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WEATHER AND POTATO BLIGHT

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Part 1

POTATO BLIGHT

INTRODUCTION

Late blight, caused by Phytophthora infestans (Mont.) de Bary, is the most serious form of disease to affect potatoes, causing significant yield losses almost every year. Carried over from year to year in infected potato tubers, the fungus is spread by spores known as sporangia. When planted, the mycelium (vegetative part of the fungus) renews growth, passes into the sprouting tissues and sporulates on the haulm above ground in suitable conditions of temperature, humidity and moisture. The disease is spread from infected to healthy foliage and, falling on the ground, the sproangia may be washed into the soil and attack the developing tubers.

The primary outbreak of blight in the field comes from infected tubers - blighted potatoes are recognised by darkish grey colouring extending from the skin inwards. The first sign of the disease on the foliage is the appearance on the leaves of small brown patches, which in warm humid weather increase rapidly in size; a faint whitish mould or mildew appears around the margin of the necrotic tissue on the lower surface of the leaf. The appearance of this growth is minimal or even absent in dry weather. In epidemic situations the leaves become blackened and shrivel up within a comparatively short time; the stalks are also attacked and the whole crop is affected by a characteristically 'evil smelling' decay.

THE PRODUCTION OF SPORANGIA

The downy mildew which develops on blighted foliage consists of sporangiophores. These are the developing branches of the fungus, which produce innumerable lemon-shaped sporangia. These are easily detached and disseminated by wind, rain and other vectors, and serve to carry infection to healthy plants. The

sporangia (reproductive cells) may germinate in either of two ways, (a) direct germination or (b) indirect germination. When a sporangium germinates directly it sends out a germ-tube which enters a stoma of the host and starts a fresh centre of infection; when a sporangium germinates indirectly its contents divide up into a number of zoospores which encyst on the leaf surface. The leaf surface is then penetrated and infection takes place.

High relative humidities are conducive to the formation of sporangia and the sporangia become abundant at relative humidities exceeding 90%
Sporangia are very active at temperatures of 12-13^{o}C and after they land on the host the fungus develops rapidly at temperatures of 18-21^{o}C; lesions appear 3 - 5 days afterwards (e.g. after 75 hours at 21^{o}C) at the point of infection and a new crop of sporangia is produced.

The vulnerable period for the sporangia is when they are on the foliage. Germination is aided if a film of water is present on the leaves but sporangia lose the ability to produce zoospores in three to six hours if the relative humidity is below 75%. A fungicide spray, if already protecting the foliage, will also kill or prevent the germination of sporangia which alight on plants.

THE POTATO GROWING SEASON

The seasonal growth of the potato crop in Ireland covers six months, April to September inclusive, from the time of planting to maturity. Murphy (1939) identified four stages in this growth period.

1. From first growth in the soil to the beginning of tuber formation, April to mid-June (11 weeks), during which only roots and haulm (aerial parts; leaves and stalks) are produced. The plants appear above ground early in May in the south and east, but in western areas and on heavy soils, emergence above ground may be some 3 weeks later.

2. From the beginning of tuberization to the apex of haulm production, the latter being reached in the last week of July or in the first week of August (7 weeks). Tuber production is at a maximum in the period from mid-July to mid-August.

3. A short period of about 2 weeks, to the third week in August on average, in which crop production continues at a somewhat reduced rate.

4. A period of six weeks to the end of September during which both haulm and crop production decrease at a gradually accelerating rate.

YIELD REDUCTION DUE TO BLIGHT

The fungus attacks and prematurely kills the haulm of the potato plant, thus preventing maximum tuber formation and reducing the yields. Further losses arise by its invasion of the tubers which subsequently rot. The foliage is most susceptible to blight at the beginning and end of the growing season and greatly resistant in the middle. From the middle of July onwards, however, and especially towards the end of August and during September, when heavy dews occur and potato foliage often remains damp for a great part of the daytime, blight develops freely on the leaves.

Potato blight is severe almost every year in Ireland. With progressive decay of the haulm during a blight attack, a point is reached at which tuber production stops. This point is reached, on average, at the 75% blight stage as assessed by the British Mycological Society (B.M.S.) key (Appendix, Table I). The 75% stage corresponds to about three quarters of the leaf area destroyed, i.e. green and brown parts are of about equal proportions. This stage is reached in this country, according to region and season, about mid to late August but can often be delayed until mid-September by most spraying treatments.

Table I below shows the potential loss in crop production according to the time of the year at which the 75% stage of blight on the haulm is reached (Large, 1958).

TABLE I

MEAN LOSS (%) OF POTENTIAL CROP IN RELATION TO 75% BLIGHT ON HAULM

End of July	Mid-August	End of August	Mid September	End of September
50	28	13	4	0

The increase in potato crop yield which results from a successful extension of the life of the green foliage can be seen from the above table to be very great.

BLIGHT CONTROL

Considerable control of late blight can be affected by proper management. Infected tubers or susceptible varieties should not be planted, especially in areas of frequent severe blight. Crops are very susceptible to blight after emergence above ground, become somewhat resistant for a period at the flowering stage and subsequently revert to being extremely susceptible. A good spray programme must start before blight appears and continue throughout the entire season according to a warning system or by routine spraying. Stalks should be burned off 2-3 weeks before harvest, i.e. during September, to prevent tuber infection and old potato dumps should also be burned-off.

(a) VARIETY RESISTANCE TO BLIGHT

An effective method of blight control is by the cultivation of resistant crops. Comparison of the resistance to blight of some common potato varieties is given in Table 2 (Dowley, 1981), the higher the number the greater the resistance.

Table 2

Variety	Foliage resistance	Tuber resistance
King Edward	3	3
Kerrs Pink	5	5
Record	6	8
Arran Consul	6	6
Golden Wonder	3	9
Pentland Crown	6	7
Pentland Dell	7	4
Cara	9	9
Clada	7	8

(b) FUNGICIDE CONTROL

Control of potato blight normally consists in covering the haulm of the growing plants with a fungicide which will kill or prevent the germination of the sporangia which alight on the plant. Fungicides, therefore, are primarily effective against the incoming inoculation, which is derived from the primary focus and is responsible for the initiation of an epidemic. It is important, therefore, to apply the first spray before the foliage is attacked. Fungicide application, made after 5% disease is apparent in the crop, is ineffective in preventing the subsequent development of a blight epidemic.

The use of fungicides against potato blight does not eradicate the disease. Its

effect is to retard the spread of the disease by killing the spores which emerge during favourable weather and thus, by lengthening the period of growth of the green parts of the plant, to ensure a better crop of tubers. It is therefore important that the timing of the applications of fungicides is appropriate both from the point of view of effectiveness and economy.

(c) FREQUENCY OF FUNGICIDE APPLICATION

The practical success of a programme based on the least number of sprays sufficient for the protection of the potato crop essentially depends on correct timing (Burke, 1955). If the fungicide is applied too late the spore, having penetrated into the foliage, is no longer vulnerable. Consequently, the interval between spray application and the production of blight spores must be short enough to ensure that all the foliage is still adequately protected by fungicide. The problem is therefore one of predicting the time when the crop will be attacked by blight.

While the omission of one or two sprays at an initial low level of infection (in June) may not carry a severe penalty, for good protection, the fungicide must be applied before blight appears. Spraying therefore should be carried out before the occurrence of a significant spell of blight weather. For regular spraying programmes the interval between sprays must be short enough to ensure all new foliage is protected, bearing in mind that fungicides also tend to be washed off by spells of very heavy rain. Normally the interval between sprays is about 10-14 days right up to the time of burning off. Failure to spray, particularly at the end of the growing season, can be extremely costly in terms of tuber infection. The latter occurs when sporangia are washed from diseased foliage to the soil by heavy rain. Infection of tubers through the stem of the plant is rare. The fallen sporangia then infect

the tubers through the skin, the potatoes nearest the surface being first infected.

Most sprays in current use form a film over the leaves and stalks. Some (Organotins) are somewhat severe on leaves, giving lower yields, especially in dry years, but give better tuber protection. Others (Dithiocarbomates), while improving growth, are not quite as good against tuber infection. Systemic type fungicides, which are absorbed into the foliage, have not been favoured in recent years, having apparently failed to provide adequate protection in certain epidemic situations during the 1980 season (Dowley and O'Sullivan, 1981, Cooke and Logan, 1982).

SUITABLE WEATHER CONDITIONS FOR SPRAYING

Weather conditions before, during and after spraying are important to the proper application of fungicides. Optimal spraying weather occurs when winds are light, i.e. less than 10 knots, drying conditions are good and when there is an absence of precipitation for several hours. Overall, field conditions must be reasonably firm to support heavy machinery, conditions which may not prevail after prolonged and repeated spells of heavy rain over several weeks.

Systemic fungicides are weather independent after about half an hour following application. Contact fungicides, on the other hand, which form a protective layer on the plant, and contain a "sticker" or "wetter" to give tenacious plant adhesion, need one to two hours under good weather conditions, and several hours when applied to wet foliage, before protection is secure. For large spraying operations, a whole day may be required to complete the programme. In many cases, however, an interval of three to four hours is sufficient.

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Part 2

EFFECTIVE BLIGHT WEATHER CRITERIA

BLIGHT PERIODS

Criteria for weather conditions immediately preceding outbreaks of potato blight were formulated in Holland in the mid-nineteen-twenties (Bourke 1955). These conditions, known as the "Dutch Rules", were:

(a) At least four hours of dew at night

(b) Minimum temperature during the night not below $10^{o}C$

(c) Mean cloudiness on the following day not below 8/10

(d) Measurable rainfall (not below 0.1 mm). in the 24 hours following the dew night.

In 1948 these rules, which were difficult to apply satisfactorily, especially rules (a) and (c), were abandoned in favour of a simpler temperature-humidity rule. The method of predicting outbreaks of blight by a temperature-humidity rule was first used by Beaumont for the southwest of England. The Beaumont rule specifies that, after a period of 48 unbroken hours with a minimum temperature not less than $10^{o}C$ and relative humidity not below 75% , a critical period occurs, which generally precedes the first outbreak of potato blight by from 7 - 21 days. The concept of "zero date", defined by Grainger (1950) was applied to the Beaumont period which establishes, from experience, the earliest date of appearance of the disease in different districts; weather-indications prior to this would be ignored. Bourke (1955) suggested that the first visual appearance of potato blight is preceded by a period of latent spread covering 3-5 "generations" of the fungus, and what happens after the "zero date" may depend as much on the weather which precedes that date as that which follows it. This consideration is put into practical use in the Irish blight warning system.

THE IRISH RULES (BOURKE)

"Beaumont periods" occur too frequently in Ireland to be a satisfactory basis for a blight warning system (Frost, 1975). Atlernative "rules" proposed by Bourke (1953), were found to be more reliable. The Irish Rules used the following criteria:-

(a) a twelve hour period with temperature 10°C or greater and relative humidity 90% or greater (in the screen) is needed for the formation of sporangia, i.e. for the infection within foliage to push out its extensions through the leaves

(b) sporangia being very vulnerable when exposed, will not undergo indirect germination i.e. the formation of zoospores, unless conditions are suitable. The time needed for zoospores to infect the host is two hours or more. Suitable conditions for indirect germination are free moisture on the leaves for up to two hours after condition (a) has been met.

(c) hours of effective blight begin on the 12th successive hour (M), i.e. after an unbroken period of eleven hours, if precipitation occurs in the interval between (M-5) and (M+3) but not until the 16th hour, i.e.after an unbroken period of fifteen hours, if no precipitation occurs between (M-5) and (M+3)

(d) if two spells with blight conditions, the first satisfying criterion (c), the second of at least 12 humid hours as in (a), follow each other, with 5 hours or less between the ending of the first spell and the beginning of the next, no lead period of 11 or 15 hours need be deducted for the second spell.

A single flush of infection from the primary lesions is very unlikely to spread the fungus sufficiently to be generally distributed in crops. It has been

found that a minimum of 3-5 generations of sporangia are needed to produce the very low blight rating of 0.1% on the British Mycological Society (B. M.S.) scale (Appendix Table 1). In general, the most seriously affected crops in this country are the main crop varieties.

In practice the issue of warnings usually commences about mid-June if needed, i.e. if suitable weather occurs and if the foliage is sufficiently mature. The early crop tends to be harvested before the main peak of the epidemic. In exceptional years, with high rainfall and long spells of humid conditions occurring early in the season, the issue of a special warning may be necessary in late May or early June.

A year of low incidence occurs when only 1 or at most 2 spells of blight weather are recorded after the appearance of blight. An epidemic Year is characterised by 2 or 3 blight spells close together, i.e. with less than 14 days separation, especially when carry over inoculum from the previous season is high.

MONITORING BLIGHT WEATHER

Hourly observations of relative humidity and air temperature are monitored from mid-April to the end of September at each synoptic station and a special report is made daily. Once a series of 12 consecutive hours meets criteron (a) of the last section the daily 'humidor' message shows the total number of hours from the beginning of the series to the termination of the spell.

The number of effective blight hours is calculated from the messages by the Agricultural Meteorology Unit and accumulated over intervals of 10-days through the season, May to September. Warnings of weather expected to be conducive to the spread of potato blight are issued as appropriate by the Meteorological Service.

SOME EXAMPLES OF POTATO BLIGHT WARNINGS

(a) The weather over the next few days will be conducive to the spread of potato blight, especially in the west and northwest. Weather conditions suitable for spraying will occur this evening and before noon tomorrow.

(b) Conditions favourable to the spread of potato blight are expected at times over the next 3 to 5 days, especially in the western half of the country. The weather today and tomorrow should be suitable for spraying.

(c) Weather conditions favourable to the spread of potato blight will occur at intervals during the week. Spells of three hours or more with good drying will occur at times.

These blight warnings are broadcast on the day of issue on the national radio service, RTE, in its main news bulletins, e.g. at 1.30 p.m. and 6.30 p.m. They are included with the relevant "live" weather forecasts from the Central Analysis and Forecast Office (C.A.F.O.). on radio and with the weather presentation on television at night. They are also included as appropriate in the recorded weather forecasts available by telephone from the C.A.F.O. and from Shannon and Cork Airports. The Meteorological Office in Belfast is advised of the warnings as are various agricultural services and experts throughout the country.

Blight warnings are usually issued sufficiently far in advance of a major blight spell for the grower to have an opportunity of spraying. As blight sprays generally protect crops for up to two weeks or more, it has been the practice not to issue warnings at intervals of less than two weeks. If a major spell of blight is imminent, however, discretion is used and the interval between warnings may be reduced below the two weeks. In the absence

of periods of heavy rain the interval between warnings may be increased beyond the two weeks.

The Meteorological Service also issues regular Potato Blight Bulletins, usually three times during the season, detailing the progress of blight spells and the reported disease levels. The latter data are obtained from weekly reports by potato inspectors in the main potato growing regions.

The principal regions for the early crop are mostly confined to counties Cork, Waterford and parts of Kerry. The main crop regions are counties Donegal, Galway and Offaly, eastern coastal counties from Louth to Wexford, and counties Cork and Kerry. The crop is grown to a varying extent in other counties.

SYNOPTIC APPROACH TO BLIGHT WEATHER FORECASTING

Forecasts of the occurrence of weather favourable to potato blight can be made using synoptic weather maps. The procedure involves relating the onset of blight weather periods to the type of meteorological situation on synoptic weather maps which gives rise to blight. Synoptic situations which are significant for blight epidemics are comparatively few and are easily recognised. Bourke (1957) identified some important blight producing situations as:

(a) a moist and usually southerly airflow of tropical origin, having dew points of the order of 16 -20^{o}C and some rain or drizzle. Extended spells of blight weather often occur in these conditions in southern and western areas and to a lesser extent in northern, north midland and eastern areas. When such moist tropical air is carried across the country by more westerly winds, the more significant spells are likely to occur in the northern and northwestern areas.

(b) the Atlantic rainbelts slow-moving off the west of Ireland and a warm moist southerly airflow with persistent fog or drizzle in southern and western areas. Eventually the rainbelts and hence the conditions favourable to blight will move eastwards. Usually southern and western regions are affected longest but all regions will be affected to some extent within a few days.

(c) stagnant or slow-moving depressions giving lengthy periods of showery or wet overcast weather. Widespread outbreaks of thunderstorms often occur, particularly in the later stages. These situations typically occur in July or August.

EXAMPLES OF SUITABLE SYNOPTIC SITUATIONS

(i) Semitropical air within a broad warm sector, having dewpoints in excess of 14°C, was steered around the Azores high during the second week in August, 1979 (Figure 1). Warm sector conditions affected southern districts on August 10th. Brighter weather developed in many areas for a spell but subsequently semitropical warm and humid air spread to all regions. Blight weather continued to affect all areas throughout the 11th and, although short clearances occurred, the spell finally terminated on the 14th and fresher, drier weather set in.

The accumulation of Effective Blight Hours in the period 10th to 14th of August 1979 is shown in Figure 1 (a). Accumulations of 50 blight hours or more were recorded in western regions and in the southwest the accumulation exceeded 90 hours. Other areas were also significantly affected, albeit to a lesser extent. Blight weather at Kilkenny was minimal during the period.

Following this period, potato inspectors reported rapid spread of the disease in western regions.

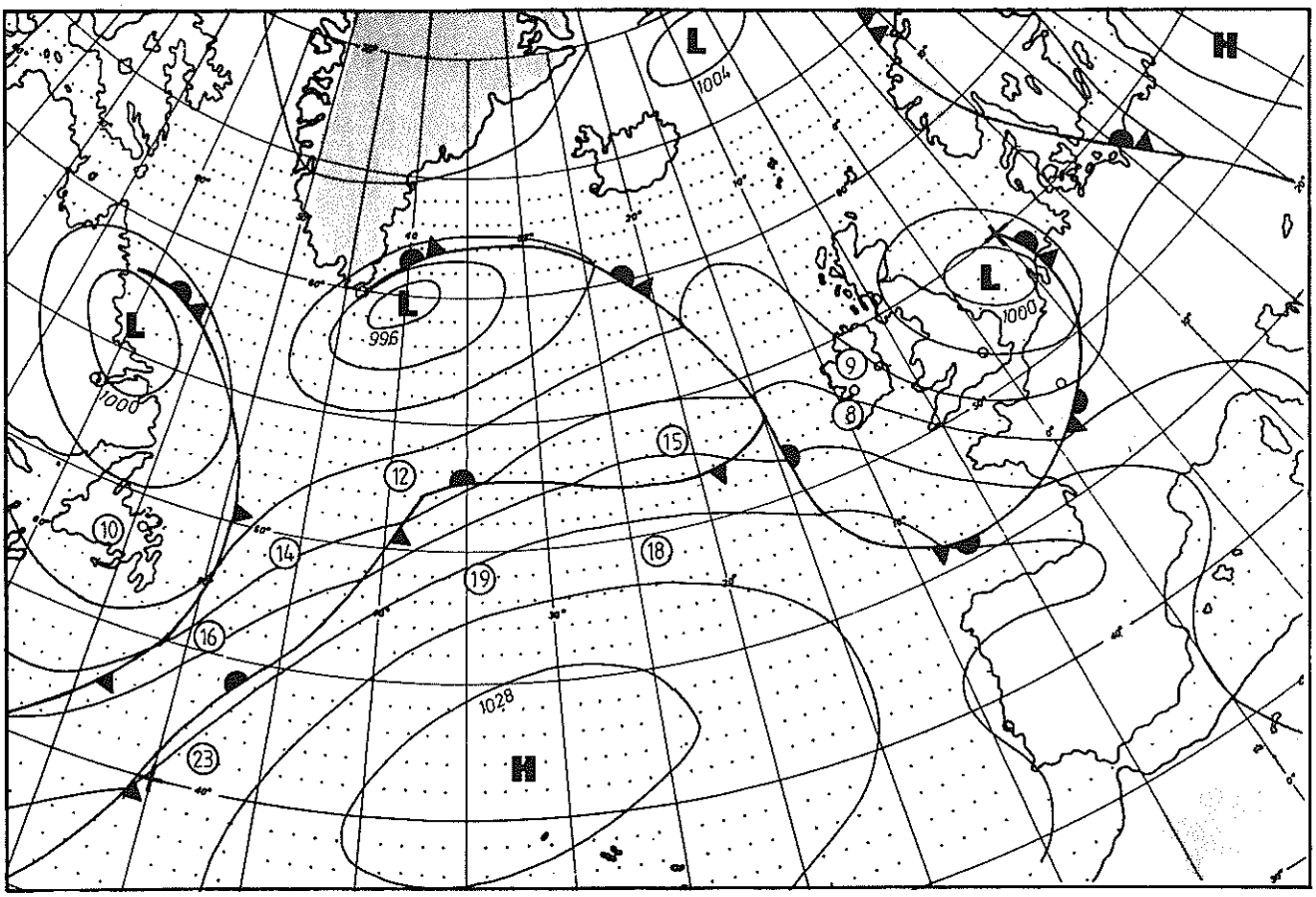

Fig. 1. Surface synoptic analysis for 1200 GMT 9th August 1979. Air mass dew points are shown in ◯

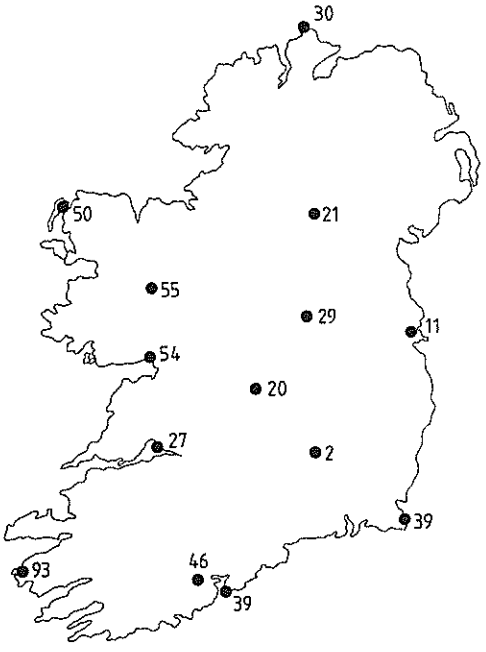

Fig. 1(a) Number of blight hours recorded August 10th - 14th, 1979.

(ii) In the second example, Figure 2, an area of low pressure had developed off the west of Ireland and a cold frontal rainbelt became slow-moving over western regions. The depression approached Ireland from the southwest on July 24th, bringing with it subtropical humid air having dewpoints of the order of 16°C. There was widespread heavy rain with very humid conditions, particularly in southern and western regions. The depression moved in over the country later and became a slack featureless thundery low (synoptic situation (c)) above. Finally the depression drifted southwestwards and a high, centred over Scandanavia, intensified over Ireland ending the most extensive blight spell of the season to July 28th.

The accumulation of effective blight hours in the spell is shown in Figure 2 (a). The accumulation exceeded 100 hours in parts of the south and 60 hours in the southeast. Elsewhere blight hours amounted to much less and parts of the midlands almost completely escaped.

Following this spell, blight was observed by inspectors in Co. Cork and in counties of the southeast to be spreading rapidly. The spread in northern counties was still slow. The level of blight in Co. Dublin was reported to be above average but following a further spell of blight weather on August 2nd/3rd its spread also became rapid.

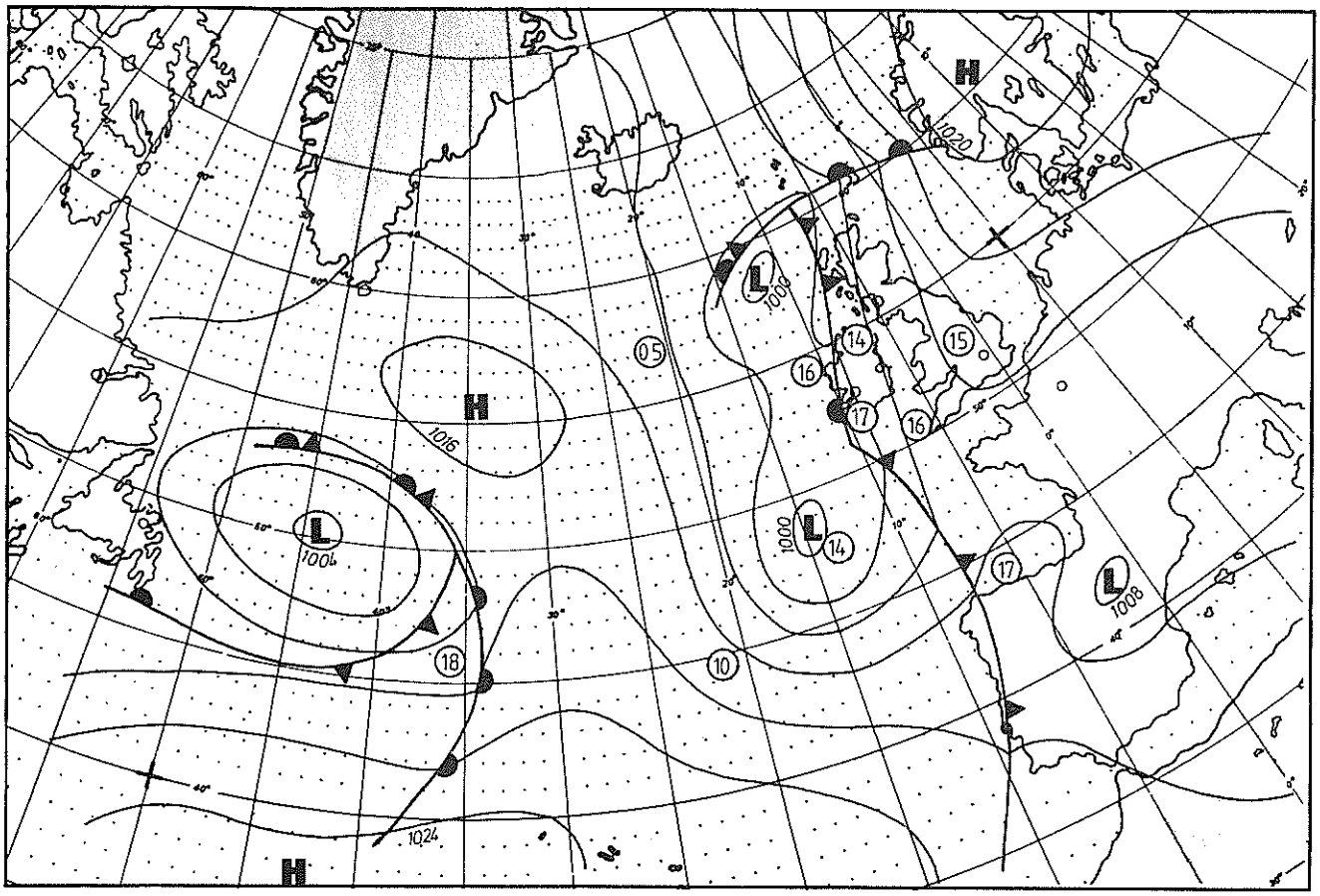

Fig. 2. Surface synoptic analysis for 1200 GMT 25th July 1980. Air mass dew points are shown in ◯

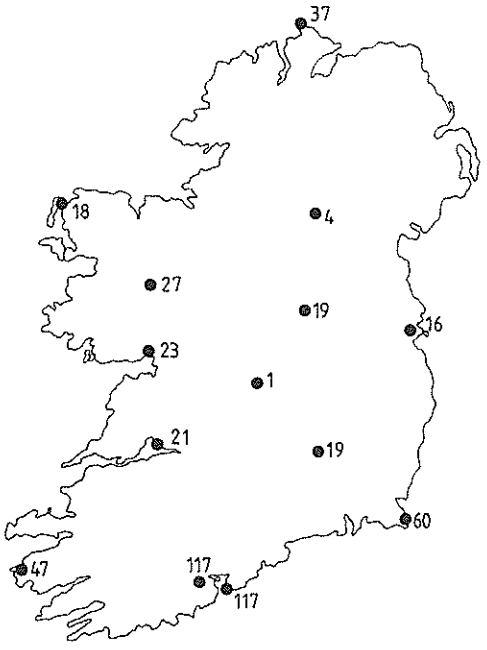

Fig. 2(a) Number of blight hours recorded July 24th - 30th, 1980.

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Part 3

AN ANALYSIS OF EFFECTIVE BLIGHT HOURS

On the basis of the Irish Rules, accumulations of effective blight hours (EBH) during the potato growing season, May 1 to September 30, have been derived by means of a computer program. Twenty five years of data were available at most synoptic stations and a shorter period at three recently established stations. The results are summarized in Tables 3 to 5 and in Figure 3.

Table 3 shows the distribution of seasonal accumulations at each of fourteen synoptic stations; Table 3 (a) gives the minimum, mean, maximum and year of maximum while Table 3 (b) gives the mean, maximum, standard deviation and coefficient of variation obtained from a slightly restricted set of data. In the latter Table, where a singularly high accumulation occurred at a station, well above the normal range of seasonal values observed there, that particular year's data were omitted from the computation. In effect this omission means that for six of the fourteen stations one year's accumulation (underlined maximum in Table 3 (a)) is omitted in deriving the parameters in Table 3 (b).

Table 3 (a) shows that accumulation of EBH over the twenty five years varied from a maximum of 919 EBH at Roche's Point to a minimum of 18 at Shannon Airport. For most stations away from the west and north, 1958 was the year with the greatest number of EBH, (Casement not being available until 1964), while the maximum at Claremorris occurred in 1960, at western coastal stations in 1970 and at Malin Head in 1964. The years with least EBH (not shown in the table) proved to be more diffuse, occurring mainly in 1968 in the west and north and in 1959 in parts of the south and midlands. Table 3 (b), because of the omission of the extreme data, shows somewhat different means and lower maxima of EBH at a

Table 3

(a) The Minimum, Mean, Maximum and Year of Maximum of Seasonal Accumulations of Effective Blight Hours (EBH), 1957*-1981.
(b) The Mean, Maximum Standard Deviation and Coefficient of Variation for a restricted period.

	(a) 1957*-1981				(b) Restricted Period (i)			
	Minimum	Mean	Maximum	Year of Maximum	Mean	Maximum	Standard Deviation	Coefficient of Variation %
Roche's Point	214	448	919	1958	427	625	141	33
Valentia Observatory	108	329	583	1970	329	583	131	40
Cork Airport	184	368	668	1980	352	479	101	29
Rosslare	162	336	740	1958	319	556	95	30
Kilkenny	27	96	331	"	86	209	39	45
Shannon Airport	18	117	232	"	117	232	52	44
Birr	20	100	187	"	100	187	43	43
Casement Aerodrome	23	78	141	1969	78	141	29	38
Dublin Airport	28	110	391	1958	98	178	39	40
Claremorris	109	265	422	1960	265	422	85	32
Mullingar	85	191	447	1958	180	280	60	33
Clones	76	183	370	"	183	370	80	44
Belmullet	111	315	557	1970	315	557	119	38
Malin Head	32	217	416	1964	217	416	97	45

(i) Data for a year with singularly high accumulation (underlined in Table 3 (a)), considered to be well beyond the normal range of accumulations for the particular station, are omitted in deriving Table 3(b).

* Cork Airport from 1962, Kilkenny 1958 and Casement Aerodrome 1964.

number of stations.

YEARLY AND SEASONAL VARIATIONS OF EBH

Considerable economic gains may be achieved from a reduced number of sprays in some seasons, if in areas where blight spells occur infrequently there is an effective warning system. A measure of the year to year variation in seasonal accumulations at each station is given by the standard deviation and the coefficient of variation. The latter parameter, which expresses the standard deviation in percentage terms of the 25-year mean, is useful to compare the relative variabilities at different stations. As seen from Table 3(b) the coefficients vary from 30% at Rosslare to 45% at Malin Head and Kilkenny and bear little relation to the magnitude of the 25-year mean. In general however, northern and south-and west-midland stations show greatest variation while stations in southern coastal areas and parts of the midlands and west, show least year to year variation. In particular, the moderately low mean accumulation of EBH and the value of the coefficient of variation at Malin Head suggest that spraying according to a reliable warning system in north Donegal, where a considerable potato crop is grown, should be more economical than spraying at regular intervals.

An analysis of the spatial distribution of EBH based on the 25-year means at synoptic stations (Table 3 (a)) is shown in Figure 3. The values used in the analysis of Figure 3, for Kilkenny, Cork Airport (height 154 m) and Casement Aerodrome, which were opened in 1958, 1962 and 1964 respectively, were derived in the following manner. The ratio was obtained between the totals of EBH at the later established station and the nearest long-term station for the entire period during which both were simultaneously in operation. The ratio was then applied to the 25-year means EBH for the latter station to estimate

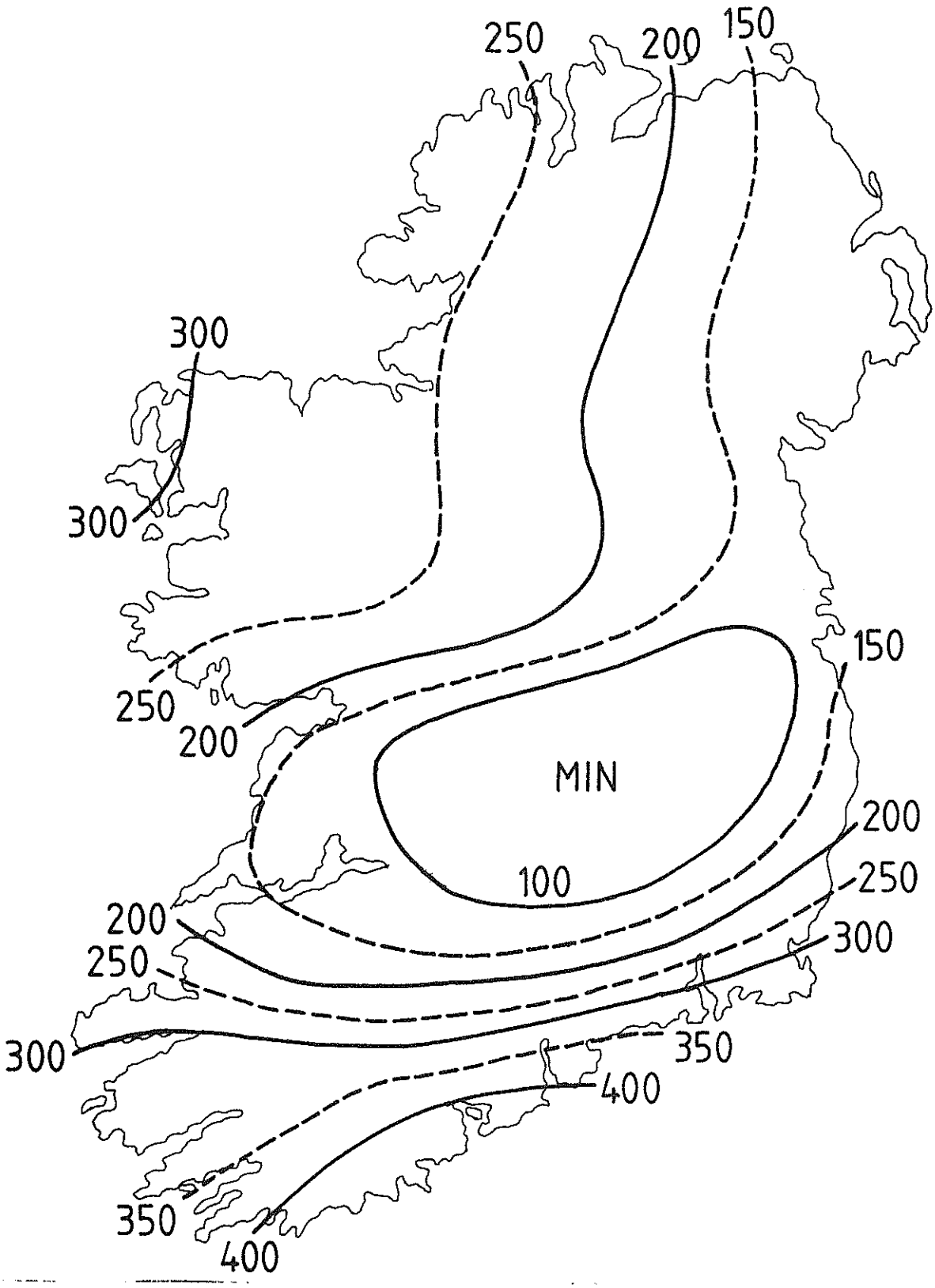

Fig. 3 Average (1957-81) accumulations of effective blight hours(EBH), May to September.

the mean value appropriate to the new station.

The isopleths show a sharp north to south gradient in the accumulations in southern regions, with increasing values towards the coasts, and an east to west gradient in the north and west. Minimum values occur in the south midlands and parts of the east. Without considering the effect of spells of heavy rain, possibly washing off the protective spray, the accumulations in the latter regions show that growers should also be able to take advantage of a reduced spraying programme. In the east, in particular, considering the relatively large coefficient of variation shown at Dublin Airport and at Casement Aerodrome, (Table 3 (b)), advantage might be gained by delaying spray operations until a warning of a blight spell had been issued.

Table 4 shows the median values of 10-day accumulations of EBH at each station over the season May 1 to September 30. (Note the last interval in the table is of 3 days only). As the year to year distribution of 10-day accumulations of EBH can be positively skewed - the majority of accumulations in any particular 10-day period being small with occasional very large values exceeding 100 EBH - median values are considered to provide a better and more representative parameter for analysis than the mean. From the table it can be seen that EBH accumulations in May are likely to be small compared to other months. A similar state also exists in June at many stations. According to the May accumulations at Roche's Point and at Valentia Observatory, which are in the principal regions where the early potato crop is grown, southern coastal areas are most likely to encounter the earliest lengthy spells. In general, the largest 10-day accumulation of the season occurs in August or September. Exceptions occur at Malin Head, where EBH peak in July,

Table 4

Median values of Accumulated Effective Blight Hours (EBH), in 10-day intervals, May to September inclusive, 1957 -81.

	May			June			July			August			September			
	1-10	11-20	21-30	31-9	10-19	20-29	30-9	10-19	20-29	30-8	9-18	19-28	29-7	8-17	18-27	28-30*
Roche's Point	4	8	9	13	19	19	25	29	20	17	29	<u>49</u>	29	<u>47</u>	23	0
Valentia Observatory	2	5	1	6	17	18	23	<u>31</u>	26	21	16	<u>29</u>	10	21	11	0
Cork Airport[1]	0	2	0	9	19	8	14	19	20	11	32	<u>39</u>	33	<u>41</u>	39	4
Rosslare	0	5	2	21	13	12	6	22	23	12	<u>26</u>	22	17	<u>29</u>	21	0
Kilkenny[1]	0	0	0	1	0	1	0	3	<u>8</u>	3	3	5	8	5	6	0
Shannon Airport	0	0	0	0	3	3	2	5	<u>8</u>	4	8	6	4	6	6	0
Birr	0	0	0	0	0	2	2	6	6	4	6	<u>7</u>	4	4	4	0
Casement Aerodrome[1]	0	0	0	0	0	2	1	3	0	3	<u>5</u>	5	3	3	3	0
Dublin Airport	0	0	0	0	0	3	1	2	2	3	<u>7</u>	5	6	6	5	0
Claremorris	0	2	0	7	5	8	12	11	22	21	<u>25</u>	22	17	<u>28</u>	20	1
Mullingar	0	0	0	3	6	6	5	11	12	10	7	16	15	<u>25</u>	8	0
Clones	0	0	0	4	4	3	6	9	10	9	6	21	17	<u>23</u>	15	0
Belmullet	0	0	0	13	13	15	19	21	<u>28</u>	18	14	21	14	<u>31</u>	19	0
Malin Head	0	0	0	4	5	4	11	21	<u>25</u>	14	13	16	4	8	5	0

* Last interval of 3 days only. Maximum and second (if 25 EBH or more) highest values underlined.

1: Cork Airport from 1962, Kilkenny 1958 and Casement Aerodrome 1964.

and at southern and western stations, where a number of peaks occur throughout the months July to September. Nevertheless, as can be seen from the minor accumulations in some 10-day periods at a number of stations, useful blight-free breaks can also occur in most years when routine application of spray may be unneccessary.

SYNOPTIC EVIDENCE FOR FIRST BLIGHT REPORTS

Frost (1974) compared the first sightings of blight in unsprayed crops at Oak Park, Co. Carlow over ten years, 1962 to 1971, with the accumulations of EBH at Mullingar and at Kilkenny, there being no hourly observations at Oak Park. All the first outbreaks occurred either in July or August. No significant correlation was found in that study between the first 'outbreak' and the accumulations of EBH starting from July 1.

In this review the data from Oak Park have been re-examined to see whether the first reports of blight could be attributed to recent major 'blight spells', which occurred shortly before the appearance of the disease. As the original reports were made once a week, and as the lesions do not appear on the foliage until three to five days following infection, EBH accumulations in the latest spells prior to the reported outbreak were examined for significance. In the re-analysis, EBH at Birr and at Casement Aerodrome were also included. Thirteen outbreaks were reported in the ten year period.

In general, weather conditions conducive to the spread of blight were found to occur in at least two stations on the same occasion. Most frequently, in 9 out of 13 reports, conditions at Mullingar, in addition to one or more of the other stations, reflected the general situation at Oak Park. Suitable conditions were widespread on one occasion and affected all stations simultaneously. A

wide range in the accumulations of EBH occurred between stations either in the preceding or concurrent (with the blight observation) ten-day interval. In five of the observations the maximum ten-day accumulation ranged from 25 to 40 EBH while on five other occasions accumulations ranged between 10 and 15 EBH. For three of the observations accumulations were of the order of 5 EBH.

The present analysis of the data at Oak Park did not seek to derive a precise relationship between prior accumulations of EBH and the observed level of blight that followed, the latter being mostly 0.1% of the BMS scale. Nevertheless it was apparent that out of the preceding accumulations a peak spell could usually be identified in association with a particular synoptic system, which affected the area a few days prior to the observed outbreak of blight. In these particular spells values of between 3 and 7 EBH were recorded at synoptic stations. On one occasion, however, following a spell of more than 20 EBH, only 0.1% blight level was reported.

It may be inferred from the above cases with some degree of confidence that, once an initial level of infection has developed in a crop, a low level of blight is likely to ensue from synoptic situations giving rise to about 5 EBH.

In two of the examples in the survey a level said to be 1-5% was reported following major spells of 23 EBH and 27 EBH in the previous ten days. As such a major blight spell is likely to result from a substantial accumulation of EBH over a single unbroken period or over a period of several days with interrupted conditions, 10-day totals are considered to be a useful measure to approximate the duration of a spell of this magnitude or greater. For the purposes of this study, therefore, it is assumed that where 25 EBH or more occur over periods of ten days or less, a significant development in blight is

likely to follow in unprotected crops, probably resulting in a serious loss in final crop production.

Table 5 shows the number of years out of twenty in which each fixed-ten-day total equalled 25 EBH or more through the season. The highest frequency is found to occur at stations in the south and southwest, where the return period in the interval from July to September is often less than two years. The frequency is greatest in July at Malin Head but for stations in the west and north midlands maximum frequency occurs in late August or September. The table shows that in order to achieve maximum yields, where feasible, spraying programmes could usefully be continued into September. On the other hand, where growth is considered to be complete, the importance of burning off the foliage, to avert the risk of tuber infection, is also clear from the table.

THE LOCAL AND ECONOMIC FACTORS

Frost (1975) found that spraying according to a warning system was generally effective but that in the wetter areas of the west and north routine spraying might be best, due to the greater risk of tuber infection. She also found that high rainfall in each of the months April to August was associated with low yields of marketable tubers. Rain in June and July had a particularly adverse effect. Somewhat similar results have been found in other countries. Utrata (1980) in Poland, showed that, while the primary factor affecting the intensity of potato blight was relative humidity during July and August, precipitation was important in July where soils were adequately supplied by water but not important in dry soils. Hutchinson (1974) in Northern Ireland concluded that in wet weather or in weather conducive to blight, spraying should be undertaken once every ten days but that in dry periods the sprays need not be renewed until the weather once again became suitable for the development of

Table 5

Number of years out of 25, (1957-1981), in which Effective Blight Hours (EBH), accumulated in 10-day intervals, May 1 to September 30, equalled or exceeded 25 hours.

	May			June			July			August			September			
	1-10	11-20	21-30	31-9	10-19	20-29	30-9	10-19	20-29	30-8	9-18	19-28	29-7	8-17	18-27	28-30*
Roche's Point	4	6	8	8	8	9	14	12	12	9	15	17	14	18	11	5
Valentia Observatory	1	3	4	3	7	9	11	12	10	8	8	13	8	8	5	1
Rosslare	2	2	5	8	7	4	9	12	12	6	14	12	9	14	10	3
Shannon Airport	0	1	0	0	0	1	5	5	3	4	6	2	3	3	3	0
Birr	0	0	0	0	1	0	2	2	2	1	2	3	4	3	3	0
Dublin Airport	0	0	0	1	4	1	1	6	1	1	5	5	3	5	2	2
Claremorris	0	1	0	3	5	3	6	8	13	10	13	12	10	17	10	2
Mullingar	0	0	0	4	3	1	3	7	7	5	8	6	8	13	5	1
Clones	0	0	1	2	5	0	4	7	5	3	6	11	10	12	6	2
Belmullet	0	3	3	7	5	7	10	11	15	10	10	12	8	14	11	0
Malin Head	0	0	1	2	5	4	8	12	13	10	6	8	4	6	1	1
	Stations opened after 1957															
Kilkenny(24)[1]	0	0	0	2	0	0	1	2	3	2	2	4	5	3	2	2
Cork Airport (20)[1]	1	2	1	5	9	4	8	8	8	6	13	13	12	16	12	4
Casement Aerodrome (18)[1]	0	0	0	0	1	0	1	4	0	2	2	1	1	2	1	0

* 3-day interval. 1: Duration (years) in brackets.

the disease.

It appears from Tables 3 to 5 and from Figure 3 that substantial economic gain could be achieved from a reduced number of applications in some years by spraying according to a reliable warning system. In regions where the seasonal and 10-day interval accumulations are small and show little variability from year to year, spraying may not be necessary except in advance of a real threat of an imminent significant blight spell. Where the year to year variability is high it seems likely that in many years considerable economies in material and labour could still be achieved using a reduced number of sprays, applied only when a blight spell is forecast. In areas with regular high seasonal accumulations, having a high frequency of major blight spells (Table 5), i.e. a low variability from year to year, routine spray applications may be best in most years. However, if the year to year variability is intead high, routine spraying may be unnecessary and a programme based on a warning system would be justified.

Some 40,000 hectares of potatoes are grown in the twenty six counties annually. Routine spray application, seven per season with a 14 day or more interval from mid June at a cost of £10 per ha per application, amounts to some £2.8 million. Assuming an initial spray and with 3 to 4 major blight spells in a year, which has been the average number at most inland stations over the past 10 years, a spraying programme based on the Meteorological Service warning system would show an annual saving of approximately £1 million in materials in addition to savings of about a similar amount on equipment and operator time. Considerable losses might also be averted by a warning service as farmers would be made aware of the imminent risk to their crop, if unprotected.

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APPENDIX

TABLE 1

BRITISH MYCOLOGICAL SOCIETY RATING SCALE

Blighted foliage (%)	Description of blighted foliage
0	Not seen on field
0.1	Only a few plants affected here and there: up to 1 or 2 spots in 11 metre radius.
1	Up to 10 spots per plant, or general light spotting.
5	About 50 spots per plant or up to 1 leaflet in 10 attacked.
25	Nearly every leaflet with lesions, plants still retaining normal form: field may smell of blight, but looks green although every plant is affected.
50	Every plant affected and about $\frac{1}{2}$ of leaf area destroyed by blight: field looks green flecked with brown.
75	About 3/4 of leaf area destroyed by blight: field looks neither predominantly brown or green. In some varieties the youngest leaves escape infection so that green is more conspicuous than in varieties like King Edward, which commonly shows severe shoot infection.
95	Only a few leaves left green, but stems green,
100	All leaves dead, stems dead or dying.

Notes: In the earlier stages of a blight epidemic parts of the field sometimes show more advanced decay than the rest and this is often associated with the primary foci of the disease. Records may then be made as, say 1 + pf 25, where pf 25 means 25% in the area of the primary foci.

Make successive assessments at intervals of 7 to 14 days to record progress of blight. Begin in good time as both nil and starting date records (0.1%) are important. Difficulties in judging allowance to be made for stem-blight on a particular date are overcome by making another assessment later. (Source: ADAS, Britain).