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CLIMATIC FACTORS

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Summary An attempt is made to compare and contrast certain features of the climate of the northern and southern portions of those areas in eastern Britain where the cropping is mainly arable.

The climatic factors discussed are those considered to be most relevant to weed control measures and procedures, viz. rainfall and soil moisture, wind and temperature. Regional contrasts in moisture parameters become evident from mid-summer onwards, those relating to temperature are noticeable throughout the growing season.

Topography dictates that a high proportion of arable land in the north must be in the lower-lying coastal regions, and that, relatively, wind would appear to be a more important constraint in the north than in the south.

Such generalisations are based upon period average values, but year-to-year differences and place-to-place differences in a given year are frequently greater than the average place-to-place differences.

INTRODUCTION

Amongst the factors governing the control of weeds are:

(i) the growth cycle of the weeds,
(ii) the growth cycle of the associated (economic) crop,
(iii) the concentration, dosage and effective life of the herbicide,
(iv) the efficiency of application of the herbicide.

Interactions exist between these factors of which time relationships between growth cycles of the weed plant and of the crop plant merit explicit mention.

At all stages in the weed control procedure one or more climatic element is likely to become relevant to some degree. However the quantitative expression of meteorological criteria is far from being achieved. One particular attempt is that of defining "spraying days" (Phillipson, 1972) in which rainfall prior to, during and subsequent to application, wind and probably temperature all need to be considered. Again, any statement on dosage rates and concentrations at least involves an implicit decision on the anticipated meteorological conditions.

The relevance of such considerations is evident in statements (Holroyd, 1972) that: (i) the winters of 1970/1 and 1971/2 were mild and gave rise to "large over-wintered annual weeds", (ii) windy weather in April and May of 1972 added to the difficulties of spraying. Reference to published data (Monthly Weather Report) of "District Values" (i.e. values based upon means of groups of four or more stations) indeed confirm that in the main arable areas, temperatures in most of the months October to March (inclusive) 1971 and 1972 ranged 0.5-1.5°C above the period average (the standard deviation for individual stations for the months in question ranges between 1° and 3°C). In addition wind records for April and May 1972 from a string of stations southwards from Aberdeen to southern England revealed that wind speeds of less than 4 mile/h were less frequent and those exceeding 25 mile/h more frequent than average (see Table 6); hence there is an encouraging consistency between the reported experience of field-workers and the official instrumental record.

The purpose of this contribution is to present data and information which can assist the formulation of criteria for improving the effectiveness of techniques of weed control. For this reason, comparative data have been selected for the predominantly arable areas in which the majority of regular herbicide applications are made.

SIMILARITIES AND CONTRASTS BETWEEN THE CLIMATE OF THE PREDOMINANTLY ARABLE AREAS OF SOUTHERN AND NORTHERN BRITAIN

For current purposes, the arable areas may be grouped into:

(i) the coastal areas bordering the Moray Firth;
(ii) eastern Scotland south of Aberdeen and east of the high ground, viz. a coastal belt varying in width from a few miles to a few tens of miles in Aberdeenshire southwards to Fife and the Lothians, narrowing again towards the Border thence to areas east of the foothills of the Pennines;
(iii) areas east of a line roughly from York to Reading.

For convenience the boundary between northern Britain (essentially (i) and (ii) above) and southern Britain can be placed along the Humber.

Topography dictates that most of the arable land in northern Britain - and more specifically in Scotland - is on or near the east coast, in contrast to southern Britain where the bulk of the area is situated 10 to 20 miles or more from the coast. Thus the weather in much of the arable areas of Scotland is markedly affected by maritime influences with the advantages (higher sunshine, higher winter temperatures) and disadvantages (lower summer temperatures, greater wind exposure) of coastal regimes.

Rainfall

Annual average rainfall in arable areas of both England and Scotland ranges from rather less than 630mm (25 in) up to about 750mm (30 in): some pertinent data are set out in Table 1.

Table 1

Average seasonal and annual rainfall at selected stations in mainly arable areas of Britain (period 1916-1950)

Station (Ht above MSL in m)	Winter mm	Spring mm	Summer mm	Autumn mm	Year mm
Inverness (74)	177	137	203	205	722
Nairn (6)	142	132	202	193	669
Aberdeen (91) (Craibstone)	215	176	212	258	861
Dundee (91)	188	160	219	223	791
Perth (23)	201	151	205	222	779
Stirling (49)	284	180	224	288	977
Edinburgh (134)	158	138	205	198	699
Kelso (59)	149	130	197	185	660
Morpeth (107)	183	151	195	201	730
York (19)	154	129	175	169	627
Cranwell (62)	143	129	160	164	596
Cambridge (12)	126	124	147	154	552
Oxford (63)	163	142	161	185	652
E. Malling(37)	176	143	160	203	682

Omitting areas such as Stirling as being possibly too wet for reliable cereal production, the contrasts between "north" and "south" are comparatively small on an annual basis and least in the spring months (remaining thus if extended to include June).

Period averages necessarily obscure the important year-to-year differences. In a particular month rainfall can vary from zero or near zero to about 400% of average. By definition such extremes are rare and a more helpful approach is that given in MAFF Irrigation Bulletin (1962). From a long series, e.g. 30 years of monthly rainfall records for the April-September period the percentage of the appropriate average for single months and sequences of 2, 3 and 4 months have been computed. The resulting percentages are ranked and the mean percentage for the lowest decile, the next lowest to the highest decile are noted. For eastern Scotland the mean percentage figure ranges from 31% in the lowest category to 207% in the highest (in North England 24½% and 205%; South England 20½% and 206½% respectively): for three successive months the corresponding figures are - 54% and 157%; 53% and 159%; 49% and 159½%.

The rainfall of the spring months of recent years (1970-1-2-3) in the arable areas presents points of immediate interest, viz:

(i) at seven stations in eastern Scotland, months with falls well below average have been more frequent than the above-average cases. Outstanding months were May 1970 (ranging from 16% to 80%) and March 1973 (22% to 47%); totals for March 1970 and 1972 and May 1971 were also predominantly below average;

(ii) in England, and especially in southern England, above-average figures were more common; the exceptions being May 1970 (10% to 45% at seven stations) and March 1973 (13% to 45%).

In addition to monthly totals the intensity of rainfall is of importance. Readily available data include:

(i) month by month number of "wet-days", i.e. 24 hours with ≥1.0mm of rain (Monthly Weather Report).
(ii) 24-hour periods with falls ≥10mm (British Rainfall) for October-March, April-September and calendar year.
(iii) falls ≥25mm (or 1 inch) in 16 hours or less (Plant 1971) for selected stations in Scotland.

Table 2

Number of "wet-days" at selected stations for months and years indicated

		Averages	1970	1971	1972	1973
Aberdeen	March	9	15	12	10	3
	April	9	15	8	6	11
	May	11	10	8	10	12
Edinburgh	March	9	5	8	12	5
	April	8	11	4	12	7
	May	10	5	10	14	13
Cranwell	March	7	13	8	9	3
	April	8	13	3	8	9
	May	8	2	8	11	13
Cambridge	March	8	7	7	7	3
	April	9	14	4	10	7
	May	8	3	8	10	11

Table 3

Frequency of occasions at selected stations of

A falls of 10mm or more in 24 hours
B falls of 25mm or more in 16 hours or less

	A		B			
	Average values (1900-1960) and range					
	Oct-March	Annual	Period	Average	Range	Year of greatest frequency
Aberdeen	9.5 (1-18)	18.0 (12-23)	1946-70	2.9	0-7	1970
Edinburgh	6.5 (4-11)	16.0 (12-24)	1949-70	1.7	0-5	1949
Manby (Lincs)	5.9 (2-15)	13.2 (7-19)		n.a.		
Cambridge	3.7 (0-8)	10.0 (8-14)		n.a.		

Although the average number of wet-days does not differ greatly between stations, variation is large between years, and between stations within years. Considering days with falls ≥10mm (Table 3, Col. A) more extensive data suggest regional contrasts with more frequent occasions of rain of these intensities in northern than in southern Britain. In eastern Scotland the annual average frequency of cases of ≥25mm in 16 hours or less (Table 3, Col. B) varies from about 1.5 to 3.0 (range 0 to 6 or 7) and Green (1973) has commented on the tendency in recent years towards a greater number of widespread heavy falls of rain.

Possibly more relevant than rainfall per se is the balance between rainfall and evaporation and the consequential effects on run-off, percolation and leaching. Estimates of evaporative loss through "potential transpiration" (i.e. the water loss from a full cover of an established green crop when soil water is freely available to the root system) have been published (MAFF Bulletin 1967). Period averages (in mm) for areas typified by the following stations are given below. Stations have been classified as either coastal or inland and set out in rough latitudinal bands.

Coastal	April-Sept.	Year	Inland	April-Sept.	Year
Kinloss	427	517			
Aberdeen	406	499			
Stonehaven	411	497	Blairgowrie	386	434
N. Berwick	420	495	Perth	377	425
			Edinburgh	401	465
Bridlington	428	502	York	424	490
			Cranwell	451	519
Lowestoft	469	551	Cambridge	461	530
Folkestone	486	580	Wye	470	540

For similar geographical situations there is a general decrease from south to north; and thus, although rainfall in some seasons, and in broad terms annually, does not differ greatly (see Table 1) such variation as exists and the decrease in water loss, may be expected to result in a rather higher level of soil moisture in the north than in the south during much of the year. A further expression of these differences is the date on which the soil is recharged to "field capacity", from the usual soil moisture deficit which develops in the summer. Yet another stage is to estimate the "excess winter (viz: October-March incl.) rainfall", that is the excess of rainfall over evaporation from the date at which capacity is achieved. The straight forward model postulates that this "excess" percolates through, or runs off from the surface layers. Data has been published for England and Wales (M.A.F.F., 1971) but so far only a preliminary scrutiny of appropriate data for Scotland has been undertaken.

On a broad regional basis the pattern of seasonal rainfall is sufficiently stable for the mean date of return to capacity N (N = no. of days from Aug. 31) to be linked with annual average rainfall R (R in inches) as shown below:

N. England	$R > 30$ ins.	$N = 108 - 2.3R$
	$R < 30$ ins.	$N = 300 - 8.7R$
Midland England		$N = 189 - 4.5R$
E. England		$N = 211 - 4.8R$
S.E. England		$N = 191 - 4.1R$

The mean date ranges from early December in E. England to early-mid November in Yorkshire and to mid-late October at the Border.

The corresponding excess winter rainfall (EWR) can also be linearly related to R, as follows:

N. England	EWR = 0.80R - 12.4
Midland England	EWR = 0.83R - 13.5
E. England	EWR = 0.82R - 13.5
S.E. England	EWR = 0.77R - 12.6

Some specific data follow (Table 4).

Table 4

"Excess winter rainfall"(in inches) for selected stations in E.England Mean value (M) standard deviation (sd) and range (S). Period 1940-59

Station	M.	sd	S.
Berwick-on-Tweed	7.25	3.0	1.4 to 12.5
Tynemouth	8.20	3.9	3.1 to 17.0
Morpeth(Cockle Pk.)	10.80	4.6	4.5 to 18.3
Durham	9.35	4.2	4.1 to 18.7
Driffield (Yorks)	8.70	4.2	2.7 to 16.3
Cranwell	5.30	2.8	1.4 to 11.1
Cambridge	4.70	2.4	0.6 to 10.7
Oxford	8.00	3.5	1.1 to 13.8
E.Malling	8.20	3.6	2.9 to 15.1

The trends implicit in the above table may be cautiously extended into south-east Scotland.

Temperature and temperature-dependent variables

Basic data for February to June for selected stations in eastern Britain are given in Table 5.

Height above sea level and distance from the sea are important determinants of temperature. Seasonal contrasts between temperature at coastal (C) and inland (I) stations may be broadly stated as follows:

	Day maximum	Night minimum
Winter	C $\geq$ I	C > I
Summer	C $\leq$ I	C $\geq$ I

Regarding height variation, day temperature and 24-hour means decrease with height - the latter at a rate of about 0.6°C/100m (or 1°F per 300ft). Night minima at any site are strongly influenced by its topographic setting (e.g. hill slope, frost hollow) but for similar settings temperature will usually decrease with height. The observations for February illustrate that in winter north-south differences lie within about 1°C; in March and April the contrast sharpens south of York, whilst in May and June three groupings are suggested, viz: north-east Scotland, south-east Scotland and thence to about York; and lastly York to the Thames.

Concerning frost - ignoring the immediate coastal strip of East Anglia, the average date of the last screen frost occurs towards the

Table 5

Period averages (1931-1960) of mean daily maximum, mean daily minimum and mean daily mean temperatures for stated stations and months (°C)

Place and Ht. above MSL (in m)	Feb. Max/min	Mean	Mar. Max/min	Mean	Apr. Max/min	Mean	May Max/min	Mean	June Max/min	Mean
Nairn (6)	6.6/0.6	3.6	8.8/1.8	5.3	11.1/3.3	7.3	13.7/5.9	9.8	16.6/8.7	12.6
Aberdeen (58) (Dyce)	5.7/0.0	2.9	7.7/1.2	4.5	10.5/2.8	6.6	12.9/5.1	9.0	16.0/8.0	12.0
Dundee (45)	6.2/0.5	3.3	8.3/1.8	5.1	11.4/3.5	7.4	14.4/7.5	10.1	17.6/8.7	13.2
Perth (23)	6.6/-0.3	3.2	8.9/1.4	5.1	12.2/3.2	7.7	15.5/5.6	10.6	18.6/8.7	13.6
Edinburgh(134) (Blackford Hill)	6.0/1.1	3.6	8.0/2.3	5.2	10.8/4.0	7.4	13.5/6.3	9.9	16.7/9.2	12.9
Edinburgh(35) (Turnhouse)	6.5/0.3	3.4	8.7/1.7	5.2	11.6/3.1	7.3	14.3/5.7	9.9	17.2/8.6	12.9
Kelso (59)	6.3/-0.4	3.0	8.9/1.0	5.0	11.7/2.9	7.3	14.8/5.3	10.1	17.8/8.3	13.1
Morpeth (107) (Cockle Park)	5.8/0.2	3.0	8.1/1.3	4.7	11.0/2.8	6.9	13.7/5.1	9.4	17.0/8.0	12.5
Durham (102)	6.2/0.3	3.3	8.8/1.4	5.1	11.7/3.2	7.4	14.7/5.5	10.1	18.0/8.5	13.2
York (19)	6.8/1.1	4.0	9.6/2.4	6.0	12.8/4.4	8.6	16.3/6.9	11.6	19.4/10.0	14.7
Cambridge(13)	7.2/0.5	3.9	10.5/1.6	6.1	13.7/3.8	8.8	17.2/6.5	11.9	20.5/9.7	15.1
Wye (56)	6.8/0.7	3.8	9.9/2.2	6.0	13.2/4.2	8.7	16.5/6.7	11.6	19.8/9.9	14.8

end of April in the south and moves to early May in N. Yorkshire, but only minor subsequent changes are noted northwards through the predominantly coastal arable areas of Scotland.

The upward seasonal movement of mean temperature through 5.6°C (42°F) marks the beginning of the "growing season". At sea level the mean date changes from about March 7 in East Anglia to March 14 north of Newcastle and to March 21 at and beyond Aberdeen. An additional delay in all areas of some two to three days is imposed by every additional 100ft above sea level.

The subsequent growth of the crop is loosely associated with the "accumulated day-degrees" above the threshold mean day temperature of 42°F.

Table 6

Cumulative "day-degrees" (accumulated temperature above 42°F) from (estimated) date of beginning of "growing season" to end-month indicated

(in degree-days °F)

Place and Ht above MSL (in m)		"Growing season" commencing date (estimate)	Cumulative day-degrees to end -			
			March	April	May	June
Aberdeen	(58)	20 March	30	133	325	676
Dundee	(45)	16 "	45	169	399	798
Perth	(23)	19 "	39	174	440	869
Edinburgh	(134)	22 "	27	138	388	745
N. Berwick	(36)	14 "	50	179	411	798
Kelso	(64)	22 "	27	147	389	791
Stirling	(49)	18 "	45	187	469	904
Morpeth	(107)	14 "	48	150	355	724
Tynemouth	(29)	5 "	85	220	446	839
York	(19)	7 "	82	250	569	1052
Cambridge	(13)	5 "	88	268	612	1113

To the extent that this parameter is valid, there is a definite contrast between the build up of units as between a) Aberdeen b) the batch of stations from Dundee as far south as Tynemouth and c) from York southwards. Within the central group some measure of the effect of siting is indicated by data from the two coastal and low-level stations of North Berwick and Tynemouth, and, respectively the rather higher and more inland stations, viz: Edinburgh (Blackford Hill) and Morpeth (Cockle Park).

Wind

Place to place comparisons of wind velocity are rendered difficult by the marked influence exerted upon wind by the immediate surroundings as well as by regional features. Probably the best overall picture of mean annual wind speed is that given in the Climatological Atlas (Meteorological Office 1952). Broadly, arable areas in south Britain experience annual wind speeds in an open situation and at 10m ($\simeq$ 33 ft) above ground of between 10 and 12.5 mile/h compared with the 12.5 to 15.0 mile/h range in Scotland.

The comparison between Mildenhall in Suffolk, well inland in East Anglia, and the most inland of the Scottish stations (Edinburgh, Turnhouse) should be noted. Although coastal sites are generally windier than those inland, the latter, if in a well exposed situation can experience winds comparable with those on the coast, see, for example, Cardington (Bedfordshire). For a comparison between average monthly wind speeds and those in months of 1972 recognised as windy, note the bracketed figures in Table 7.

Table 7

Period average (1963-1973) wind speeds (measured in open situations at 10m (= 33ft) above ground) for sites and months indicated. The values for April and May 1972 are in brackets.

(in mile/h)

Place	March	April	May	June
Kinloss (C)	14.6	13.3(12.2)	12.4(12.8)	11.0
Dyce	13.6	12.2(12.9)	11.4(13.8)	10.3
Leuchars (C)	14.7	13.3(11.7)	12.2(12.2)	11.6
Turnhouse	12.8	11.6(11.4)	10.8(10.8)	10.5
South Shields (C)	12.4	11.0(11.1)	10.1(11.1)	8.5
Shoeburyness (C)	16.8	15.4(18.1)	14.5(17.1)	14.2
Cardington	14.5	13.7(16.1)	12.9(14.8)	11.9
Cranwell	12.1	11.6(15.4)	10.9(14.7)	9.9
Manston (C)	13.7	12.6(16.3)	11.9(15.4)	11.9
Mildenhall (a)	10.9	9.9(13.3)	8.6(12.5)	7.9

(C)= near the coast
(a)= Honington (1970-1972)

The importance of wind speed in relation to weed control measures has been mentioned, and merits a more detailed examination of wind distribution: amongst relevant information are the average percentage frequencies of wind speeds within the ranges <4 mile/h, 4-12 mile/h and >12 mile/h for April and May (Table 8) together with the corresponding figures for these months of 1972.

Table 8

Percentage of time with wind speeds (mile/h) within stated ranges for the months of April and May (i) period averages (ii) for 1972

Station		April			May		
		<4	4-12	>12	<4	4-12	>12
		%	%	%	%	%	%
Dyce	(i)	32.9	38.2	29.0	33.1	39.5	27.3
	(ii)	15.9	25.0	59.1	13.5	27.5	58.6
Leuchars	(i)	28.3	44.7	27.0	23.4	47.5	28.9
	(ii)	10.4	45.2	44.3	11.3	38.3	50.1
Cranwell	(i)(a)	18.2	43.8	36.2	19.0	45.5	30.3
	(ii)	2.2	30.8	66.9	5.8	35.1	59.0
Mildenhall	(i)	18.9	53.4	27.5	19.1	53.8	27.0
	(ii)(b)	6.1	34.0	59.8	4.7	42.2	50.1

(a)= Instrument unserviceable - April 1.8%: May 5.2%
(b)= Honington

CONCLUSIONS

In relation to weed control measures, rainfall and soil moisture and, arguably, wind, are the most important climatic elements, with soil temperature (closely coupled with air temperature) of almost equal relevance.

The arable areas are concentrated on the eastern side of Britain, and there are both similarities and contrasts between the climates of the northern portion (roughly North Yorkshire northwards) and the southern portion.

The differences between rainfall of the two regions, annually - but more strikingly in early season (March - June) - are small. However, such differences and the northwards decrease in evaporation lead, on average, to a higher level of soil moisture for a longer period of the year in the north than further south. There is an associated decrease northwards in the average occasions of dry top-soil, and an increase in the amount of winter rainfall which can contribute to leaching. These differences are also reflected in the variations in the dates of return to field capacity i.e. centred around mid-December in E. Anglia to mid-October at the Scottish border.

Regional temperature differences in the October-March period are slight but become increasingly evident as the season advances. In consequence there is a 2-3 week south to north delay in the date of commencement of the "growing season", and a similar difference in the mean date of last spring frost. The joint effect of delay and lower temperature (particularly during daylight) is illustrated by differences in the build-up of seasonal "accumulated temperature".

Necessarily for topographical reasons, arable areas in the north are on or near the eastern coastal regions, and hence are liable to stronger winds than those affecting most of the arable area further south.

Year-to-year differences and place-to-place differences in a given year are frequently greater than regional comparisons based upon average values; these latter values nevertheless provide the bases from which variation can be evaluated.

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THE INFLUENCE OF SOIL PROPERTIES ON HERBICIDE PERFORMANCE

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Summary The effect on herbicide performance of soil texture, stoniness, structure and depth, clay minerals, organic matter, soil moisture, aeration and temperature are discussed, comparing these properties in the northern and southern environments. The most likely source of differences in herbicide performance due to soil factors is higher soil organic matter in the northern environment though lower soil temperatures and higher soil moisture content may also have an effect.

INTRODUCTION

Many soil properties have an influence on the use, action and degradation of herbicides. These include soil texture, soil moisture content, the type and content of clay minerals, soil organic matter, soil reaction, aeration, temperature and microbial activity. Some of these properties are related to inherent characteristics of the soil, others to its development, management and to climate. The effects of each of these characteristics will be discussed, and any differences between the northern and southern environment that may affect their performance will be assessed.

SOIL TEXTURE

Soil texture refers to the size of the particles which dominate the physical characteristics of a soil. It may be determined in the laboratory by particle size analysis or in the field by hand assessment. Many physical properties are related to texture, for example, available water capacity, drainage, aeration and soil structure. The determination of soil texture by hand has many advantages - principally its speed in the field, when an on-the-spot assessment can be made, and with suitable training and care can give reliable and reproducible results. The texture scale widely used in England and Wales by ADAS Soil Scientists has been used to classify soils according to their adsorption characteristics. Technical representatives of several of the firms making herbicides have been instructed in the use of this textural scale and it is generally regarded as being very useful in assessing herbicide dosage in the field, particularly in East Anglia.

Field texture is influenced not only by the size and proportion of mineral particles present in the soil but also by the organic matter content. As the organic matter content rises the influence of the mineral particles on texture diminishes, and the 'loamy' feel of soils increases.

Variations in the texture of surface soils are related mainly to the type and distribution of soil parent materials and are often related to topography. A broad picture of the nature of soil parent materials may be obtained from geological maps and reports, but the influence of the underlying rock is complicated by the mixing effects of ice action and other geological processes. In general, rocks are older in the north and more acidic in character and give rise to a higher proportion of soils with a sandy texture; arable soils with a high clay content are less common in the North than for example in East Anglia with its extensive areas of Chalky Boulder Clay and London Clay. Information on soil parent materials and soil texture may be obtained from Soil Survey publications, which are available for several arable areas in England, Wales and Scotland (See references for examples).

STONE CONTENT

The stone content of soils can directly influence the action of herbicides. Dilution of the soil with inert stones increases the concentration of surface-applied materials in the soil. They may also influence herbicide activity indirectly by their effects on soil moisture content; when a soil is drying, a large content of stones would make the soil dry more quickly in comparison with a stone free soil, on rewetting a stony soil would become saturated more quickly. Information on stoniness can be obtained from Soil Survey Memoirs and can be assessed in the field using standardised descriptive terms (e.g. Soil Survey Staff 1960). Soils derived from hard rocks tend to produce more stony soils and any differences in stone content between soils in the northern and southern environments would be related to soil parent material rather than to the environment.

SOIL STRUCTURE AND ROOTING DEPTH

Soil structure has a profound effect on crop growth particularly on the early growth of seedlings and subsequent root development. In situations where roots are restricted to a shallow depth the contact between herbicide and root may be greater compared to a plant with normal rooting. Restrictions to root depth may be due to cultivation pans, natural hard indurated layers or rock close to the surface. Cultivation pans are not uncommon in intensive arable areas in the southern environment and are related to soil texture, soil structure, seasonal rainfall, cropping and management. There is no information on the incidence of cultivation pans in the northern environment though indurated layers 30-40 cm from the surface occur in several areas (Glentworth and Muir, 1963).

INORGANIC CLAY MINERALS

Cation exchange phenomena in soils are related to the content of organic matter and to the content and type of clay minerals. Clay minerals with a rigid structure, e.g. kaolinite, are much less reactive than those with an expanding lattice, e.g. montmorillonite, with other groups such as illite intermediate in character. Herbicides may be adsorbed on to the external surfaces of clay minerals and thereby retained in an exchangeable form and prevented from leaching. They may also enter the interlayer spaces of expanding minerals and in this position their accessibility is much reduced. For a fuller discussion on the mechanism of adsorption by clay colloids, several reviews may be consulted, e.g. Weber (1970).

Examination of data in Soil Survey reports shows that the clay present in Scottish soils, with a few exceptions, is essentially illitic in character. Soils in the Southern environment tend to be more variable with several major groups of clay minerals occurring in different soils; the clay fraction is dominated by montmorillonite in soils derived from Clay-with-Flints, Chalk and Gault.

The significance of the type and content of clay minerals may be important on a few soils, particularly clay soils dominated by montmorillonitic minerals. In many soils the importance may be relatively small, because soil organic matter seems to have a greater bearing on the performance of many herbicides rather than their reaction with clay minerals; in the northern environment there are fewer soils with a significant proportion of montmorillonite.

SOIL ORGANIC MATTER

Organic matter in soils is made up of plant, animal and microbial tissues either still living or in various stages of decay and humus, a complex product, synthesised from organic residues. The content of organic matter in any soil is dependent on the input of residues, and on the rate of breakdown. The input is related to the cropping system, particularly to the proportion of grass crops in the rotation, and the rate of decay to the intensity of microbial activity, which in turn is influenced by soil moisture and aeration, pH value, mineral supply and soil temperature. The combined effects of a longer winter period and lower soil temperatures in Spring and Summer in the northern environment will be to reduce microbial activity and tend to give soils with a higher content of organic matter, and possibly a slightly different form of organic matter, less completely decomposed. Because organic matter in soil is also related to soil texture (higher with increasing clay content), soil drainage (higher in wetter soils), cropping systems and depth of cultivation, detailed comparison between the northern and southern environments cannot be obtained and only general information is available. In England and Wales the results of analyses on soil samples taken at random in connection with the Survey of Fertilizer Practice have been given by Church and Hooper (1973), (Table 1).

Table 1.

Average values of soil characteristics for different cropping and soil texture groups in England and Wales, 1969 and 1970

Texture	Rotation	pH (water)	% Organic matter
Loams and sandy loams	Arable - tillage	7.0	3.2
Silty and clay loams	(193 fields)	7.2	3.5
Loams and sandy loams	Ley-arable	6.6	5.0
Silty and clay loams	(265 fields)	6.9	4.5

In the East of Scotland College area, organic matter figures from a survey of 120 fields have been provided by Speirs (private communication) (Table 2).

Table 2.

Soil organic matter levels at experimental sites in the East of Scotland 1971-73

Texture	Rotation	% Organic matter
Loamy sands and sandy loams	Arable	3.8
	Arable + 25% grass	4.1
	Arable + 50% grass	5.1
Loams	Arable	3.9
	Arable + 25% grass	4.3
	Arable + 50% grass	5.1
Sandy clay loams and clay loams	Arable	3.9
	Arable + 25% grass	4.6
	Arable + 50% grass	4.9

In Northern Ireland tentative figures for organic matter have been given by McConaghy (private communication), for regularly cultivated soils: Sandy and light loams had 2.6 - 4.3%, medium loams 5.1 - 6.9% and medium heavy loams 5.5 - 7.7%. In the West of Scotland the mean organic matter content of 200 samples from arable and horticultural areas taken in 1973 was 5.1% (Moon, private communication).

The above figures from each area show that cropping has a large effect on organic matter levels, and that in general higher levels are found in the northern environment. The significance of any difference in the content or nature of organic matter is difficult to assess because of the complexity of reaction and interaction between organic matter, microbial activity and the herbicide. However, the known different performance of some herbicides in the North may be due to differences in organic matter. Where differences in organic matter are large, a number of methods may give similar results but for accurate comparisons the same determination should be used.

SOIL REACTION

In the northern environment there are fewer base-rich rocks and therefore soils in their natural state would, in general, be more acid. There is also a greater "leaching factor" in Northern soils, i.e. the amount of water percolating through the soil each year. This may be partly due to higher rainfall, but mainly to the lower water loss by evapotranspiration. The higher amount of water passing through the soil would also encourage the development of acid soils. However, on soils used for arable and horticultural crops, the pH is usually maintained by liming near neutrality pH 6.0 - 6.5 so that differences between the two environments are not likely to be large. There will always be a tendency for soils to be more acid in the Northern environment.

SOIL MOISTURE, AERATION AND TEMPERATURE

The mobility, action and degradation of herbicides is influenced by the moisture content of the soil and also by temperature. At lower temperatures the mobility of some herbicides may be less because of a reduced rate of cation exchange, and some may be more persistent because of slower rates of the chemical processes such as hydrolysis or of reduced microbial activity. However, these effects may be partly offset by higher soil moisture in soils in the northern environment which would improve mobility and sustain microbial activity in summer in comparison to drier soils in the south at that time of year.

When aeration is inadequate because of an increased demand for oxygen or a reduced rate of gaseous interchange between the soil air and the atmosphere, anaerobic conditions may develop. Under these conditions reduction processes take place and a wide range of products may be formed, very different to those of a fully aerated soil. Different breakdown processes for herbicides in anaerobic soils would seem to be possible. Anaerobic pockets found in arable and horticultural soils are often present as a result of management practice, e.g. recent incorporation of fresh plant material, or soil compaction; it is not known whether they occur more frequently in the northern or southern environments.

FORESTRY

The soil environment in forests is usually very different from arable land; soils are often acid, with low levels of nutrients, soil temperatures would tend to fluctuate less because of the insulating effect of vegetation. Organic matter is often much higher on the surface, with a mat of forest litter and partly decomposed plant residues, and is often less decomposed, with a higher organic matter to nitrogen ratio. In the northern environment, forests are mainly in upland areas, often cooler with a higher rainfall.

CONCLUSIONS

Effect on soils in the Northern environment

Soil temperature	Cooler. Slower rate of microbial activity and of chemical reactions
Evapotranspiration	Lower. Soils more moist, greater leaching
Rainfall	Equal or higher; increased leaching
Organic matter	Higher; possible different form
Soil texture	Similar on intensively cropped soils; few clay soils
Clay minerals	Fewer clays with expanding lattice structure

It must be emphasised that these are broad generalisations to indicate probable trends; there are many exceptions and in particular cases analysis of the soil would be required to give accurate comparisons. Higher soil organic matter would seem to be the most likely cause of any differences in herbicide action in the northern environment, lower soil temperature and higher soil moisture may affect persistence and degradation.

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Discussion on preceding two papers

Mr. J.G. Elliott

Can I ask the two speakers if they can give us a little information about what is effectively the meeting point between them, i.e. soil temperature, which always seems to me (particularly in spring) to be extremely indicative of the general growing environment. Have we got factual data about the north versus south in respect of the general rise in soil temperature during the months of say April and May?

Dr. Gloyne

There is a great deal of material on soil temperature. I was dealing with air temperature merely because it is more conveniently handled in slides. At a first approximation and a useful one, you can read soil temperature for air temperature. In other words, the contrasts that I have been indicating with respect to air temperature are roughly applicable to soil temperature.

Dr. Batey

Soil temperature does affect many things in the soil and is a very important factor. For example, all chemical processes are related to temperature, not so much the termination point of a process but the speed of it. If the temperature increases by 10° you will double the rate of a chemical reaction. Therefore any relative change in temperature will directly affect many soil reactions. This applies to a very wide range of soil properties. Hydrolysis is an important reaction in the breakdown of herbicides. Also microbial activity is very much influenced by soil temperature which in turn influences organic matter levels and the degradation of herbicides. These factors are all related to the single parameter of soil temperature.

Dr. Gloyne

Most of our soil observations unfortunately are at either 10 cm or below, whereas, from the herbicide angle, interest is mainly in the top 5 cm or so. In that zone the day temperature is considerably higher and the night temperature is lower than down where we measure it. Now this top layer temperature is very sensitive to moisture content, to things like colour, vegetative cover etc., and to the extent that these differ, you will get important differences at the levels at which those involved with soil-applied herbicides are most interested. The general average is much as I have shown on the board in terms of contrast, but when you come to this important thin top layer we are much more ignorant of what happens. The response is very largely a function of soil structure, type, moisture content, etc.

Dr. Batey

I think moisture content particularly has a very large effect on temperature, but also don't forget the effect of slope and aspect, both of which govern the intensity of radiation reaching the soil. In this respect there may be quite large differences in soil temperatures in the top layers e.g. between north and south facing slopes despite very similar air temperature. Similarly with soil colour; if the soil is bare and exposed to direct radiation and it is dark coloured you will get a very high amplitude between day and night temperatures. The best example is the Fens, very hot in the day and freezing at night so you get sugar beet crops lost at quite a late date because of the very intense radiation. As soon as you get a crop cover this acts as a blanket and the amplitude is very much damped as to the variation in soil temperature.

Mr. R. Makepeace

I would like to make a comment on soil types in terms of residual herbicides. In South-East England the ADAS have a system of soil textural classification and this is the basis on which they make a recommendation for herbicides. Also in the south east and particularly in East Anglia they have an association with organic matter which is reliable, to the extent that they have even re-organised their classification of textural soil classes on an organic content basis. In this situation they are dealing with organic matter contents of the order of 1-2%. Now, when you come up for example to the eastern arable land of Scotland you will find that for a given soil type the physical texture is similar to that in Eastern England but the organic matter is completely different. In a loamy sand situation in East Anglia you would never expect to have more than 1.5% organic matter, whereas in these areas the percentage is running at 5-6 quite regularly. There is therefore considerable danger in extending recommendations based on soil type from East Anglia to areas of northern Britain and to Ireland and vice versa. In addition, variation in performance has been experienced even in soils in different areas, but with similar organic matter contents. I think we are all in the dark here, and it is surely time that we really got down to classifying what constitutes organic matter and what its importance is in terms of the use of herbicides.

Dr. Batey

Thank you for bringing up this point and opening up other questions. I have, in fact, a copy of the latest textural classification of E. Anglia relating organic contents within the texture scale and it seems to operate fairly well there as you mentioned. You can separate organic matter fairly simply in a broad classification into 1) a mull type organic matter which is very well decomposed and mixed into the soil, 2) a more acidic situation with a much rawer type of less decomposed organic matter. This will be black-coloured, with a wider carbon to nitrogen ratio as an indication of its lower status of breakdown. There are also other ways of characterising it. I think we have got to really get down to this and find out which of these characteristics are important to various weed control chemicals and which are not. Organic matter is an intensly complex, biological, chemical and physical entity, but there may be relatively simple ways of classifying it for specific purposes. I think if agronomists and soil scientists got together on this problem, it should be possible to produce a guide for you. We really ought to be characterising the soil better than we are doing at present.