomerata, 6 lbs. Festuca pratensis, 1 lb. Cynosurus cristatus, 1 lb. Poa trivialis, 2 lbs. Trifolium pratense, 1 lb. Trifolium hybridum and ¾ lb. Trifolium repens, all per acre. Adjoining plots were manured without ploughing. On both sets of plots basic slag was applied at the rate of 200 lbs. P_2O_5 per acre (almost 1 ton 9%) and lime at the rate of 3000 lbs. CaO per acre. Botanical analyses and soil samples were taken at intervals from October 1939 onwards. Samples of the herbage on these plots were also taken in October 1939, and the nitrogen, P_2O_5 and CaO contents determined. The results were as follows:-

Botanical analyses, 1939.	Unploughed.			Ploughed.			
	Control:	Slag:	Slag+Lime.	Control:	Lime:	Slag:	Slag+Lime.
Lolium perenne	-	-	-	28	38	39	44
Dactylis glomerata	-	-	-	5	4	1	1
Phleum pratense	-	-	-	18	25	18	22
Cynosurus cristatus	1	11	13	3	5	1	-
Poa spp.	-	1	-	-	3	2	-
Trifolium pratense	-	-	-	-	1	2	8
" hybridum	-	-	-	-	1	8	7
" repens	10	28	32	2	5	13	15
Holcus spp.	27	24	26	3	2	1	-
Agrostis spp.	29	14	9	20	4	1	-
Anthoxanthum odoratum	6	-	-	-	-	-	-
Ranunculus spp.	12	6	7	11	5	12	3
Juncus spp.	15	16	13	3	1	-	-
Potentilla spp.	-	-	-	6	5	1	-
Alopecurus geniculatus viz.	-	-	-	1	1	1	-
Useful Plants	11	40	45	56	82	84	97
Inferior "	89	60	55	44	18	16	3
Soil pH, 0 - 3"	4.52	4.95	5.26	4.72	6.34	5.33	6.19
" " 3" - 9"	4.69	4.88	5.09	4.98	5.38	4.98	5.42
Herbage Analyses 1939 (% of dry matter).							
Nitrogen	1.840	2.600	2.650	1.580	1.670	1.800	2.510
P_2O_5	.369	.684	.682	.404	.361	.552	.479
CaO	.676	1.460	1.420	.688	.880	1.240	1.190

The application of basic slag has had a marked effect in increasing the nitrogen,

P_2O_5, and CaO content of the herbage on both the unploughed and the reseeded sections. The addition of lime along with slag to the old pasture has had no effect in that direction. On the reseeded area the lime by itself has increased the CaO content of the herbage, but has had little effect on the P_2O_5 and nitrogen content. Applied to the reseeded land with basic slag, it has greatly increased the nitrogen content; this is probably due to the higher proportion of red clover present.

Botanical Analyses of Plots on Reseeded Area:-

	September, 1941.				September, 1942.			
	Control:	Lime:	Slag:	Slag+Lime.	Control:	Lime:	Slag:	Slag+Lime.
Lolium perenne	20	25	24	28	14	20	24	28
Dactylis glomerata	18	14	17	17	-	-	4	9
Phleum pratense	15	15	20	21	-	1	2	4
Cynosurus cristatus	3	6	2	2	12	18	17	16
Poa spp.	2	3	2	-	10	9	5	5
Trifolium pratense	3	3	3	6	-	-	-	-
" repens	5	13	16	15	13	28	33	30
Holcus spp.	9	5	3	1	19	10	4	2
Agrostis spp.	21	5	7	3	27	2	6	1
Ranunculus spp.	4	7	6	7	4	9	5	5
Bellis perennis	-	-	-	-	-	3	-	-
Potentilla spp.	-	4	-	-	-	-	-	-
Juncus spp. viz.	-	-	-	-	1	-	-	-
Useful Plants	66	79	84	89	49	76	85	92
Inferior "	34	21	16	11	51	24	15	8
Soil pH, 0 - 3"					5.26	6.06	5.79	6.85
" " 3" - 9"					5.31	5.74	5.48	6.36

It is clear that a superior sward resulted from ploughing and reseeding to that obtained by manuring and liming the old pasture. Though the old sward was improved in mineral and nitrogen content, it was later in starting growth in the Spring and produced much less bulk than the newly-seeded pasture, slagged and limed. Though the control plot reseeded contained superior plants to the old untreated pasture, its nitrogen and mineral content was similar, and its production was much less than that of the slagged and limed land. While the lime alone gave a sward of good botanical analysis with 75-80% useful plants, these plants lacked vigour, and the yield was little better than that of the control plot. On the other hand, the basic slag at the rate of 1 ton per acre has had an effect almost equal to that of the basic slag plus lime, both on

yield and character of the herbage, thus emphasising the more clamant need for phosphate than for lime. The inferior plants on the control plot are approximately 50% of the sward; on the 'lime only' plot they amount to 25%; on the 'slag only' plot to 15%, and on the limed and slagged plot to under 10%.

KNOWESIDE HILL PASTURE IMPROVEMENT.

In June, 1938, an area of 2 acres of hill grazing land was selected on Knoweside, Maybole for experiments in pasture improvement. One third was ploughed, one third received surface cultivation, and the remainder was left uncultivated. A scheme of manurial treatment was included, consisting of lime only, basic slag (15%P_2O_5) only, basic slag plus lime, basic slag plus lime plus potash, the lime being applied at 2 tons ground lime (80% CaO) per acre, basic slag at 10 cwts., and 30% potash salts at 2 cwts. per acre. After manuring and cultivation the ploughed area was seeded with the following grass seed mixture:- Lolium italicum 14 lbs., Lolium perenne (Kent) 10 lbs., Lolium perenne (Ayrshire) 10 lbs., Dactylis glomerata 8 lbs., Poa trivialis 2 lbs., Cynosurus cristatus 2 lbs., and Trifolium repens (Kent indigenous) 2 lbs., all per acre.

The seeds established themselves most satisfactorily on the portions receiving both slag and lime; on the lime only section the braird was very patchy, and later many weeds and inferior grasses returned; the slag only section was superior to the lime only section, but inferior to slag and lime. The cultivated area showed similar improvements in accordance with the manurial treatment but on a smaller scale; and on the uncultivated sward the improvement was still less, being negligible on the lime only plot.

During 1939 - 42 the superiority of the lime plus slag sections on the reseeded area was very marked, and showed a strong contrast to the immediately adjoining unimproved hill pasture. The botanical analyses and the soil pH figures for the various plots in the autumn of 1942 were as follows:-

	Cultivated.	Ploughed and Reseeded.				Original Sward.
	Slag+K_2O +CaO	Slag+K_2O +CaO	Slag +CaO	Slag	CaO	Untreated.
Lolium perenne	24	36	38	30	25	-
Dactylis glomerata	2	4	5	8	7	-
Phleum pratense	2	4	1	1	-	-
Cynosurus cristatus	3	3	2	-	1	-
Poa spp.	5	7	6	4	2	-
Trifolium repens	20	27	23	20	11	2
Lotus corniculatus	2	2	-	-	2	2
Holcus spp.	4	7	10	6	1	6
Agrostis spp.	16	8	10	13	19	15
Anthoxanthum odoratum	3	-	-	6	1	9
Cerastium vulgatum	-	2	2	1	3	-
Plantago lanceolata	-	-	2	3	4	-
Ranunculus spp.	-	-	1	-	-	-
Musci	3	-	-	7	7	-
Carex spp.	12	-	-	1	17	8
Juncus spp.	2	-	-	-	-	1
Calluna vulgaris	2	-	-	-	-	7
Festuca ovina	-	-	-	-	-	20
Nardus stricta	-	-	-	-	-	13
Molinia caerulea	-	-	-	-	-	8
Potentilla spp.	-	-	-	-	-	7
Aira spp.	-	-	-	-	-	2
Soil pH, 0 - 3"		6.45	6.77	5.95	6.28	5.35
" " 3" - 9"		6.35	6.58	5.88	5.99	5.65

It is apparent that all plots were superior in botanical analysis to the original sward, and that ploughing, manuring and reseeding proved more effective than surface cultivation of the original sward, though cultivation and manuring produced a tremendous improvement over the untreated sward. It is evident also that lime alone will not suffice for such land deficient in both phosphate and lime, as shown by a pH value of 5.23 and an 'available P_2O_5' figure of 1.0 mgm./100 gms. soil when sampled in 1938.

GENOCH RESEEDING EXPERIMENT.

Similar results were obtained in a similar experiment laid down a year later, in June, 1939, on a piece of marginal land immediately adjoining the hill on Genoch farm, Straiton. A similar seed mixture was sown on the ploughed and reseeded land and, as at Kneweside, this land produced a superior sward to the corresponding section cultivated. The slagged and limed areas were superior to the parts receiving slag only or lime only, as indicated by the following botanical analyses figures in the autumn of

1942, three years after the experiment was laid down.

	Cultivated.	Ploughed and Reseeded.				Original Sward.
	Slag+K_2O +CaO	Slag+K_2O +CaO	Slag +CaO	Slag	CaO	Untreated
Lolium perenne	20	33	34	27	24	-
Dactylis glomerata	2	6	5	4	5	-
Cynosurus cristatus	6	9	8	6	2	-
Poa spp.	6	8	6	3	2	-
Trifolium repens	13	21	22	13	9	10
Holcus spp.	18	11	10	16	19	17
Agrostis spp.	15	9	11	18	21	21
Anthoxanthum odoratum	4	1	2	5	10	4
Ranunculus spp.	4	2	2	8	5	5
Carex spp.	2	-	-	-	3	13
Plantago lanceolata	3	-	-	-	-	6
Festuca ovina	3	-	-	-	-	20
Rumex acetosella	4	-	-	-	-	4
viz.						
Superior plants	47	77	74	53	42	10
Inferior "	53	23	26	47	58	90
Soil pH, 0 - 3"		6.38	6.69	5.57	5.75	5.00
" " 3" - 9"		5.80	5.85	5.50	5.63	5.20

The results obtained at this and the other two centres, where ploughing, manuring and reseeding were compared against cultivation and manuring, or manuring without cultivation, and proved much superior, especially when both lime and slag were applied, are in accordance with the results reported in certain East of Scotland experiments (32). Generally speaking, the best swards have again been obtained on the plots with the highest soil pH values, apart from the fact that the potash dressing (in addition to slag and lime) has given a further slight improvement in the sward, though the soil pH figure is slightly lower.

BRACKENHILL LATIN SQUARE GRASSLAND PLOTS.

In previous experiments conducted by the writer it had been found necessary to apply twice as much P_2O_5 in basic slag as in superphosphate to produce the same immediate result when applied to a grassland surface. This relationship between the availabilities of the superphosphate P_2O_5 and the slag P_2O_5 is also mentioned in the Permanent Basic Slag Committee's report No.9, 1931, dealing with yields of meadow hay.

In October, 1939, fifty plots, each $\frac{1}{200}$ acre in extent were laid off on young

grass 'seeds', and to twenty of these plots randomized over the area basic slag was applied at the rate of 150 lbs. P_2O_5 per acre (1667 lbs. 9% slag). In March, 1940, superphosphate was applied to other twenty plots at the rate of 75 lbs. P_2O_5 per acre (417 lbs. 18% superphosphate). Ten of the 'slag' plots and ten of the 'superphosphate' plots received in November 1939 ground lime dressings at the rate of 3,000 lbs. CaO per acre. Ten plots were left as control plots. Potash salts were applied in early April at the rate of 50 lbs. K_2O per acre to all plots, including the control plots. In mid-April sulphate of ammonia was applied to the 'superphosphate' plots, and calcium cyanamide to ten of the 'slag' plots. Nitrochalk was applied ten days later to the other ten 'slag' plots. There were thus two sets of 25 plots each. Nitrogen was supplied by all three manures at the rate of 23 lbs. per acre.

The grass seed mixture used for sowing down the land in the spring of 1939 was of the simple type, only a few species being included: the quantities per acre were as follows:- Lolium perenne 34 lbs., Dactylis glomerata 2 lbs., Phleum pratense 3 lbs., Trifolium pratense 1 lb., Trifolium hybridum 1 lb., and Trifolium repens ½ lb.

The hay crop was cut towards the end of July (for ryegrass seed production) and weighed a week after cutting, the mean yield in lbs. per plot being as follows:- (Abbreviations used as previously).

	Control	A	AL	BL	B	Standard Error.
Cyanamide Series	26.4	34.4	34.6	34.8	31.8	± 1.31
Nitrochalk "	30.0	40.2	40.4	44.4	39.4	± 1.81

Dry weather had followed the application of the manures, and it would appear that the nitrochalk had in the circumstances acted more efficiently than the cyanamide. All manures gave significantly higher yields than the control plots, the 'basic manure and lime' plot proving best in the 'nitrochalk' series, while the lowest yield apart from the control plots, was given by the basic manure (unlimed) on the 'cyanamide' series. Other yield differences between treatments were insignificant.

Samples of the hay were drawn from the nitrochalk series of plots, and nitrogen, P_2O_5, and CaO contents determined with the following results:-

Hay Analyses - Nitrochalk Series. (Percentages calculated both as harvested and on dry matter basis.)

	Control		A		AL		BL		B	
Moisture	16.00%	-	16.02%	-	17.66%	-	17.28%	-	16.50%	-
Nitrogen	.595	.708	.537	.639	.530	.644	.518	.626	.496	.594
P_2O_5	.220	.262	.218	.260	.227	.276	.211	.255	.213	.255
CaO	.204	.243	.180	.214	.260	.316	.241	.291	.203	.243

Weight of various constituents removed (in cwts. per acre) :-

Nitrogen	.179 cwts.	.216 cwts.	.215 cwts.	.230 cwts.	.195 cwts.
P_2O_5	.066 "	.088 "	.092 "	.094 "	.084 "
CaO	.061 "	.072 "	.105 "	.107 "	.080 "

The highest percentage of nitrogen is shown by the control plots; the yield per acre was, of course, lower. The P_2O_5 percentages show only small differences between treatments. The CaO percentages are definitely higher where lime was applied. It is obvious that the amounts of all constituents removed by the crop on the control plots are less than under the various treatments. As regards treatments, the nitrogen removed was less on the basic manure plot and greater on the basic manure plus lime plot than on the other treated plots. The CaO figure is definitely higher on the limed plots, and the P_2O_5 figures show little difference between treatments.

While the P_2O_5 content of the crop under the various treatments is higher than that for the control sections, the total P_2O_5 content is only 6.6% of that applied to the 'basic manure' plots and 13.4% of that applied to the 'acid manure' plots. Viewed in another way, the additional P_2O_5 content of the 'basic manure' crop as compared with the 'control' crop is only 1.8% of that applied, and of the 'acid manure' crop 3.6% of that applied. This would suggest that in 1939 there were P_2O_5 residues in the soil from previous manuring, and that the hay crop in 1940 only required a relatively small additional amount of P_2O_5 in order to give a normal yield. It may be that a low rate of availability in Ayrshire soils of phosphate applied under normal soil conditions necessitates heavier applications than on first examination would seem to be required. It has been found necessary in farm practice to give such heavy dressings before definite improvements in the state of the grassland are obtained. With a light

P_2O_5 dressing in the first year on land newly sown out to grass in Ayrshire, no inferiority can as a rule be detected compared with a liberal dressing, but in later years the benefit of the heavier dressing becomes very marked. The need for heavy phosphate applications in other parts of the country, and the question of phosphate fixation in Ayrshire soils, have been referred to in an earlier section.

At the commencement of these investigations the pH of the top 3" of soil averaged 4.95 and of the next 6" was 5.19; the 'available P_2O_5' figure was .5 mgm./100 gms. soil, and the 'available K_2O' was 5.5 mgm./100 gms. soil. Differences between plots were slight and were almost eliminated when the mean of all the plots under each treatment was taken. Two years later, in September 1941, and again, three years later, in September 1942, differences in pH value between the soils under the various treatments were determined: pH values averaged as follows:-

		Control	A	AL	BL	B
1941,	pH 0 - 3"	5.14	5.07	5.65	5.88	5.32
	pH 3" - 9"	5.24	5.15	5.25	5.31	5.24
1942,	pH 0 - 3"	5.15	5.08	5.77	6.00	5.36
	pH 3" - 9"	5.26	5.22	5.35	5.45	5.30

It is evident that the lime and manurial treatments have influenced the pH values of the top 3" of soil to far greater extent than those of the next 6". This is to be expected from surface applications without any subsequent cultivation. The difference in pH value between 'acid manure' and ' basic manure + lime ' plots in the top 3" is .92, a figure four times greater than the .23 difference for the next 6". With lime or basic manure the surface pH is higher than that of the underlying soil, while on the other plots it is lower.

Botanical analyses made in October, 1940 showed that the herbage differences, though detectable, were only slight, but confirmd the impression by the eye that deterioration had set in on certain plots, especially the control and 'acid manure'. The mean botanical analysis for each treatment was as follows for the two series:-

	Control		A		AL		BL		B	
	Series 1;	Series 2.	1;	2.	1;	2.	1;	2.	1;	2.
Lolium perenne	35.2	32.6	37.2	37.2	37.8	39.0	36.2	35.8	37.4	35.6
Dactylis glomerata	14.0	8.2	14.2	8.8	13.8	9.4	15.6	9.2	10.2	9.6
Phleum pratense	9.6	10.4	10.4	10.6	12.6	16.2	11.6	17.2	9.8	15.0
Trifolium pratense	-	-	-	-	-	.2	.4	-	.2	-
" hybridum	1.4	.4	1.0	.8	1.2	1.0	1.8	1.6	1.6	1.2
" repens	1.0	.8	.8	.4	1.2	.4	.6	.8	1.4	.8
Holcus spp.	31.0	38.8	29.6	34.6	28.2	26.6	28.0	28.0	32.2	29.6
Agrostis spp.	1.4	2.2	.4	.4	-	1.4	-	.2	.8	.2
Ranunculus spp.	4.2	4.8	4.0	5.0	3.6	3.6	3.2	5.6	3.8	5.4
Trifolium dubium	2.2	2.0	2.4	2.2	1.6	2.2	2.6	2.0	2.6	2.6

Summarised, these figures give:-

	Control	A	AL	BL	B
Useful Plants	58.8	63.0	68.3	67.5	64.0
Inferior "	41.2	37.0	31.7	32.5	36.0

By September 1941, and still more a year later, deterioration had become marked on the control and 'acid manure' plots. Botanical analyses results averaged as below:-

September, 1941.	Control		A		AL		BL		B	
	1;	2.	1;	2.	1;	2.	1;	2.	1;	2.
Lolium perenne	17.2	11.0	19.4	13.8	25.8	24.2	30.6	25.8	24.0	21.2
Dactylis glomerata	9.2	8.0	11.6	10.0	13.2	10.0	10.0	11.4	12.8	7.6
Phleum pratense	6.4	7.4	9.4	7.8	9.4	12.0	12.6	15.0	11.4	11.8
Cynosurus cristatus	.2	-	.4	.2	.2	.2	1.0	.6	.4	.2
Poa spp.	2.2	-	3.0	1.0	5.6	3.8	8.6	4.8	7.0	1.8
Trifolium pratense	-	-	-	-	-	-	.2	†	.4	-
" hybridum	3.4	1.6	2.2	1.2	2.0	.4	1.4	.6	3.6	1.4
" repens	2.4	1.0	2.4	.8	4.4	3.6	11.0	4.4	7.2	1.6
Holcus spp.	22.2	26.4	22.0	25.0	18.2	22.4	13.2	22.4	17.6	24.8
Agrostis spp.	26.6	30.0	20.8	27.2	10.2	9.8	5.4	3.8	8.4	14.6
Ranunculus spp.	6.6	12.4	6.8	11.2	7.0	12.0	6.0	9.6	6.0	12.2
Trifolium dubium	3.6	2.2	2.2	1.8	2.0	2.2	-	1.6	1.2	2.8
September, 1942.										
Lolium perenne	13.4	11.4	16.6	13.4	31.0	30.2	39.8	31.0	28.6	24.2
Dactylis glomerata	3.6	4.0	2.6	3.0	5.4	4.8	7.2	9.2	7.8	7.0
Phleum pratense	3.8	9.8	6.6	10.2	10.0	10.8	10.4	19.0	8.6	15.8
Cynosurus cristatus	1.2	-	1.2	-	1.4	-	1.6	-	1.4	-
Poa spp.	.6	-	.4	-	.4	-	2.0	-	1.2	-
Trifolium hybridum	-	-	-	-	-	1.0	-	1.2	-	.6
" repens	4.2	3.0	3.6	3.4	11.6	7.8	11.8	8.2	10.6	5.6
Holcus spp.	26.2	20.0	25.0	21.4	22.8	20.2	13.0	18.4	23.4	21.6
Agrostis spp.	32.8	36.2	31.2	33.6	5.0	5.8	3.2	1.8	5.8	10.6
Ranunculus spp.	13.0	13.4	11.2	12.6	10.2	11.6	9.4	10.6	11.8	11.6
Bellis perennis	-	-	-	-	-	-	.4	-	-	-
Trifolium dubium	1.2	2.2	1.6	2.4	2.2	1.8	1.2	.6	.8	3.0

Summarised, these tables give the following results:-

September, 1941.	Control	A	AL	BL	B
Useful Plants	36.9	43.5	60.2	69.8	58.2
Inferior "	63.1	56.5	39.8	31.2	41.8

September, 1942.

	Control	A	AL	BL	B
Useful Plants	29.2	32.5	62.2	71.6	57.6
Inferior "	70.8	67.5	37.8	28.4	42.4

During 1942 the control and 'acid manure' plots were easily picked out; they lacked the vigour of growth and healthy appearance of the others, displaying a 'whiteness' throughout the entire season. The 'basic manure + lime' plot had the most vigorous appearance in each row, and the 'acid manure + lime' plot had generally a better colour than the 'basic manure' plot. The appearances and contrasts were similar to those on the Demonstration Area in the adjoining field, of which an account has already been given.

BRACKENHILL LATIN SQUARE SWEDE PLOTS.

These May 1940 plots were laid off in a 5 by 5 Latin square on swedes, the five treatments being 'basic Manure' with and without lime, 'acid manure' with and without lime, and control. The plot size was $\frac{1}{100}$ acre. As lime is more important for grass seeds than for the turnip crop, and tends to sink rapidly in the soil, it was decided to withhold the lime till 1941. This is in accordance with what I recommend as farm procedure in the interests of production. There were accordingly only three treatments in 1940 on the turnip crop. The basic manure supplied 200 lbs. P_2O_5 per acre in the form of basic slag, and 35 lbs. nitrogen per acre as nitrochalk; the acid manure supplied 150 lbs. per acre P_2O_5 as superphosphate, and 35 lbs. nitrogen per acre as sulphate of ammonia. Experiments in Ayrshire have indicated that in the year of application the P_2O_5 in basic slag is approximately 75% of the efficiency of that in superphosphate, when applied to cultivated land. In addition 35 lbs. K_2O per acre were applied as 30% potash salts to all plots. All manures were applied in the drills after cultivation was completed. The drills were thereafter split and the swede variety 'Best of All' sown in the first week of May.

The control plots were visibly more backward throughout the growing season. The yields and dry matter contents under the various treatments were ascertained at lift-

ing time in November with the following results:-

	Mean Yield Tons/acre.	Standard Error.	Mean % Dry Matter.	Yield Dry Matter Tons/acre.
Control	15.60		10.97	1.71
Acid Manure	18.86	± .37	10.61	2.00
Basic "	20.57		10.81	2.22

The basic manure has given both the highest yield of crop and the highest yield of dry matter, the difference between the various treatments being highly significant.

At the outset in May 1940 the mean pH value of the soil to 9" was 5.24 and of the subsoil 5.80. In 1941 a standard dressing of 2,000 lbs CaO per acre was applied to the whole field before sowing the oat crop. In addition CaO was applied at the rate of 3,360 lbs. per acre to five 'acid manure' and five 'basic manure' plots, the remaining 'acid manure' and 'basic manure' plots receiving no further lime. The manures, lime and Yielder oats were sown in mid-April 1941. Nitrogen was applied at the rate of 50 lbs. per acre, and phosphate at the rate of 50 lbs. P_2O_5 per acre, the manures on the 'acid manure' plots being sulphate of ammonia and superphosphate, and on the 'basic manure' plots nitrochalk and basic slag. The crop was cut and stacked in September and threshed in March. Mean yields (in cwts. per acre) were as follows:-

	Control	A	AL	BL	B	Standard Error.
Total Yield (September)	60.0	74.6	69.0	69.2	73.0	
Grain " (March)	15.2	24.6	22.8	23.0	24.2	± 1.09
Difference (Straw, Chaff, Moisture)	44.8	50.0	46.2	46.2	48.8	

It would appear, therefore, that manuring gave an increased yield, there being no difference in that respect between 'acid' and 'basic' manure; the 'limed plots' yielded less than the 'unlimed' (which had received a lime dressing in common with the rest of the field). The further lime dressing evidently raised the pH value too high for optimum results from the oat crop, the surface soil on these areas having a pH of almost 7.0 while oats prefer a somewhat acid soil. The standard lime dressing of 2,000 lbs. per acre CaO applied to the whole area between the turnip and oat crops had apparently corrected the acidity sufficiently for optimum growth of the oat crop; the additional lime applied had produced a slight reduction in yield. The detrimental effect

of too much lime on the oat crop was experienced by North Ayrshire farmers during the latter part of last century, when shell lime applications of 4 tons per acre each rotation were common. The effect of high pH values in producing 'oat-sickness' in the North of Scotland has also been mentioned by Hendrick and Moore (33). The mean soil pH figures determined in the late autumn of 1941 were as follows:-

	Control	A	AL	BL	B
pH 0 - 3"	6.17	6.06	6.74	6.77	6.51
pH 3" - 9"	5.41	5.31	5.46	5.85	5.59

A simple grass seeds mixture, similar in composition to that used two years previously for the adjoining plots, had been sown in 1941 with the oats, and in 1942 the land was under hay. The rate of application of nitrogen was 25 lbs. per acre, and sulphate of ammonia was used on the 'acid manure' plots at the rate of 120 lbs. per acre, and nitrochalk on the 'basic manure' plots at the rate of 160 lbs. per acre. Superphosphate was applied to give a further 50 lbs. P_2O_5 per acre to the 'acid manure' plots, thus bringing the total P_2O_5 applied during the three years up to the rate of 250 lbs. per acre for 'acid' and 'basic' plots alike. The hay crop was cut at the end of July and weighed two weeks later. Mean yields (in tons per acre) were as follows:-

Control	A	AL	BL	B	Standard Error.
1.82 tons.	2.15 tons.	2.45 tons.	2.52 tons.	2.26 tons.	± .093

The increased yields of the 'acid' and 'basic' manurings over the control plots are significant, while the further increases, due to liming, are also significant. The differences between acid and basic manuring are not significant.

The botanical analyses made in September 1942 gave the following results:-

	Control	A	AL	BL	B
Lolium perenne	35.8	39.6	45.0	48.6	43.6
Dactylis glomerata	13.2	10.4	12.0	13.0	11.6
Phleum pratense	13.8	14.2	18.0	16.4	17.4
Trifolium hybridum	5.6	5.0	5.6	5.2	4.6
" repens	2.2	1.0	.6	1.4	1.4
Holcus spp.	15.2	16.8	9.0	6.2	10.4
Agrostis spp.	.4	.8	-	-	-
Ranunculus spp.	13.2	11.8	9.8	8.6	10.6
Bellis perennis	.6	.4	-	.6	.4
viz.					
Useful Plants	70.6	70.2	81.2	84.6	78.6
Inferior "	29.4	29.8	18.8	15.4	21.4

The mean soil pH figures determined at the same time were as follows:-

		Control	A	AL	BL	B
Soil pH,	0 - 3"	5.86	5.80	6.54	6.92	6.21
" "	3" - 9"	5.45	5.43	5.66	6.05	5.65

It is again obvious that the inferior plants are in smaller proportion on the plots with the higher pH values: for example, on the limed portion of the basic manure plot, having an average pH of 6.92 in the top 3", the inferior plants comprise 15.4% of the herbage, while on the unlimed portion of the acid manure plot, with a pH of 5.80 in the top 3", the inferior plants form 29.8% of the herbage.

As compared with the soil figures a year previously, the pH value of the surface soil is slightly lower, and that of the lower layer, 3" - 9", slightly higher. This is to be expected from the lime tending to sink in the soil. The average fall in pH in the top 3" of the soil is .23, while the average rise in the 3" - 9" layer is .13.

COMPARISON WITH RESULTS OF OTHER GRASSLAND INVESTIGATIONS.

The predominance of Lolium perenne and Trifolium repens, and the association they form, on good permanent pastures in the English Midlands and elsewhere has been described by Armstrong (34). He has also commented on the prevalence of Agrostis vulgaris and other weeds in inferior permanent pastures, and found that the choicest grazing land was associated with soils rich in available phosphate. Smith and Crampton in a discussion (35) on natural and artificially induced grasslands emphasise that the former only occur on limestone and allied soils, while the latter show marked variations apparently unconnected with their habitat, and are frequently unstable in regard to their herbage, and require constant attention if the higher grazing value is to be maintained and degradation to scrub, etc. prevented.

Studies on the botanical composition of older grasslands (36) by Wyllie Fenton have shown that intensive manuring and rotational grazing in Devon improved the flora, resulting in the production of swards containing 70-80% Lolium perenne and Trifolium repens, with 5% Agrostis, 5% Poa trivialis and with small quantities (less than 3%

of each) of Dactylis glomerata, Ranunculus spp., Bellis perennis, and Hieracium spp. The percentage of Agrostis in the original sward is not stated, although at the outset of the grazing trials it averaged less than 13% of the sward. It would appear therefore that in the Devon investigation the conditions for the growth of Agrostis were less favourable than those obtaining at Brackenhill and on the other Ayrshire farms mentioned above.

Wyllie Fenton has also reported investigations affecting grassland retrogression in Devonshire permanent pastures (37), and how transition from Group I pastures (Trifolium repens and Lolium perenne dominant) to Group II pastures (Trifolium repens dominant and Agrostis sub-dominant) and to Group III pastures (Agrostis dominant; and Holcus lanatus, Cynosurus cristatus or Anthoxanthum odoratum sub-dominant) and lower groups, or vice versa, may take place. He finds the chief deficiency of most permanent pastures to be phosphate and lime. Such pastures also often suffer from inefficient management and inadequate grazing.

In his botanical survey of grasslands in the East of Scotland (38) he found that the botanical composition of grasslands, which have been recently sown, are, other things being equal, determined by the nature of the seed mixture. With similar seed mixtures strongly similar grasslands will, he states, be obtained, and the use of an inferior strain of any species may cause marked changes in the flora. In most of the botanical analyses quoted for rotation grass, Lolium perenne and Trifolium spp. constitute approximately 80% of the species present, Lolium perenne predominating in the first year, and Trifolium repens in the later years. In only one case was there an appreciable proportion of Agrostis spp. In only a few special cases also did Agrostis occur in considerable quantities in the permanent pasture swards. In most of these Trifolium repens was dominant. He also comments that in natural or semi-natural grasslands skilful management will produce improvement, that acidity is one of the commonest causes of inferior vegetation, and that, although the geological formation and nature of the surface soil may be a decisive factor in determining the flora

under natural conditions, this is not necessarily true of all agricultural land. His conclusions are that "In grasslands of long duration soil condition and general treatment play a very important part; grazing is a most important biotic factor. Deficiency in nitrogen, calcium, phosphorus or potassium or of more than one of these, is reflected in the flora of the grassland."

In the view of Wyllie Fenton, therefore, the nature of the grass seed mixture is the most important factor affecting the composition of the sward in rotation grass. He found, however, that in grasslands of long duration, soil condition - manuring, liming, drainage - and general management play a very important part. He states that fertility and other conditions in soils under rotation cropping are generally favourable to the establishment of the superior sown species of herbage plants. My experience in the investigations at Brackenhill and elsewhere in Ayrshire was that soil condition, especially the lime- and phosphate- status, was the most important factor affecting the botanical composition of rotation grass swards. Grass seed mixture effects were limited even in the first two years, and as a rule were relatively small thereafter. Under average conditions in West Scotland the Lolium perenne-Trifolium repens association forms a lower proportion of the sward, seldom more than 50 - 60% even under the best conditions on typical dairy farms, as compared with 80% in many of the cases quoted for East and South-east Scotland and Devonshire by Wyllie Fenton. On the other hand, Poa trivialis, Cynosurus cristatus, Agrostis spp., and Holcus lanatus are much more prevalent in our West swards than in these East Scotland or South England pastures.

Stapledon in his recent writings has stressed the importance both of the seed mixture, including special strains of pasture plants, and of a satisfactory lime- and phosphate- status of the soil, if good pasture is to secured and maintained. He has found in his investigations that numerous viable seeds of Agrostis and Holcus lanatus are present in soils (39), and that these plants will spread rapidly if the soil fertility conditions are not sufficiently high for the survival of the sown species.

GENERAL OBSERVATIONS PREVIOUS TO 1941.

In connection with investigational and advisory work carried out by me on many Ayrshire farms, numerous soil samples were taken for examination. Almost every farm in the County was visited by me on one or more occasions between 1928 and 1940 in connection with some fertility problem, and pH values were determined roughly in the field or more accurately in the laboratory. In the later years 'available P_2O_5' and 'available K_2O' figures were also determined in the routine examination of these soils.

As already mentioned, serious deficiencies in lime and phosphate for good pasture were found on very many farms. On many such farms oat and potato yields were normal. Even at pH values only slightly exceeding 4.0, good yields of these crops were being obtained so long as the soil was otherwise in a good state of fertility. On soils in poor condition, on the other hand, even liberal manurial applications failed to produce satisfactory oat and potato crops when the pH was much under 4.5. Between 1920 and 1930 very little wheat was grown in Ayrshire, and barley had ceased to be a rotation crop, and even as a catch crop after potatoes it was yielding unsatisfactorily on many farms. These two cereal crops are more sensitive to soil acidity than oats and fail before pH values have sunk so low. The following figures for seven farms give the comparisons between pH values and 'available' P_2O_5 and K_2O in mgm./100 gms. of soils on which wheat growth was apparently normal, and of those immediately adjoining in the same fields where the crop was poor or even a complete failure.

Farm.	Wheat Normal.			Wheat Poor.		
	pH	P_2O_5	K_2O	pH	P_2O_5	K_2O
Stanley	5.07	12.3	1.7	4.41	17.0	3.4
Warrix	5.45	20.7	23.8	4.57	18.0	25.1
Springside	4.90	18.0	6.1	4.36	22.4	10.7
Helmes	4.97	4.5	11.9	4.30	1.4	24.1
Houdston	4.96	28.5	19.1	4.52	36.3	26.7
Girvan Mains	5.43	96.0	16.6	4.67	98.0	26.6
S. Sanquhar	6.33	25.1	.5	4.52	20.5	7.1

It would appear from the above figures that, under Ayrshire climatic and soil conditions, a full crop of wheat cannot be expected when soil pH values fall much under 5.0. In almost all these cases the P_2O_5 and K_2O figures were higher where the crop

was poorer, probably due to the less vigorous crop taking up smaller amounts of these constituents. The amounts present in all cases are greater than those found in the average Ayrshire soil capable of growing good crops. The wheat on the areas with the pH values of 4.41, 4.36 and 4.30 failed completely; the critical figure appears to be around 4.7 to 4.8.

The critical pH figure for red clover would appear similar to that for wheat as suggested by the following data for three farms and Morriston Demonstration Area:-

Farm.	Red Clover Present.			Red Clover Absent.		
	pH	P_2O_5	K_2O	pH	P_2O_5	K_2O
Threave	4.77	10.5	1.8	4.52	8.0	2.8
Barneil	5.13	9.5	6.7	4.77	12.0	8.8
Enterkine	5.17	.5	6.4	4.59	2.1	9.3
Morriston	5.50	5.8	6.4	4.70	6.7	19.7

Such results are typical of farms where, when sowing back land to grass, liming was less common ten years ago than now, and where the difference in soil acidity between the potato land and the turnip land of the previous year was often sufficient to decide the fate of red clover. The difference of the effects of the potato manure with its higher sulphate of ammonia and lower phosphate content compared with the turnip manure often sufficed to cause a red clover failure on the 'potato' section, while it succeeded on the 'turnip' section. On the other hand, there were farms on which lime and basic slag were being employed and where the red clover failed on the 'turnip' section and did well on the 'potato' section. This was most common where the farmer had been using very little potash and the soil showed a low 'available K_2O' figure, as on the farm of Mossend, Kirkmichael, where in accordance with normal practice three times as much K_2O was applied to the potato as to the swede crop. The potash taken from the soil by both crops is practically the same, a 10 ton potato crop removing approximately the same weight of K_2O as a 27 ton swede crop. The following are the soil figures obtained on Mossend when the land was under hay:-

	pH	P_2O_5	K_2O
'Turnip' section: no red clover.	5.54	5.4	1.9
'Potato' " : red clover.	5.31	3.7	4.0

The part of the County in which the available supply of potash was most often found the limiting factor was that included in Monkton, Ayr, Tarbolton, Stair and Mauchline parishes, and in certain parts of the northern half of the County. Seldom was it the factor responsible on soils in the Carrick division, though such soils are mostly of lighter texture than those further north. They are apparently better provided with potash than the heavier North Ayrshire soils.

During the period June 1938 - June 1940, 450 farm soil samples were drawn by me in the northern part of the County and 595 in the southern portion. Many of these samples were taken because the farmers concerned suspected the need for lime, through crops and/or pasture not giving satisfactory results, and desired to have their suspicions confirmed. This is reflected in the fact that only 159 or 15% of this total of 1,045 samples returned pH values of 5.50 or over: 80 of these soils were from the northern parishes and 79 from the southern parishes. Over 71% of the samples showed 'available P_2O_5' figures of under 7.0 mgm./100 gms. soil and 64% showed similarly low 'available K_2O' figures. Almost 10% of the soils returned 'available P_2O_5' figures of over 14.0 mgm./100 gms. soil, and 13.6% gave similarly high 'available K_2O' figures. The following table gives the numbers of soils falling into each category:-

		North Ayrshire.		South Ayrshire.		Total.	
		Number	%	Number	%	Number	%
High	P_2O_5	30	6.7	73	12.3	103	9.9
Medium	"	92	20.4	105	17.6	197	18.8
Low	"	328	72.9	417	70.1	745	71.3
High	K_2O	42	9.3	100	16.8	142	13.6
Medium	"	94	20.9	139	23.4	233	22.3
Low	"	314	69.8	356	59.8	670	64.1
Total Soils		450		595		1045	

There is comparatively little difference between the proportions of soil samples showing low phosphate figures in the two parts of the County, but there are more low potash figures in the northern portion. Here the proportion of potash deficient soils was almost as great as the phosphate deficient ones. The proportion of potash deficient soils in the southern half of the County was 10% less.

The tolerance of crops and pasture to acidity is exemplified by the figures below from Lissens Moss farm, Dalry, where varying proportions of clay and moss occur in most fields. Where the clay predominates in the soil, crops do well, but where the brown unchanged moss predominates, crops, as well as pasture, fail. The figures are for soil samples taken from a three-acre area in a field typical of the district.

Soil Class.	Loss on Ignition.	pH	P_2O_5	K_2O
Clay	24.5%	4.62	2.0	22.0
Black moss	71.4	3.98	.5	26.8
Brown "	64.7	3.44	2.4	29.6

On this type of land satisfactory oat crops were obtained from the clay section, and the better grasses established themselves when sown; unless slag or lime were applied deterioration set in. On the black moss oats yielded more straw and less grain than on the clay land, but superier sown grasses failed from the start. On the brown moss with abnormal acidity neither oats nor young grass seeds were able to grow.

Generally, my experiences in Ayrshire were that crops would grow on soils with lower pH values than those on which these crops failed in the North of Scotland (33) and in the English West Midland Province (40). While red clover, wild white clover and wheat all failed in the North when pH values sank to under 5.3, and in the West Midlands (apart from white clover) before a pH figure of 5.0 was reached, they grew satisfactorily in Ayrshire down to a pH of 4.8; and on soils well supplied with phosphate and potash wild white clover flourished at pH values of 4.5, the same figure as reported for the West Midland Province. Swedes, however, failed at approximately the same figure, around 4.7, as in the North. The swede critical pH figure in the Midlands was 4.9. Potatoes and oats were commonly found thriving in Ayrshire on soils with pH values just over 4.0, whereas in the North failures occurred in these crops before the figure had sunk to 4.5, and in the West Midlands at 4.2. The Ayrshire intensively manured soils, such as were found in the early potato growing areas, appeared to have the ability to grow good crops at lower pH values than those at which they failed on the less-well-managed soils in other parts of the County. The

beneficial influence of heavy phosphate dressings in reducing toxic effects of soil acidity, without raising the pH value, has been reported both by British (41) and American investigators (42). The poisonous effects appear to be eliminated by precipitation both in the soil and in the plant of aluminium and possibly other compounds.

1941 - 42 SURVEY.

During the second half of 1941 and early months of 1942 a special survey of 221 South Ayrshire farms of all sizes and types, and selected at random from each class, was made in order to ascertain their general condition and requirements, including the amount of land under rotation, the possibilities of increased crop production and of the maintenance of increased numbers of livestock, the need for lime, manures, drainage, buildings, etc., as well as the area of land which could be reclaimed from rough grazing. The holdings before the random selection were classified according to size, and 10% were taken from the 5 - 50 acre group, 15% from the 50 - 100 acre group, 20% from the 100 - 150 acre group, 25% from holdings over 150 acres, and 25% from farms consisting of rough grazing only. The sample accordingly included approximately one-sixth of all holdings over 5 acres and represented one-fifth of the total agricultural land of South Ayrshire. The general condition of many of these farms had been greatly improved during the preceding ten years with liberal manurial and lime dressings, while little had been done on a number of others to increase their productive capacity. In conjunction with this survey three soil samples, on the average, were taken from each holding. Generally on the dairy farm one sample was taken from land being cropped at the time, one from land recently laid down to grass, and one from land which had been longer under pasture, and was to be put through a course of cropping at an early date. On cropping farms or when the land was only a short time in grass the samples were mostly taken from the land under crop, and on holdings under ten acres in extent only one sample was generally required, as the manurial treatment and cropping had usually been uniform. On larger-sized farms or when special conditions rendered it advisable, additional samples were taken, the chief aim in all cases being to get as true a picture

as possible of the soil conditions of each holding from a limited number of samples.

Examination of these soil samples showed that on most farms pH values were higher than was the case ten years before. On only a few farms were samples of under 5.0 pH encountered, and such soils were generally confined to marginal land or rough grazing on such farms, while a very large number of soil samples on the better managed farms had pH values of over 6.0. The arithmetic mean of the pH values for all soils taken in the course of the survey was 5.50, the figure on the best farms approximating to 6.0, while on the most neglected farms it averaged 5.1. A selection was made of well-managed farms throughout the area, where liming had been regularly practised since 1930, and amounting to 10% of the total number, and a further 10% selection was made comprising those on which little or no lime had been employed, and each of the latter being comparable in soil type to, and in many cases adjoining, a counterpart of the other group. The 'mean' pH value of all the soils taken on the better farms was 5.93, and that of all soils tested from the poorly-limed farms was 5.15. On potato-growing farms, where values of under 5.0 were the rule ten years previously, they were now the exception. In spite, however, of the amount of basic slag and ground rock phosphate applied in the interval, the 'available P_2O_5' figure had only risen slightly, indicating that 'phosphate-fixation' had taken place in such a way that the routine analytical methods failed to detect such added phosphate as 'available' phosphate.

The condition of the grassland on the individual farms was found to be a reliable indicator of the general fertility of the farm. The prevalence of Agrostis and Holcus in the pastures denoted soils with definite lime requirements, large quantities of Agrostis being present with pH values of 5.0 or under, while little or no Agrostis and Holcus was found with a pH of over 6.0. On most farms the lowest pH figure was found on ploughed land or old grass due for ploughing, and the highest on land recently sown out. This resulted from the practice recommended to, and adopted often by, farmers in recent years of applying lime when sowing out to grass; the land, which had been many years in grass, having been laid down before the farmer had commenced liming his sown-

out land as part of his normal farming practice.

The soil samples taken in connection with this survey totalled 678, and, as a rule, only one sample was taken from the rough grazings on each farm, even where these were of greater extent than the arable land. When the rough grazings area was small relative to the size of the holding, the samples were confined to the improved land. The 'arithmetic mean' of all pH values was 5.50; excluding marginal and rough grazings soils, we obtain a figure of 5.60 as the 'mean' pH of all arable soils sampled. The parishes with the highest 'mean' pH values are Girvan (5.81), Ayr (5.71), Dalrymple (5.65), Kirkoswald (5.63), Dailly (5.62), and Stair (5.61), and those with the lowest 'mean' pH values are Barr (5.15), Dalmellington (5.16), Muirkirk (5.24), Straiton (5.28), New Cumnock (5.29), and Old Cumnock (5.29). The latter list contains those parishes with the greatest proportions of marginal land and rough grazings; the former list includes those parishes with relatively small areas of marginal land and/or rough grazings. The number of farms where production was suffering from insufficient employment of manures and lime was 56, while a further 52 were using satisfactory dressings of manures but were neglecting to lime, and were, therefore, not deriving full benefit from the manures applied: under the latter condition the pastures were suffering in yield much more than the arable crops. That is to say, production on 25% of the farms was under the maximum through lack of both lime and other manures, and 23% were suffering from lack of lime only. On a much smaller number of farms defective drainage was affecting production, and on some of the better hill land production was suffering from the spread of bracken. On one half of the farms, therefore, soil fertility was at a high level, and only slight increases in production could be obtained by drainage operations or by manuring and/or liming.

It was found in the course of this survey that a proportion of the land classified as rough grazing was superior to land classed on other farms as 'crops and grass' and was capable of being raised to the 'crops and grass' category through manuring and/or ploughing and reseeding. An area of approximately 4,500 acres was capable of

easy improvement, drainage being only required on small sections. This area is approximately 7.6% of the total of rough grazings surveyed, and, if improved, would have the effect of raising the 'crops and grass' acreage of the total area surveyed by approximately 15%. To reclaim a further equal area of rough grazing more extensive drainage operations would be required as a preliminary step, and the time and expense required would be much greater.

The following tables summarize some of the survey results:-

Parish.	Total crops and grass. acres	Acreage surveyed. crops & grass.	rough grazing.	Badly drained. acres	%	Farms surveyed.	Deficient in manures & lime.	lime only.	Soils sampled.	Mean pH
Ayr	8600	1586	2	24	1.5	19	2	2	45	5.71
Monkton	2300	252	-	3	1.2	3	1	1	8	5.48
Tarbolton	10254	1976	57	98	5.0	16	5	2	49	5.57
Coylton	7524	1727	1071	36	2.1	13	4	3	39	5.56
Dalmellington	944	261	982	135	51.7	2	2	-	7	5.16
Dalrymple	4593	875	1216	127	15.5	6	2	1	18	5.65
Auchinleck	6432	1168	4300	258	22.1	10	4	3	28	5.50
Muirkirk	3361	606	6730	74	12.3	6	3	1	16	5.24
New Cumnock	12183	2483	6866	348	14.0	15	7	3	48	5.29
Ochiltree	10502	1946	273	373	19.2	14	4	5	45	5.49
Old Cumnock	9087	1525	611	348	22.9	13	3	4	37	5.29
Stair	4710	1016	21	32	3.1	8	2	1	22	5.61
Ballantrae	6100	990	3145	66	6.7	7	2	2	20	5.45
Barr	3264	533	8848	54	10.1	6	2	2	20	5.15
Colmonell	12604	1985	6363	176	8.9	19	2	4	55	5.53
Dailly	5191	1336	2039	59	4.4	8	2	2	25	5.62
Girvan	5363	963	2518	20	2.1	6	-	1	22	5.81
Kirkmichael	10476	2428	537	225	9.3	13	4	5	48	5.44
Kirkoswald	8341	1955	519	57	2.9	11	3	-	38	5.63
Maybole	15234	3527	817	111	3.1	19	2	5	66	5.60
Straiton	5490	910	11613	148	16.3	7	-	5	22	5.28
	152553	30048	58528	2772	9.2	221	56	52	678	5.50

It will be observed that the total area surveyed was almost 90,000 acres, of which fully 30,000 acres were improved land, generally fit for cropping and classed as 'crops and grass' in the agricultural returns. There was practically no land outwith the 'crops and grass' category in the parishes of Ayr, Monkton, Stair and Tarbolton, while in Barr, Straiton and Muirkirk the rough grazings exceeded the 'crops and grass' area by more than eleven times. The other parishes in which the rough grazings area surveyed was higher than the improved land area were Colmonell, Ballantrae, Dalmellington, Auchinleck, New Cumnock, Girvan, Dailly and Dalrymple.

The area under crops and grass on which production was suffering seriously from lack of drainage or defective drainage was 2,772 acres, equal to 9.2% of the total acreage of improved land surveyed. The figure varied from under 2% in Monkton and Ayr parishes to over 50% in Dalmellington parish, the next highest parish figure obtained being 23% in Auchinleck and Old Cumnock, 19% in Ochiltree, 16% in Straiton, 14% in Dalrymple and New Cumnock, and 12% in Muirkirk.

The following tables give a comparison of the three pH values taken on 10% of the farms surveyed where liming had been regularly practised, and of those of a further 10% on which very little liming had taken place, each being comparable in soil type and farming practice with a farm in the other group:-

Regularly limed.	pH values.			'Mean pH'
Trees, Ayr.	6.06	5.78	5.54	5.79
Doonholm, Ayr.	6.76	6.07	5.95	6.26
Fulshawwod, Ayr.	6.22	5.88	5.78	5.96
Messbog, Tarbolton.	5.95	5.76	5.65	5.79
Raithhill, Coylton.	6.28	5.80	5.50	5.86
Bogside, Coylton.	6.40	6.16	6.04	6.20
Auldhouseburn, Muirkirk.	5.61	5.61	5.56	5.59
Braehead, New Cumnock.	5.95	5.85	5.31	5.70
Gatehead, " "	5.78	5.59	5.50	5.62
Barshare, Old Cumnock.	6.20	5.77	5.50	5.82
Carston, Ochiltree.	6.07	5.88	5.69	5.88
Lessnessock, Ochiltree.	6.34	5.78	5.57	5.90
Lawhill, Stair.	6.43	5.75	5.55	5.91
Muirston, "	6.01	5.90	5.81	5.91
Boghouse, Colmonell.	6.30	5.94	5.85	6.03
Balluskie, "	5.90	5.85	5.81	5.85
Hawkhill, Dailly.	6.84	5.78	5.63	6.08
Balcamie, "	6.07	6.02	5.75	5.95
Drumbeg, Kirkoswald.	6.68	6.52	5.99	6.40
Dalduff, Maybole.	6.09	5.97	5.85	5.97
Whitefaulds, Maybole.	6.59	6.20	6.02	6.27
Malcolmston, Dalrymple.	5.95	5.80	5.61	5.79
'Mean'	6.20	5.89	5.69	5.93

The 'mean pH' of the 66 soils from these farms regularly limed during the past ten years was 5.93. Even on these farms certain fields had not been recently limed as shown by the 5.31 pH on Braehead, and 5.50 on other farms. At Drumbeg, where all fields sampled had been recently limed, the lowest figure was 5.99 and the highest 6.68. At Whitefaulds and Bogside most fields have been limed several times in the last twenty

years, and this is reflected in 'mean pH' figures of 6.27 and 6.20 for these farms.

Liming Not Practised.

	pH values.			'Mean pH'
Newlands, Monkton.	5.50	5.37	5.05	5.31
Blackhill, Ayr.	5.26	5.24	4.76	5.09
Enterkine, Tarbolton.	5.16	5.15	4.81	5.04
Barmoorhill, "	5.56	5.29	5.26	5.37
Shalloch, Coylton.	5.26	5.13	4.98	5.12
Carnochan, Straiton.	5.37	5.15	5.09	5.20
Cressflat, Muirkirk.	5.26	5.11	4.82	5.06
Tardoes, "	5.47	5.00	4.95	5.14
Merkland, New Cumnock.	5.47	5.13	4.70	5.10
Nether Guelt, Cumnock.	5.11	4.72	4.41	4.75
Drumbowie, Ochiltree.	5.28	5.21	5.14	5.21
Berlandmains, Cumnock.	5.24	5.19	5.09	5.17
Knockshoggle, Coylton.	5.50	5.31	4.90	5.24
West Tarelgin, Ochiltree.	5.26	5.24	5.15	5.22
Spenceton, Colmonell.	5.40	5.16	4.95	5.17
Ballaird, "	5.31	5.29	5.13	5.24
Dinmurchie, Barr.	5.21	5.03	5.00	5.08
Balgaverie, Dailly.	5.29	5.26	5.17	5.24
Barnford, Kirkmichael.	5.28	5.00	4.85	5.04
Kileekie, "	5.47	5.31	5.17	5.32
Broomknowes, Maybole.	5.37	5.06	4.74	5.06
Burnton, Dalmellington.	5.59	5.16	4.94	5.23
'Mean'	5.35	5.16	4.96	5.15

The 'mean pH' of the 66 soils from the farms where little or no liming had been done in recent years was 5.15; 20% of the samples were under 5.0. A few of the fields on these farms or portions thereof had been limed or slagged some time previously, which explains the higher figures for individual soils at Newlands, Merkland, Knockshoggle, Kileekie and Burnton. On most of the other farms with low pH figures and only a small range in pH, none of the soils sampled had been limed or slagged. It may be added that, at the time of the survey, lime had been delivered to some of these farms and ordered for others for land recently sown out to grass after a course of cropping. An improvement in the soil pH figures on many of these farms can be expected in the near future.

The following tables show the pH range for each of the South Ayrshire parishes, and the number of soils sampled therein for the survey included in each .1 range of pH (for example, the figure 5.2 signifies the range 5.20 - 5.29 inclusive), and also the number of soils with high, medium, and low P_2O_5 and K_2O figures in each parish:-

	3.7	3.8	4.0	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.7	6.8	7.3
Monkton												1			3		1		2	1										
Ayr									1					3	2	2	8	6	7	2	8	2		2			1	1		
Tarbolton										1			3	2	5	4	10	8	7	4	2	2	1							
Stair											1	1			3	4	3	1	2	3	1	1	1			1				
Coylton								1			1	2	1	3	4	6	8	3		2	2	1	1	2	1	1				
Dalmellington											3		1	2			1													
Dalrymple																3	6	5		1	2		1							
Auchinleck						1	1						1	4	3	1	5		7	1	3	1								
Muirkirk										1		4	2	2		2	2	2			1									
New Cumnock				1	3			1		1	1	4	3	4	10	6	5	3	2	3	1									
Ochiltree										1			2	10	5	7	8	3	3	3	1	1			1					
Old Cumnock						1	2		2	1	2	1	6	3	1	5	7	1	2	1	1			1						
Kirkmichael											1	2	5	5	8	9	6	2	5	4	1									
Kirkoswald									1	1		1	3	3	3	6	3	2	7	2	2	1	1	1		1				
Maybole							1	1	1		2	2	6	4	5	8	2	7	3	6	5	5	2	1	2	1	1			1
Straiton												5	7	2	4			3	1											
Dailly											1			3	4	2	3	3	3	2		2		1					1	
Girvan									1				2	2	2	3				2			2	1	3	2	1	1		
Barr		1				1	1				2	2	4	3		1	1	1	3											
Colmonell	1		1		1			1			3	2	3	4	2	6	2	4	6	7	4	2	3	2	1					
Ballantrae						1				1		2	2	2	1	3	1	2	3				1				1			
Totals	1	1	1	1	4	4	5	4	6	7	17	29	51	61	65	78	82	56	63	44	34	18	13	11	8	6	4	2	1	1

	P_2O_5 - High	Medium	Low.
Monkton	-	-	8
Ayr	8	9	28
Tarbolton	1	9	39
Stair	-	1	21
Coylton	-	4	35
Dalmellington	-	-	7
Dalrymple	-	-	18
Auchinleck	1	2	25
Muirkirk	-	3	13
New Cumnock	5	7	36
Ochiltree	-	4	41
Old Cumnock	-	3	34
Kirkmichael	2	11	35
Kirkoswald	12	5	21
Maybole	19	15	32
Straiton	1	6	15
Dailly	6	8	11
Girvan	9	5	8

	K_2O - High	Medium	Low.
	-	1	7
	9	5	31
	1	4	44
	-	5	17
	8	12	19
	4	2	1
	4	5	9
	-	7	21
	2	4	10
	12	14	22
	5	19	21
	6	11	20
	8	16	24
	10	7	21
	8	18	40
	5	5	12
	5	3	17
	12	4	6

P_2O_5 continued.

	High	Medium	Low
Barr	6	4	10
Colmonell	10	16	29
Ballantrae	5	1	14
Totals	83	115	480

K_2O continued.

	High	Medium	Low.
Barr	8	4	8
Colmonell	22	21	12
Ballantrae	14	6	-
Totals	143	173	362

It will be observed that the soils range in pH from 3.7 to 7.3, 79% of all samples falling between 5.10 and 5.99, and 60% lying between 5.20 and 5.79. Almost 50% of the soils have pH values of under 5.50, nearly 29% being under 5.30. While at this lower figure, Ayrshire arable crops (apart from beans) are not likely to suffer much from soil acidity, the best results from pasture cannot be secured, and it can be concluded that these 29% of soils are incapable of giving their maximum production when under pasture, though many of them will yield satisfactory arable crops.

In classifying the soils into high, medium and low categories for P_2O_5 and K_2O content, 7.0 mgm./100 gms. of soil has been taken as the division between medium and low 'available' P_2O_5 and K_2O, and 14 mgm. as the division between high and medium. I have found in Ayrshire that yields generally suffer if phosphate or potash is omitted from the manurial dressing when the quantity of the 'available' constituent is given as less than 7 mgm. Between 7 and 14 mgm. one or two crops may be taken without supplying the manurial constituent, but it is only where figures of over 14.0 are obtained that crops can continue to be grown for several years without supplying the manurial ingredient in question. It will be observed that more soils show deficiency in P_2O_5 than in K_2O, 70.8% being in the low P_2O_5 group compared with 53.4% for low K_2O. Medium P_2O_5 figures are returned by 17% of the samples, and high figures by 12.3% of the samples, these high figures being mostly confined to potato-growing soils. Medium K_2O figures are given by 25.5% of the soils and high K_2O figures by 21.1%. If the four northernmost parishes, Monkton, Ayr, Tarbolton and Stair are compared with the four southernmost, Girvan, Barr, Colmonell and Ballantrae, it will be observed that they are much more deficient in potash, and considerably poorer in available phosphate than the latter. Of the 123 soils sampled in the northern parishes, 95 or 77.8% are low in phosphate, and 98 or 79.9% are low in potash, while only 9 or 7.2% are high in phosphate, and 10 or 8.1% are high in potash. In the southern parishes, of the 117 soils sampled 61 or 52.1% are low in phosphate, and 26 or 22.2% are low in potash, while 28 or 23.9% are high in phosphate and 56 or 47.9% are high in potash. These

figures are in accordance with the results of experiments conducted in these areas between 1924 and 1939, when basic slag was found to act well without being supplemented with potash in the southernmost parishes, but had to be accompanied by a potash dressing on most Central and North Ayrshire farms for the full (and in some cases, any) benefit to be secured.

It has been previously mentioned that phosphate-fixation renders it difficult to decide whether soils returning low 'available P_2O_5' figures will respond to phosphate dressings, and that phosphate-fixation appears to be less when the pH figure is high. A survey and an examination of soil samples does not afford a reliable method of investigating this question, as it is complicated by two factors, viz. the fact that most farmers who lime well generally apply also liberal dressings of phosphate in the form of basic slag or ground phosphate, and that potato-growing soils are those which show the highest available P_2O_5 figures, due to the liberal dressings of phosphate given year after year. As such soils also receive liberal sulphate of ammonia applications, the pH values of such soils are not generally high, even in cases where high P_2O_5 figures are returned. On seriously lime-deficient soils the phosphate accumulation may often be great, through crops being unable on account of high soil acidity to grow satisfactorily, and take up the necessary phosphate for a full crop.

The following figures are of interest, however, as they are from the Brackenhill replicated plots laid down with swedes in May, 1940, certain plots being limed and 'basic' and 'acid' manures being included in the manuring scheme. Though more P_2O_5 was removed in higher crop yields from the plots with the higher pH values, the 'available P_2O_5 figures returned were generally higher on the higher pH plots. Results were:-

Treatment.	pH	P_2O_5 (mgm./100 gms. soil).
Control	6.31	2.0
'Acid' Manure	6.19	5.3
'Basic' "	6.43	4.7
'Acid' Manure + Lime	6.73	5.7
'Basic' " + "	6.96	6.5

AGRONOMIC INVESTIGATIONS: REQUIREMENTS AND METHODS.

I have described above some of the investigations conducted by me, in which the inter-related effects of manures on soils and of soils on crops and grassland have been studied and recorded, replicated plots being employed in most cases, so that the results could be subjected to statistical analysis. In addition I have studied generally the conditions on Ayrshire farms, and have also made a special study of the conditions on a random selection of South Ayrshire farms, and find that the state of the pastures on a farm usually reflects the efficiency of the farmer, and that the conditions and problems on the experimental and investigational areas are applicable to much of the land in South-west Scotland.

It is generally accepted that in agronomic investigations the inter-relation between soils and crops, as affected by environment, climate, manuring, etc. must be taken into account. The existence of agronomy depends on the acceptance of the view that knowledge is to be gained by experiment. This involves study in the field with an uncontrollable setting, which is more difficult than in the laboratory or glasshouse, but is nevertheless essential. It may be necessary to augment field work by special glasshouse or laboratory investigation, but while "We may learn much by chemical analysis and pot-cultural work, the final answer to our questions can be obtained only in the field" (43). Stapledon (44) has also pointed out that research in agronomy is research in the field, and its aim should be to study all factors which are operative at once and together, and in their natural interplay. The investigation does not only seek to apply scientific knowledge to the practical problem, but also to establish new knowledge. Though the agronomist on finding himself at a crossroads or meeting place of several sciences (45) may select a special branch of advanced research, it is very important that he should be able to maintain a broad generalised outlook and a proper sense of balance.

Scientific method, as outlined by Brierley (46), involves five essential steps:

1. Observation.
2. Perception of relationship.

3. Inductive reasoning leading to a provisional working hypothesis.
4. Experimental testing of hypothesis.
5. Elevation of the confirmed hypothesis to principles of generality.

The farmer, especially if observant and intelligent, can carry out the first three steps, and may thereafter without having conducted properly controlled experiments, reach certain general conclusions, to which he endeavours to give effect in his practice. His lack of training in scientific method and in the layout of accurate experiments, and his want of laboratory and other facilities generally precludes his activities as regards the fourth step.

As Trumble has stated (47), the agronomist is faced primarily with a practical problem, to which economic considerations are generally attached. He must also have an understanding of ecology, soils, climatology and biology, as well as of statistical methods. His task is to analyse the agricultural problem in terms of the many interacting factors of soil, climate and biology, including management, and to understand the role of limiting factors in their relation to the field complex.

In field investigations the interacting factors often render it difficult to get direct comparisons of single pairs of factors. For example, in grassland investigations the influence of a scheme of manurial treatment may be to render the herbage more palatable to stock, so that it is kept very closely grazed, while the herbage under the other treatment may be allowed by the grazing stock to become rougher. Whether the mowing machine is used or not in an attempt to more nearly maintain comparable conditions between the treatments, the conditions and effects of grazing cannot be identical on both sections, as mowing, light grazing and severe grazing have different effects on the same sward. The comparison must accordingly in agricultural problems often be one between the production (including yield and feeding value) of the individual plots, as resulting from the effects of ecological, climatic and oft-times complicated conditions arising from the plant-animal complex.

In the studies and investigations which I have conducted and described above, I have through close and continued observation, while Organiser for Ayrshire, detected

certain practices of soil manuring and management on the one hand, and on the other a certain state of soil fertility, as denoted by the condition and yield of grassland and arable crops. The problem which I had was to test out accurately these hypotheses, arrive at certain conclusions, and at the same time, or thereafter, by demonstration endeavour to have the results incorporated in improved farm practice.

DISCUSSION OF RESULTS.

The results reported herein indicate the importance of phosphate and lime for the successful establishment of good pasture on Ayrshire soils. Where phosphate had been previously applied in liberal dressings of mixed manure, as at Hunterston and Morriston, the addition of lime enabled the beneficial results on the sward to be secured. With a pH value of 3.9, great benefit from liming accrued also to all crops, including potatoes. The 1924 liming effects were very marked on the Hunterston hay crop and aftermath in 1939. With a soil pH of 5.0 at Morriston, potato and oat yields only benefitted slightly from lime applications, but much benefit accrued to mangolds, swedes and hay. The limed plots yielded a herbage of higher CaO content, and therefore of greater nutritional value to farm stock.

The seed mixture used had a limited effect on the composition of the sward, its influence being confined to the early years of the pasture. On the other hand, soil reaction had the greatest effect on the sward later, the differences between treatments being clearly visible, while seed mixtures plots' boundaries could not be detected. Even grazing strains showed only slight differences in sward establishment from commercial strains of grasses. While Wyllie Fenton has stated that the nature of the seed mixture chiefly determined the botanical composition of rotation grasslands, and that older grasslands are mainly influenced by manurial, liming and/or drainage treatment and general management, my investigations have shown that in Ayrshire the soil condition, especially in regard to lime and phosphate, is of prime importance, the seed mixture being only of secondary importance, especially after the second year.

It was found possible by the use of basic manures (basic slag, ground rock phosphate, nitrochalk and calcium cyanamide) to maintain crop yields at approximately the same level as with superphosphate and sulphate of ammonia during the cropping rotation on a typical Central Ayrshire farm (Brackenhill), while bringing the soil into better condition as regards lime and phosphate content for the growth of pasture in later years. Such pasture was of higher feeding value due to higher CaO content. Further improvements in yield and nutritional value resulted from the application of lime when sowing out to grass, and its beneficial influence in raising the surface soil pH. The beneficial influence of basic manures was not unexpected in view of the generally lower base status of Ayrshire soils, compared with those carrying naturally good pastures in other parts of the country.

In the Brackenhill experiments (and on upland Ayrshire farms, generally) the effect of taking a root crop in order to clean the land in preparation for sowing down to grass was evident in the hay crop and first year's pasture, but not to any extent in later years, where the soil was in poor condition or deficient in lime. Where the pH value was too low and/or phosphate was lacking, inferior grasses, chiefly Agrostis and Holcus, replaced the sown plants, which soon became weak and died out. The liming of land deficient in phosphate enabled the sown plants to survive, but their productivity was low in the absence of phosphate. On the other hand, phosphate applied as slag gave a sward of healthy appearance, as well as of satisfactory botanical analysis, high in nitrogen, P_2O_5 and CaO content, and consequently of high nutritional value. With inferior old swards at Brackenhill, Knoweside and Genoch, greater improvements were achieved through ploughing, liming, manuring and reseeding than through the liming and manuring of the old sward, which contained only an extremely low proportion of useful herbage plants.

The normal amount of lime dressing (2,000 - 3,000 lbs. CaO per acre) recommended to farmers generally benefitted the oat crop, in addition to the grasses and clovers seeded therewith. When a heavier dressing was employed, the benefit to the grasses

continued right up to a pH value of 7.0, but the oats suffered in yield as the soil pH approached neutrality. When lime was applied to the sow-out in the late autumn after the nurse crop had been harvested, it had little effect on the yield and composition of the hay in the following year, and the sward was only slightly influenced during this first year. In the next two years, however, the influence of the lime and phosphate on the herbage became marked. The control plots and those unlimed plots receiving 'acid' manures deteriorated greatly during that period, whilst the others showed relatively little change, thereby demonstrating the importance of maintaining (and, preferably, improving) the base status of the surface layers of the soil.

In the Brackenhill latin square plots, as was to be expected, the use of lime and basic manures, both separately and together, raised the soil pH, mainly in the top layer. The limed sections and the basic manure sections showed at the end of three years a higher pH in the top 3" than in the next 6", while the acid manure (unlimed) and control sections showed a lower pH in the top 3" than in the next 6". The botanical analyses figures were correlated to the pH values of the top 3", just over 30% useful plants being present at the end of the three years on the acid manure plots (with pH values in the top 3" of approximately 5.0), and over 70% useful being found on the basic manure plus lime plots, with pH figures approaching 6.0. At a surface layer pH of 5.5 the superior herbage plants and the inferior plants were in approximately equal proportions. On the turnip crop the basic manure has given significantly better results. While raising of the soil pH to over 6.5 in the top 3" depressed the oat yield, it reduced the proportion of inferior plants in the sward from seeds sown therewith. Accordingly, at the commencement of the first year's pasture only 30% of inferior plants are present on the plots (acid manure) with the lowest pH values. These approximate, however, to 6.0 in the top 3" of the soil.

That effects of previous lime and phosphate treatment can continue for several years was shown by the slag residual effects obtained on Carbelle and other Ayrshire farms, where the relative values of various basic slags were investigated. On the

marginal cropping land at Carbello, also, the great benefit to the pasture later of giving in addition to the phosphate requirement, the full lime requirement to a pH of 7.0 in the top 9", even although this required an extraordinarily heavy lime dressing, was obvious. The natural deficiencies of most Ayrshire soils in phosphate and lime enable good results to be obtained from the use of basic slag, and such soils have proved suitable for testing out the relative availabilities of the phosphate in various types of slag and ground rock phosphate.

Observations made previous to 1941 and experiments conducted on Ayrshire farms had shown that many soils were yielding good oat and/or potato crops, but were only producing second- and third-rate pastures. Wheat and red clover failures were also occuring on certain areas, where pH values had fallen to under 4.8. Low phosphate figures were general over the county except on intensively manured potato-growing lands, phosphate-fixation being apparently a contributing factor. Low potash figures were most common in Central Ayrshire, occurred regularly in parts of North Ayrshire, and were least common in the south of the county. The crops on intensively-manured soils with high P_2O_5 content appeared to be able to tolerate relatively low pH values.

The 1941 - 42 survey of random selected farms, constituting one-fifth of the area of South Ayrshire, showed that there were still farms, where production was suffering definitely from lack of lime and/or manures, and others contrasting strongly with these, where little increase in production through manuring could be expected. Though a general improvement in pH values had taken place during the previous ten years, there were considerable differences between well-managed and badly-managed farms on similar land. The best-managed farms had 'mean pH values' of over 6.0, while farms on which liming had been neglected averaged 5.0. Over 70% of the soil samples showed low 'available' phosphate figures and over 50% low potash figures, the phosphate-deficient soils occurring all over the area, while the very low potash soils were confined mainly to the parishes between Ayr and Mauchline, very few being found in the four southernmost parishes.

CONCLUSIONS.

The conclusions to be drawn from these investigations and observations are that on the soils of upland dairy farms in Ayrshire, as well as on cropping farms at a lower elevation, a satisfactory supply of phosphate and a satisfactory base status, as denoted by pH values approximating to 6.0, are of prime importance for the establishment and survival of the superior herbage plants. On account of extensive land reclamation and drainage schemes and the adoption of manuring, Ayrshire agricultural soils are in many cases far removed from their primeval natural condition. Irrespective of their origin and natural profiles and properties, all Ayrshire soils in their present condition demonstrate this need for a satisfactory base and phosphate status, such as may be secured especially by lime and basic slag applications, if maximum productivity is to be maintained. Under the conditions prevailing in all the cases discussed (and in other experiences of the writer) the composition of the grass seed mixture employed was of relatively small importance. All mixtures were successful where the soil was satisfactory in regard to lime and phosphate, and all failed where it was not satisfactory. A sufficient supply of phosphate and a satisfactory pH value are essential for success. If the pH value initially is 5.0 or less, liming is definitely required if a first class sward is to be secured and maintained. The evil effects of not using lime can be obviated to a great extent, but not completely, by using basic slag as the source of phosphate, and nitrochalk or calcium cyanamide as the source of nitrogen. Manuring with such 'basic' manures during the rotation has proved a much better preparation for good pasture thereafter than the employment of the ordinary 'acid' manures, sulphate of ammonia and superphosphate. Basic slag has proved valuable for crops and pastures on Ayrshire soils, high solubility being important especially where limited dressings are used.

The application during the rotation to poor land of the quantities of manurial constituents shown to be necessary by soil analysis has proved very beneficial with lasting effects on the pasture. In this way again suitable manuring (including liming)

during the rotation has proved a good preparation for pasture, the condition of which has been shown to be closely related to the soil reaction and phosphate status. By suitable manuring during the rotation typical Ayrshire soils can be successfully improved in phosphate and base status for first class pasture to be secured and maintained.

If the pH value of a soil is much over 5.0, little benefit accrues from liming to the oat or potato crop, and this fact has been responsible in the past for many farmers overlooking the need for lime, when laying down land to pasture at the end of a rotation. Taking a cleaning crop during a cropping rotation on land deficient in lime and phosphate is of comparatively little value to the pasture afterwards, if the lime requirement and phosphate deficiency are not remedied when sowing out. The sward obtained is that suited to the soil conditions. The success attending direct reseeding of poor land can only be obtained also, if soil deficiencies are met. Under satisfactory conditions swards containing over 75% superior plants were obtained, while through neglect to remedy the lime and phosphate deficiencies a sward with over 75% inferior plants resulted. On land intensively cropped and manured, and with a considerable phosphate reserve, lime by itself will be effective in securing a good sward. Properly treated, land not only gives a higher yield of herbage, but also a sward of greatly increased value for production purposes.

The most productive farms with highest crop yields and best pastures, as shown by the 1941 - 42 survey, were those where the soil pH values, through attention to liming, were in the region of 6.0. The poorer crop yields and inferior pastures were found on these farms, where, through neglect of liming, soil pH values approximated to 5.0. The general need for potash dressings in certain Central Ayrshire parishes in order to secure the full benefit of lime and phosphate applications, a need seldom arising in the southernmost parishes, was confirmed by this survey. Generally speaking, the soils of Ayrshire have been improved in pH during the past ten years. The improvement in 'available' phosphate is not so evident, as it cannot through phosphate-fixation be detected accurately by the present analytical methods.

ACKNOWLEDGMENTS.

The previously published literature bearing on the subjects of these studies has been perused, and a list of references is appended.

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APPENDIX OF TABLES.

LAY-OUT AND pH VALUES OF BRACKENHILL LATIN SQUARE HAY PLOTS.

(Top figure is pH value of top 3" of soils; lower figure is pH of 3" - 9".)

Series 1. Series 2.

pH values: October, 1939.

1	2	3	4	5	26	27	28	29	30
B	BL	0	A	AL	0	A	AL	BL	B
5.33	4.95	5.29	4.76	5.09	5.09	5.09	4.91	4.98	4.98
5.23	4.91	5.13	4.91	5.09	5.41	5.19	5.40	5.17	5.19
6	7	8	9	10	31	32	33	34	35
AL	0	BL	B	A	AL	B	0	A	BL
4.76	4.93	4.88	5.09	4.98	5.13	4.98	4.78	4.76	4.81
5.33	5.33	5.05	5.05	5.35	5.33	4.88	5.23	5.43	4.88
11	12	13	14	15	36	37	38	39	40
A	AL	B	0	BL	BL	0	A	B	AL
5.09	4.97	5.02	4.81	5.00	4.83	4.97	4.83	4.91	4.99
5.28	5.33	5.14	5.33	4.90	5.05	5.37	5.23	5.02	5.43
16	17	18	19	20	41	42	43	44	45
BL	B	A	AL	0	B	AL	BL	0	A
4.98	5.02	4.82	4.77	4.74	4.98	5.05	4.98	4.91	5.02
5.07	5.07	5.16	5.16	5.21	5.09	5.29	4.95	5.26	5.40
21	22	23	24	25	46	47	48	49	50
0	A	AL	BL	B	A	BL	B	AL	0
5.02	5.09	4.83	4.81	4.91	4.83	4.93	4.90	4.88	4.98
5.50	5.45	5.40	5.16	5.09	5.19	4.95	4.93	5.31	5.26

pH values: Spptember, 1941.

B	BL	0	A	AL	0	A	AL	BL	B
5.43	5.79	5.20	4.92	5.93	5.23	5.06	5.44	6.03	5.30
5.20	5.23	5.13	5.02	5.27	5.30	5.16	5.27	5.23	5.27
AL	0	BL	B	A	AL	B	0	A	BL
5.92	5.38	6.22	5.20	5.13	5.41	5.16	5.16	5.06	5.96
5.32	5.34	5.36	5.30	5.13	5.23	5.20	5.26	5.18	5.38
A	AL	B	0	BL	BL	0	A	B	AL
5.11	5.75	5.34	5.15	5.32	6.55	5.11	5.11	5.39	5.72
5.13	5.34	5.38	5.20	5.16	5.49	5.34	5.22	5.29	5.39
BL	B	A	AL	0	B	AL	BL	0	A
5.56	5.23	4.99	5.38	4.89	5.39	5.43	5.79	5.11	5.03
5.38	5.30	5.08	5.13	5.10	5.29	5.25	5.34	5.23	5.23
0	A	AL	BL	B	A	BL	B	AL	0
5.20	5.18	5.96	5.93	5.44	5.06	5.63	5.16	5.46	4.97
5.30	5.18	5.34	5.34	5.13	5.16	5.27	5.11	5.13	5.15

pH values: September, 1942.

Series 1.

B	BL	0	A	AL
5.44	6.04	5.12	5.02	5.54
5.26	5.31	5.21	5.12	5.23
AL	0	BL	B	A
5.90	5.23	5.71	5.40	5.05
5.40	5.31	5.46	5.23	5.19
A	AL	B	0	BL
5.07	5.83	5.40	5.31	5.62
5.18	5.37	5.33	5.31	5.28
BL	B	A	AL	0
6.30	5.28	5.14	5.37	4.98
5.45	5.35	5.21	5.23	5.23
0	A	AL	BL	B
5.24	5.16	5.52	6.02	5.37
5.37	5.31	5.28	5.56	5.26

Series 2.

0	A	AL	BL	B
5.23	5.09	5.97	6.30	5.48
5.41	5.31	5.40	5.52	5.42
AL	B	0	A	BL
6.21	5.26	5.10	4.98	5.83
5.43	5.28	5.14	5.14	5.37
BL	0	A	B	AL
6.30	5.09	5.12	5.31	5.12
5.57	5.24	5.31	5.38	5.56
B	AL	BL	0	A
5.35	5.66	6.01	5.12	5.16
5.28	5.31	5.52	5.21	5.26
A	BL	B	AL	0
5.07	5.90	5.35	5.80	5.07
5.20	5.50	5.24	5.24	5.19

HAY YIELDS: August, 1940 (in lbs per $\frac{1}{100}$ acre plot.).

Series 1.

B	BL	0	A	AL
24	30	24	33	30
AL	0	BL	B	A
29	23	27	26	30
A	AL	B	0	BL
38	39	33	29	38
BL	B	A	AL	0
43	40	32	38	30
0	A	AL	BL	B
26	39	37	36	36

Series 2.

0	A	AL	BL	B
28	40	40	40	38
AL	B	0	A	BL
43	40	35	44	48
BL	0	A	B	AL
43	25	38	40	48
B	AL	BL	0	A
37	30	44	25	40
A	BL	B	AL	0
39	47	42	44	37

Botanical Analyses: September, 1940.

Series 1.

	Control						Acid Manure						Acid Manure+Lime						Basic Manure+Lime						Basic Manure					
Plot	3	7	14	20	21	Mean;	4	10	11	18	22	Mean;	5	6	12	19	23	Mean;	2	8	15	16	24	Mean;	1	9	13	17	25	Mean.
Lolium per.	35	38	36	32	35	35.2	42	39	33	35	36	37.2	43	37	40	32	37	37.8	42	34	34	36	35	36.2	41	37	37	34	38	37.4
Dactylis glo.	14	14	15	13	14	14.0	10	16	14	15	14	14.2	10	16	14	15	14	13.8	18	16	15	14	15	15.6	6	11	12	12	10	10.2
Phleum pra.	8	7	11	12	10	9.6	12	9	11	10	10	10.4	11	12	15	14	11	12.6	10	13	12	14	9	11.6	7	7	11	13	11	9.8
Trifolium pra.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	.4	1	-	-	-	-	.2
Trifolium hyb.	1	1	1	2	2	1.4	-	-	1	2	2	1.0	2	1	1	2	1.2	3	1	2	3	1.8	2	-	1	2	3	1.6		
Trifolium rep.	-	1	1	1	2	1.0	1	-	-	1	2	.8	1	2	1	1	1	1.2	-	1	-	1	1	.6	1	2	3	1	-	1.4
Holcus lan.	32	31	30	32	30	31.0	24	32	35	31	26	29.6	28	26	27	31	29	28.2	22	27	35	25	31	28.0	34	35	31	29	32	32.2
Agrostis spp.	5	1	-	1	-	1.4	2	-	-	-	-	.4	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	-	-	.8
Ranunculus spp.	3	4	3	5	6	4.2	2	3	4	5	6	4.0	4	4	1	4	5	3.6	2	4	1	5	4	3.2	6	4	1	4	4	3.8
Trifolium dub.	2	3	3	2	1	2.2	2	1	4	3	2	2.4	3	1	1	2	1	1.6	5	2	2	2	2	2.6	1	2	3	5	2	2.6

Series 2.

Plot	26	33	37	44	50	Mean;	27	34	38	45	46	Mean;	28	31	40	42	49	Mean;	29	35	36	43	47	Mean;	30	32	39	41	48	Mean.
L.pe.	36	35	29	33	30	32.6	37	34	37	40	38	37.2	38	36	44	38	39	39.0	34	36	36	38	35	35.8	40	36	27	38	37	35.6
D.gl.	12	11	7	5	6	8.2	8	12	8	10	6	8.8	13	13	12	6	3	9.4	14	11	5	6	10	9.2	6	10	13	8	11	9.6
P.pr.	13	9	10	10	10	10.4	12	7	12	12	10	10.6	15	16	15	14	21	16.2	17	13	20	20	16	17.2	14	14	14	17	16	15.0
T.pr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	.2	-	-	-	-	-	-	-	-	-	-	-	-
T.hy.	-	1	-	1	-	.4	1	-	1	2	-	.8	1	-	1	2	1	1.0	1	2	2	1	2	1.6	2	2	-	1	1	1.2
T.re.	2	-	1	1	-	.8	1	-	1	-	-	.4	1	1	-	-	-	.4	1	1	-	1	1	.8	1	-	2	1	-	.8
H.la.	29	37	39	41	48	38.8	36	41	32	27	39	34.6	27	25	22	31	28	26.6	25	32	28	27	28	28.0	31	30	32	28	27	29.6
A.spp.	-	1	7	1	2	2.2	-	-	2	-	-	.4	-	6	-	1	-	1.4	-	-	1	-	-	.2	-	-	-	-	1	.2
R.spp.	5	4	7	7	2	4.8	3	5	7	5	5	5.0	3	5	5	6	4	3.6	5	4	6	5	8	5.6	4	6	7	5	5	5.4
T.du.	5	2	-	1	2	2.0	4	1	-	4	2	2.2	3	2	-	2	4	2.2	4	1	3	2	-	2.2	2	2	5	2	2	2.6

Botanical Analyses: September, 1941.

Series 1.

	Control						Acid Manure						Acid Manure+Lime						Basic Manure+Lime						Basic Manure					
Plot	3	7	14	20	21	Mean;	4	10	11	18	22	Mean;	5	6	12	19	23	Mean;	2	8	15	16	24	Mean;	1	9	13	17	25	Mean
Lolium per.	18	15	19	19	15	17.2	25	22	15	17	16	19.4	33	29	23	24	20	25.8	29	26	30	34	34	30.6	24	26	22	21	27	24.0
Dactylis glo.	6	9	11	14	6	9.2	12	11	11	11	13	11.6	12	10	11	19	14	13.2	5	12	13	9	11	10.0	8	13	16	14	13	12.8
Phleum pra.	12	6	5	5	3	6.4	15	10	8	5	9	9.4	13	10	12	10	12	9.4	15	13	14	14	7	12.6	16	12	10	11	8	11.4
Cynosurus cri.	-	½	-	-	-	.2	-	-	2	-	-	.4	-	1	-	-	-	.2	1	-	1	1	2	1.0	2	-	-	-	-	.4
Poa tri.	3	3	3	1	1	2.2	7	2	3	2	1	3.0	6	10	6	2	4	5.6	11	8	6	8	10	8.6	11	9	6	4	5	7.0
Trifolium pra.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	.2	1	-	-	-	1	.4
T.hy.	3	4	4	4	2	3.4	2	4	4	-	1	2.2	3	-	5	2	-	2.0	1	-	2	-	4	1.4	6	2	4	-	6	3.6
T.re.	1	6	2	-	3	2.4	4	-	1	1	6	2.4	5	7	5	1	4	4.4	11	16	2	10	16	11.0	10	5	8	7	6	7.2
Holcus lan.	14	27	22	21	27	22.2	12	22	26	27	23	22.0	11	15	20	22	23	18.2	10	16	19	13	8	13.2	10	19	20	21	18	17.6
Agrostis spp	31	19	26	28	29	26.6	15	19	23	25	24	20.8	8	7	15	6	15	10.2	4	4	8	4	7	5.4	4	8	8	12	10	8.4
Ranunculus spp.	6	8	4	6	9	6.6	7	7	5	9	6	6.8	7	9	3	9	7	7.0	12	5	5	7	1	6.0	8	5	4	8	5	6.0
Trifolium dub.	6	3	2	2	5	3.6	1	3	2	3	1	2.2	2	2	-	5	1	2.0	-	-	-	-	-	-	-	1	2	2	1	1.2

Series 2.

Plot	26	33	37	44	50	Mean	27	34	38	45	46	Mean	28	31	40	42	49	Mean	29	35	36	43	47	Mean	30	32	39	41	48	Mean
L.pe.	9	10	11	14	11	11.0	15	12	14	16	12	13,8	24	25	26	25	21	24.2	28	25	28	25	23	25.8	21	21	19	25	20	21.2
D.gl.	9	5	6	9	11	8.0	8	11	8	13	10	10.0	11	14	9	5	11	10.0	10	17	11	14	5	11.4	12	6	4	5	11	7.6
P.pr.	4	9	7	8	9	7.4	8	8	11	8	4	7.8	12	11	14	10	13	12.0	14	15	14	15	17	15.0	6	14	13	15	11	11.8
C.cr.	-	-	-	-	-	-	1	-	-	-	-	.2	-	-	-	1	-	.2	1	-	2	-	-	.6	-	-	-	1	-	.2
P.tr.	-	-	-	-	-	-	3	-	2	-	-	1.0	5	6	4	4	-	3.8	9	4	4	5	2	4.8	1	5	2	1	-	1.8
T.hy.	2	2	2	2	-	1.6	2	-	2	2	-	1.2	-	1	-	1	-	.4	-	1	½	1	-	.6	3	2	1	-	1	1.4
T.re.	-	1	2	2	-	1.0	1	1	1	1	-	.8	6	3	3	3	-	3.0	10	2	6	4	-	4.4	-	1	3	3	1	1.6
H.la.	29	30	27	22	24	26.4	24	29	23	24	25	25.0	22	25	22	23	20	22.4	17	23	20	24	28	22.4	28	30	20	24	22	24,8
A.sp.	31	27	33	30	29	30.0	26	27	25	28	30	27.2	8	5	7	11	18	9.8	2	4	4	2	7	3.8	17	7	20	12	17	14.6
R.sp.	13	15	12	13	9	12.4	9	9	14	8	16	11.2	11	8	15	13	13	12.0	7	8	9	9	15	9.6	7	11	17	12	14	12.2
T.du.	3	1	-	-	7	2.2	3	3	-	-	3	1.8	1	2	-	4	4	2.2	2	1	1	1	3	1.6	5	3	1	2	3	2.8

Botanical Analyses: September, 1942.

Series 1.

	Control						Acid Manure						Acid Manure+Lime						Basic Manure+Lime						Basic Manure					
Plot	3	7	14	20	21	Mean;	4	10	11	18	22	Mean;	5	6	12	19	23	Mean;	2	8	15	16	24	Mean;	1	9	13	17	25	Mean.
Lolium per.	10	16	16	13	12	13.4	18	20	19	12	14	14.6	29	30	32	31	33	31.0	47	40	35	40	37	39.8	29	27	32	28	27	28.6
Dactylis glo.	3	4	6	3	2	3.6	3	3	3	2	2	2.6	4	5	5	8	5	5.4	4	5	11	8	8	7.2	6	10	7	7	9	7.8
Phleum pra.	3	4	8	3	1	3.8	5	12	8	4	4	6.6	12	8	12	10	8	10.0	10	10	13	9	10	10.4	8	12	7	7	9	8.6
Cynosurus cri.	1	1	-	1	3	1.2	1	1	2	-	2	1.2	1	3	1	1	1	1.4	1	1	2	2	2	1.6	2	1	2	2	-	1.4
Poa tri.	1	-	-	1	1	.6	1	-	-	1	-	.4	-	-	1	-	1	.4	3	3	2	1	1	2.0	3	1	-	2	-	1.2
Trifolium rep.	3	3	6	2	7	4.2	4	3	4	3	4	3.6	10	13	12	9	14	11.6	10	12	9	14	14	11.8	13	9	10	10	11	10.6
Holcus lan.	25	28	25	28	25	26.2	26	24	23	24	28	25.0	26	24	21	23	20	22.8	10	14	16	13	12	13.0	21	24	25	24	23	23.4
Agrostis spp.	40	32	25	35	32	32.8	30	25	31	36	34	31.2	6	5	4	5	5	5.0	3	4	2	4	3	3.2	5	4	3	7	10	5.8
Ranunculus spp.	14	12	12	12	15	13.0	10	12	10	14	10	11.2	10	10	10	9	12	10.2	10	9	8	8	12	9.4	12	12	12	12	11	11.8
Bellis per.	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	.4	-	-	-	-	-	-
Trifolium dub.	-	-	2	2	2	1.2	2	-	-	4	2	1.6	2	2	2	4	1	2.2	2	2	-	1	1	1.2	1	-	2	1	-	.8

Series 2.

Plot	26	33	37	44	50	Mean;	27	34	38	45	46	Mean;	28	31	40	42	49	Mean;	29	35	36	43	47	Mean;	30	32	39	41	48	Mean.
L.pe.	13	10	10	14	10	11.4	18	14	11	14	10	13.4	29	28	39	30	25	30.2	34	28	32	28	33	31.0	28	24	20	27	22	24.2
D.gl.	10	4	4	-	2	4.0	4	5	5	-	1	3.0	7	3	3	7	4	4.8	7	14	8	10	7	9.2	11	6	4	7	7	7.0
P.pr.	12	7	9	13	8	9.8	8	10	13	10	10	10.2	15	15	17	17	20	16.8	15	17	20	21	22	19.0	11	14	16	19	19	15.8
T.hy.	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-	-	1.0	3	1	2	-	-	1.2	2	1	-	-	-	.6
T.re.	9	2	1	1	2	3.0	6	-	5	1	5	3.4	8	9	6	10	6	7.8	8	5	13	9	6	8.2	4	5	9	4	6	5.6
H.la.	26	17	18	21	18	20.0	26	24	16	20	21	21.4	21	22	17	19	22	20.2	20	22	14	17	19	18.4	28	20	19	21	20	21.6
A.sp.	16	40	48	36	41	36.2	23	30	36	39	40	33.6	4	10	3	7	5	5.8	-	1	1	5	2	1.8	4	13	15	9	12	10.6
R.sp.	14	17	9	14	13	13.4	13	12	12	15	11	12.6	12	10	13	10	13	11.6	13	11	10	10	9	10.6	10	14	13	11	10	11.6
T.du.	-	3	1	1	6	2.2	2	5	2	1	2	2.4	2	1	1	-	5	1.8	-	1	-	-	2	.6	2	3	4	2	4	3.0

LAY-OUT AND pH SOIL VALUES OF MAY 1940 LATIN SQUARE PLOTS.

Top figure is pH of soil, 0 - 9", in May 1940.
Lower " " pH 2 subsoil, 9" - 18", in May 1940.

A	O	BL	B	AL
4.93	5.19	5.00	5.24	5.37
5.65	6.12	5.92	5.83	5.85
B	AL	A	BL	O
5.21	5.24	5.26	5.32	5.29
5.78	5.95	5.80	5.88	5.95
BL	B	O	AL	A
5.21	5.26	5.23	5.28	5.13
5.75	5.87	5.83	5.76	5.71
O	BL	AL	A	B
5.28	5.26	5.35	5.38	5.35
5.66	5.69	5.71	6.02	5.69
AL	A	B	O	BL
5.17	5.31	5.31	5.32	5.24
5.61	5.69	5.85	5.84	5.75

September 1941: soil pH figures, 0 - 3", and
" " " ,3" - 9".

A	O	BL	B	AL
5.95	6.26	7.01	6.57	6.72
5.26	5.37	5.75	5.52	5.65
B	AL	A	BL	O
6.33	6.51	6.13	6.51	6.14
5.43	5.54	5.33	5.71	5.35
BL	B	O	AL	A
7.18	6.66	6.02	6.70	6.16
5.67	5.61	5.50	5.40	5.24
O	BL	AL	A	B
6.30	7.01	6.86	6.27	6.63
5.39	5.88	5.63	5.49	5.75
AL	A	B	O	BL
6.92	5.81	6.38	6.12	7.11
5.76	5.22	5.63	5.42	6.25

September 1942: Soil pH figures, 0 - 3";
and 3" - 9".

A	0	BL	B	AL
5.76	5.88	6.80	6.13	6.42
5.31	5.38	5.88	5.61	5.68

B	AL	A	BL	0
6.40	6.77	5.99	7.09	6.01
5.71	5.71	5.54	6.21	5.54

BL	B	0	AL	A
6.80	6.11	5.71	6.39	5.59
5.92	5.59	5.42	5.52	5.38

0	BL	AL	A	B
5.75	6.90	6.61	5.82	6.04
5.46	6.04	5.82	5.50	5.66

AL	A	B	0	BL
6.49	5.84	6.35	5.95	7.01
5.56	5.44	5.68	5.43	6.18

PLOT YIELDS OF SWEDES 1940 (in lbs.).

A	0	BL	B	AL
456	350	466	475	433

B	AL	A	BL	0
494	387	423	470	355

BL	B	0	AL	A
513	422	340	421	432

0	BL	AL	A	B
383	420	420	410	454

AL	A	B	0	BL
450	392	460	320	434

PLOT YIELDS OF OATS 1941 (in lbs.).

A	O	BL	B	AL
91	63	84	81	90
B	AL	A	BL	O
90	63	83	79	68
BL	B	O	AL	A
78	74	68	80	84
O	BL	AL	A	B
74	74	82	86	83
AL	A	B	O	BL
78	81	88	69	79

PLOT YIELDS OF HAY 1942 (in lbs.).

A	O	BL	B	AL
41	36½	57	51	55
B	AL	A	BL	O
51	66	58	60	52
BL	B	O	AL	A
53	47½	44	57	55
O	BL	AL	A	B
41	59	48	48	51
AL	A	B	O	BL
49	39	53	30	53

BOTANICAL ANALYSES OF MAY 1940 INDIVIDUAL PLOTS.

September, 1942.

	Control						Acid Manure						Acid Manure+Lime						Basic Manure+Lime						Basic Manure					
Plot	2	10	13	16	24	Mean;	1	8	15	19	22	Mean;	5	7	14	18	21	Mean;	3	9	11	17	25	Mean;	4	6	12	20	23	Mean
Lolium per.	37	37	33	35	37	35.8	44	35	40	37	42	39.6	43	46	44	44	48	45.0	43	52	47	47	54	48.6	42	45	39	45	47	43.6
Dactylis glo.	17	11	15	11	12	13.2	10	9	13	11	9	10.4	13	11	14	10	12	12.0	12	10	15	14	14	13.0	13	10	13	10	12	11.6
Phleum pra.	13	15	13	12	16	13.8	12	13	17	17	15	14.2	17	18	17	20	18	18.0	15	18	15	18	16	16.4	16	17	17	18	19	17.4
Trifolium hyb.	6	5	5	6	6	5.6	4	6	4	7	4	5.0	5	5	7	7	4	5.6	7	4	6	4	5	5.2	4	4	5	6	4	4.6
Trifolium rep.	1	2	4	3	1	2.2	1	1	2	1	2	1.0	-	2	-	1	-	.6	4	-	1	2	-	1.4	1	1	3	2	-	1.4
Holcus lan.	14	17	15	17	14	15.2	16	21	18	13	16	16.8	12	8	9	8	8	9.0	9	6	6	6	4	6.2	13	12	11	8	8	10.4
Agrostis spp.	1	-	1	-	-	.4	1	2	-	1	-	.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus spp.	11	13	13	16	13	13.2	10	14	10	13	12	11.8	10	10	9	10	10	9.8	10	9	10	9	5	8.6	11	11	11	10	10	10.6
Bellis per.	-	-	-	-	3	.6	2	-	-	-	-	.4	-	-	-	-	-	-	-	1	-	-	2	.6	-	-	1	1	-	.4