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PHYSICAL AND ECONOMIC OPTIMA IN SOWING DENSITIES OF SPRING BARLEY IN SCOTLAND

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by

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The work presented in this thesis is the result of my own investigations and has neither been accepted nor is being submitted for any other degree.

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PREFACE

In general, studies on the patterns of innovation in industry and agriculture have described innovations that have already occurred (McCarthy, 1971). Although these studies are useful in describing the characteristics of innovations, they have not, themselves, formed part of the adoption process of any innovation.

The analysis contained in this thesis involves the collection of evidence that would assist in the adoption process of a simple innovation in agriculture. The innovation proposed is the reduction in sowing densities for spring barley, which could lead to savings in costs.

The evidence is both technical and economic and the arguments are set against the background of barley production and marketing, both of seed and grain, with particular reference to Scotland. Projections are made into the likely effects of some developments in the industry and the crop, and the possible future savings from density reductions are calculated.

The analysis is intended not only to provide information on a specific agricultural problem but to illustrate an approach to agricultural management involving both technical and economic appraisals.

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Section I

A description of the current theories on the adoption of innovation in agriculture is included, showing the importance of economic argument in the adoption process. The analysis presented in this thesis is considered as an example of a possible innovation in farm practices.

Chapter 1

INNOVATION IN AGRICULTURE

1.1 A definition of innovation

Barnett (1953) (vide: Jones, 1963) defines innovation as 'any thought, behaviour or thing that is new because it is qualitatively different from existing forms'.

Carter and Williams (1957, p.15) go further and distinguish two steps in the innovatory process: invention, the creation and development of a new idea, and innovation, the act of bringing the invention into practical use. McCarthy (1971), however, includes both steps in a single definition developing far beyond the invention:

"Innovation originates with the recognition that an opportunity exists or that a problem may be resolved. The process of elaboration which produces a practicable and adopted solution to the problem, or continues until the opportunity originally perceived has been grasped, comprises the innovative process".

This chapter will look at the sources of innovation, the adoption process, the characteristics of innovation, and the communication of possible innovations in the agricultural industry. An example of a possible innovation will, also, be presented, with which the following chapters will be concerned.

1.2 Sources of innovation in agriculture

The pre-requisite for innovation, that is the invention, or new idea, and its development, in the agricultural industry generally comes from outside the individual units of the industry, the farms. Agriculture, in effect, is comprised of many small firms, which, because of their size are incapable of supporting research and development staff (Carter and Williams, 1957).

Research and development for the industry is taken up by Government establishments, the research and development units of commercial firms, and by farmers' unions, which often stimulate marketing innovations (Thomas, 1954; Wright, 1966).

Therefore, the farmer is not directly concerned with the discovery and development of a new idea. His part in the innovatory process is as the possible adopter.

1.3 <u>The adoption process</u>

Three stages in the adoption of hybrid corn in two Iowa (U.S.A.) communities were recognised by Ryan and Gross (1943): awareness of the innovation, conviction of its usefulness by a trial and final adoption. However, Beal and Bohlen (1957) (vide Rogers, 1963a; Jones, 1967) expanded the number of stages involved in the process to five: awareness, interest, evaluation, trial and adoption. This is now generally accepted as being the probable nature of the adoption process.

<u>Awareness</u>

Awareness is the stage when the individual is exposed to the innovation but lacks complete information about it (Rogers, 1962). The awareness may depend on the recognized need for an innovation, or the awareness may create a need for that innovation.

<u>Interest</u>

At this stage, the farmer will actively seek further information about the new idea. This may depend greatly on his personality and on his need for the possible innovation (Rogers, 1962) (Chapter 1: 1.4).

Evaluation

The evaluation of a new idea is the mental application of that idea to present and anticipated future situations, and upon which the individual decides to run a trial. Jones (1967) recognizes two basic evaluation characteristics: socio-technical, which is the adopter's perception of the newness and complexity of the innovation, and socio-economic. He notes that the 'economic characteristics of any farm practice influences its adoption', although he recognizes that social factors may considerably modify the importance to the farmer of the economic considerations. Ryan and Gross (1950) found, in a survey of the adoption of hybrid corn in Iowa, that the decision to use the new seed was primarily economic; the new corn was a 20% better yielder than the standard cultivars. But there were distinct sociological and psychological forces influencing the economic judgements, and consequently affecting the rate of adoption (Chapter 1: 1.4).

Trial

In the trial stage the farmer uses the innovation on a small scale in order to determine its worth in his own situation, and thus its usefulness for complete adoption. Ryan and Gross (1943) found that although a great deal of testing had been undertaken, Iowa farmers nearly always ran their own trials before adopting the new hybrid corn. Rogers (1962) considers that the results of these trials are very important in the adoption-rejection decision.

Adoption

The farmer is considered to have adopted an innovation when, following his trial stage, he has decided to generally utilize the innovation. In the Iowa hybrid corn case, the length of the adoption period from awareness to complete adoption averaged nine years per grower (Ryan and Gross, 1943), of which 3.5 years were from the trial to 100% use, and was influenced by the availability of inbreds.

1.4 The rate of adoption

The rate of adoption is dependent on two factors: the characteristics of the innovation and their effects on the possible recipients, and the attitudes of the recipients of the new ideas to innovation in general.

Characteristics of innovations, and their effects on adoption

Rogers (1963b) noted five characteristics of innovation which affected the rate of its adoption. He surveyed particularly the adoption of 2 - 4D weed killer in the Mid-West (U.S.A.).

(i) Relative advantage - there may be an economic or convenience advantage. Grilliches (1960) found that the rate of hybrid corn acceptance in the Corn Belt and the South (U.S.A.) was dependent upon the profit farmers expected to realize from the shift from the old standard cultivars to the new hybrids. He also noted that the rate of adoption was much quicker in the Corn Belt, because the expected profits were higher than in the South, and the commercial pressure was greater.

Tully, Wilkening and Presser (1946) looked at the rates of adoption and diffusion of a herbicide, and of artificial insemination. They studied the effect of three adopter goals on the rate of adoption of the herbicide: extra convenience, economic benefits and visibly 'doing a better job'. The ratio of adopters to non-adopters was found to be three times as great when the practice was seen as an extra convenience, than when seen as inconvenient; four to eight times as great when seen to be of economic benefit rather than of no benefit, and seven to nine times as great when seen as 'doing a better job'. In the case of artificial insemination, there was a four and a half times as great an adoption ratio when the practice was seen as convenient, but a knowledge of the economic benefits resulted in an eleven times as great an adoption than a lack of economic knowledge.

(ii) Compatibility - the consistency of the innovation with current values. Jones (1963) recognizes that if a new practice is relatively compatible with the current practices of the adopter, then the innovation's adoption and diffusion is generally more rapid.

(iii) Complexity - Rogers (1963b) found that the herbicide 2-4D was considered by many farmers to be a complex innovation as it required calibration and other skills, and consequently this slowed its adoption rate and diffusion. Jones (1967) noted that simple changes in material or equipment which may require little mental activity, were much more readily adopted than improved practices, when a change may be relatively more difficult to understand. He further considered (1972 - personal communication) that a saving in cost with little visible benefit could be considered as a 'negative advantage', which would be considered a rather complex idea, with a consequently slower acceptance.

(iv) Divisibility - 'take it or leave it' ideas are more difficult to accept by farmers (Rogers, 1963b) than changes which can be tried on a small scale first. Ryan and Gross (1950) found, in hybrid corn adoption, that the divisibility of the innovation allowed for small scale trials to be undertaken with ease. As it had distinct economic benefits, obvious from simple trials, it was relatively quick to spread, and as it did not require a 'speculative or dramatic decision' from the grower, even the most conservative growers were able to try the corn without much risk.

(v) Communicatability - the degree with which an idea can be communicated to others. Rogers (1963b) noted that innovators found it difficult to convince neighbours of the benefits of using 2-4D weed killer because the chemical was sprayed on the crop before the weeds emerged. The lack of conspicuousness of an innovation has been pointed out (Jones, 1963) as a distinct disadvantage to rapid adoption and diffusion. Burr (1960) noted that material changes had a relatively quick adoption, but method changes, or practice changes, took much longer because of the less visible benefits.

Wilkening (1961) (vide: Sheppard, 1963) summarized the characteristics of an innovation that were required for rapid adoption as: little cost required, little change involved, quick returns available, and that it was simple and easily taught.

<u>Characteristics of the adopters, and their acceptance of innovation</u>

Five types of adopter have been proposed by Rogers (1963b): innovators, early adopters, early majority, late majority and laggards. He suggests that there is a trend in social status in the same order, the innovators being of the highest social orders. They are generally also the largest, wealthiest and most specialized growers, and are generally the younger farmers. Sheppard (1963) and Gane (1972 - personal communication) also noted that the younger farmers are generally the earlier adopters. Further, Jones (1963), in a study of fifty-five mid-Cardiganshire farmers, found a very highly significant relationship between the level of adoption of a number of innovations and the farmers' total income, socio-economic status, farming type and acreage. Lower levels of adoption were found amongst poorer, older and more isolated farmers. In fifty two East Midland mixed type farms, Jones (1963) noted that the early adopters were generally younger, although not always so, and with a relatively high standard of education, and with good contacts in the advisory services and with other innovators. He further found (1967) that an experience of 'urban' life was related to innovativeness, as were a higher social status (that is, a cosmopolitan social life), entrepreneurial activity and achievement motivation characteristics. Innovators also make more use of specialized literature, travel widely and generally have a wider range of farming acquaintances.

However, the rate of adoption is not only influenced by the character of the individual but also by the farming community of which he is a part. Jones (1967) pointed out that an environment which is favourably disposed towards change and innovation may be more capable of accepting further innovations than an environment of mixed views. This has been confirmed by Bradner and Strauss (1959), who noted that the uptake of hybrid corn in Kansas was faster in areas where hybrid sorghum had been grown than in areas where non-hybrid crops were grown.

1.5 The communication of innovations

The pace at which an innovation is diffused is a function of its communication, that is, the informing of potential users of its availability and characteristics. The communication, in order that it may be accepted, must present the innovation in the form which is most attractive to the potential users. Dodd and Osborne (1958) realized that to encourage the adoption of an improved practice there was 'a need to define the factors which farmers may regard as of prime importance in connection with any new techniques; these may be technical or managerial, and are always likely to be economic in the long run'.

The importance of the economic consideration was stressed further by Osborne (1961) and Jenkins (1963) who noted that the National Agricultural Advisory Service (N.A.A.S.) concentrated on the economic implications in their literature and advice on innovations. Dodd and Osborne (1958) had shown the effectiveness of presenting economic data in leaflets in a 1956 survey of 150 farmers in Cambridgeshire. One group were given a leaflet that showed that a change from Hybrid 46 to Cappelle wheat would give an 8% better yield and an extra profit of £4 per acre. The other group did not get the special leaflet. By 1957, the proportion of Cappelle had risen from 41% of the total acreage to 65% on farms not receiving the leaflet, but to 77% on farms receiving the leaflet. The difference between the two groups was significant.

Although hybrid corn in the U.S.A. had a markedly superior economic potential compared with standard corn, Ryan

(1948) noted that it still required an energetic sales promotion, stressing those economic benefits.

However, the acceptability of an innovation, even with strong economic arguments may still be poor. The Pea Growing Research Organization (P.G.R.O.) showed substantial yield benefits from a number of trials on vining peas, from higher plant population than were in current use. Gane (1972 - personal communication) found that many growers failed to take advantage of the P.G.R.O.'s discovery because of the resistance against having certain higher seed costs, although there was a possible increase in profitability. Further, if the growers who undertook trials did not have immediately obvious benefits then they tended to reject the innovation, and were difficult to re-convince.

Sheppard (1961) found that grassland farmers continued to refuse to adopt an innovation even if they were unable to provide a sound reason for not doing so; whilst Rogers (1963b) found that tobacco farmers were loathe to change to more profitable cucumber growing because they considered it 'feminine'.

Thus resistance to change is often difficult to overcome. However, advisory services in Britain stress the economic and managerial benefits of innovations as being the most successful forms of persuasion (Jenkins, 1963).

1.6 The proposed innovation: a reduction in sowing densities in spring barley in Scotland

Boyd (1952) and Holliday (1960) reviewed a large number of trials in England and Wales on the relationship between the sowing density and grain yield of spring barley (Chapter 6:6.2).

Boyd (1952) found that the physical optimum sowing density, from his review, was 1.0 cwt per acre, whilst 1.5 cwt per acre was commonly used in Britain. Holliday (1960) noted 1.25 cwt per acre to be the physical optimum sowing density; however, as the seed became more expensive then the economic optimum sowing density dropped to well below the physical optimum.

However, although considerable reductions in sowing density have been shown experimentally to be possible, and an economic argument has also been presented, there is evidence to suggest that in Scotland there has been little reduction in sowing densities since. Britton (1969) in a survey of cereal growing in the United Kingdom found an average sowing density, on Scottish farms surveyed,of 1.65 cwt per acre, well above Boyd's (1952) suggested physical optimum.

Jones (1967) has pointed out that two basic factors influence the uptake of an innovation: socio-technical and socio-economic. That is the innovation must be technically understood and understandable, and a strong economic argument has a great influence on its adoption. It must be presumed, therefore, that barley growers in Scotland have not been convinced either technically or economically of the benefits of a reduction in their sowing densities. Boyd (1952) and Holliday's (1960) results were based on observations of English experiments, but no equivalent reviews have been undertaken on Scottish experiments, nor has there been any detailed experimentation on the physical relationship of plant density and grain yield under Scottish conditions. Therefore, the Scottish growers may not have had a sufficient technical stimulus to lower their sowing densities. Further, as Jones

(1967) has pointed out, there must be an economic stimulus for the acceptance of an innovation. Holliday's (1960) economic suggestions were based on English experiments, but no similar suggestions have been made based on Scottish data.

Therefore, two basic factors stand out that may have prevented a lowering of the sowing densities in current use in Scotland: firstly, that insufficient technical data has been presented to the growers, and, secondly, that there has not been a sufficiently strong economic argument that advocates that growers change their practices.

The following chapter will look at the sowing densities currently in use in Scotland, and will present detailed experimental results, and review all available Scottish field trial data, on the sowing density/yield relationship for spring barley under Scottish conditions. An economic analysis will be presented of the technical data accumulated in the light of current and future seed costs, from which recommendations will be made concerning the potential economic optimum sowing densities for spring barley in Scotland.

Section II

This section serves as an introduction to the technical and economic analyses presented in the following sections. A description of barley growing with particular reference to Scotland is presented, along with a summary of seed quality control methods in current use. Additionally, current barley growing practices in Scotland were examined by means of postal surveys, and the results of the surveys are analyzed and discussed in this section.

Chapter 2

PRODUCTION AND MARKETING OF BARLEY IN GREAT BRITAIN

2.1 Barley growing in Great Britain

In 1879, the area of land under barley in Great Britain reached 2.7 million acres, which at that time was the largest acreage ever grown. In that year it rained throughout the summer resulting in a disastrously late harvest. 'From that year the decline was almost continuous ..... until 1933, when barley was down to 0.8 million acres' (M.A.F.F., 1968, p.35) (Figure 2.1.a).

The wartime deficiency payments (Chapter 2:2.7) stimulated barley growing, and by 1945, 2.2 million acres were being grown. An unprecedented increase followed in the fifties, and by 1966 the barley acreage reached 6.13 million acres, or 50.2% of all crops and fallow land (tillage) and 20.8% of all the crops and grassland in Great Britain (M.A.F.F., 1968, p.36).

Since 1966, there has been a fall in acreage to 5.54 million acres in 1970, but barley still accounted for 45.8% of the total tillage and 18.0% of all the crops and grassland in Great Britain (D.A.F.S., 1971).

The decline in barley growing from 1879-1933 was accompanied by an increase in oat acreages, which reached 4.0 million acres in 1918 and 3.7 million acres in 1942, and did not fall below 2.0 million acres until 1958. In 1956, barley overtook oats for the first time since 1879 (M.A.F.F., 1968, p.36) (Figure 2.1.a).

The increase in the popularity of barley occurred for several reasons. Firstly, there had been a general increase in the demand for cereals largely because of an increase in the numbers of livestock in Great Britain since 1945 (M.A.F.F., 1968, p.122-129).

Secondly, although yield increases occurred in all three major cereals because of the greater use of fertilizers and

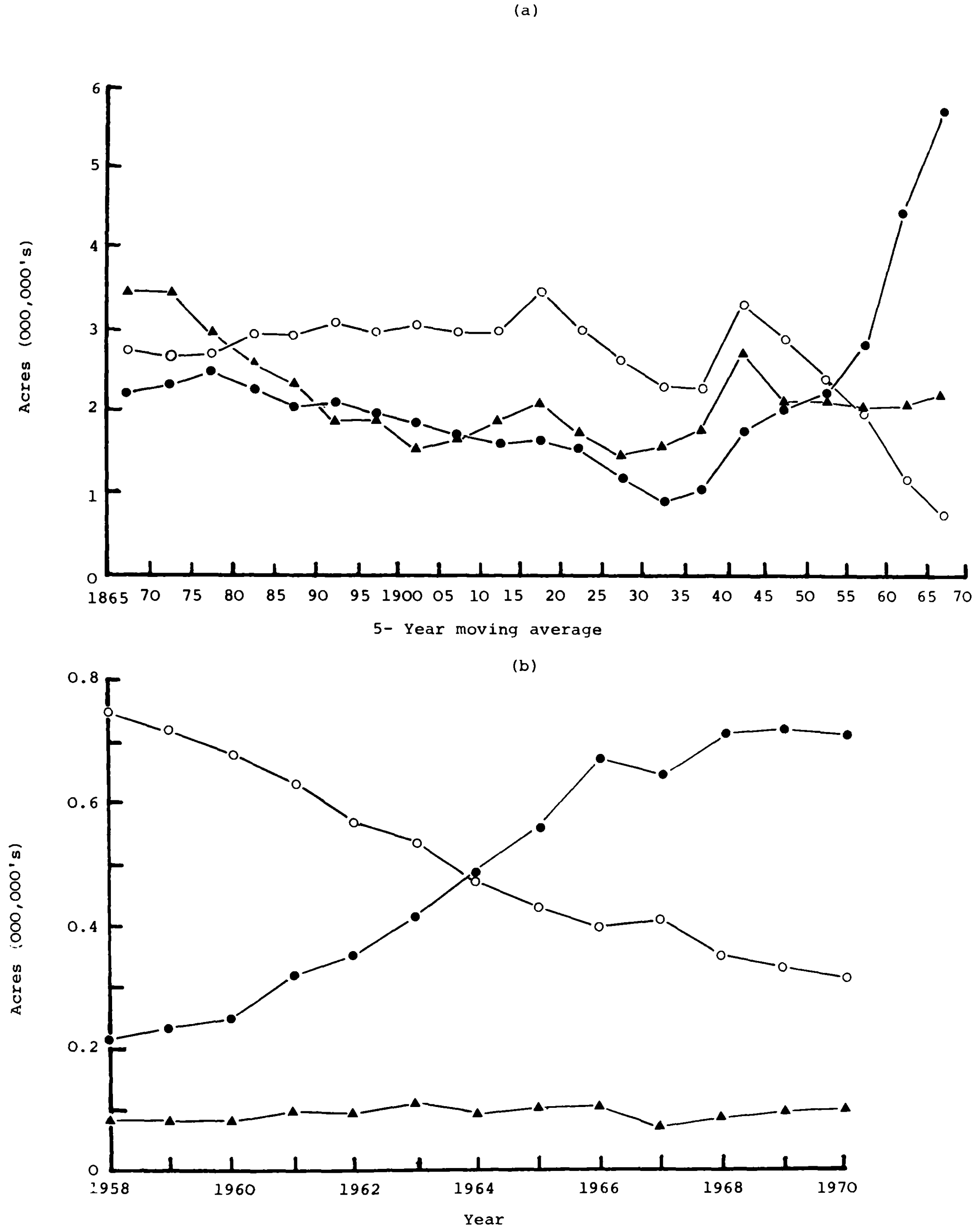


Fig. 2.1 (a) Cereal acreages in Britain from 1865 to 1970. Five year moving averages calculated from annual figures. (b) Annual cereal acreages in Scotland from 1958 to 1970.

Barley = ● , oats = ○ ,wheat = ▲

Source: M.A.F.F. (1968; 1970; 1971)
D.A.F.S. (1970; 1971)

herbicides on improved cultivars, the increases in barley yield were especially high, particularly in comparison with oats (Figure 2.2.a). This stimulated a shift from oat to barley growing. Barley was also preferred to oats as an animal feed-stuff because of its higher nutritional value (Britton, 1969, p.25).

New barley cultivars and better husbandry techniques enabled barley to be grown more economically in areas formerly thought more suitable for oats (Britton, 1969, p.24). Furthermore, there was a significant post-war movement towards using cereals as cash-crops rather than feeding on the farm, which in the case of barley includes malting and feed compounding, whereas the oat market is much more restricted (Britton, 1969, p.25).

Production was further stimulated by Government policy towards agriculture (Chapter 2:2.7) including guaranteed prices and husbandry aids, such as lime and fertilizer subsidies (Britton, 1969, p.24).

2.2 Barley growing in Scotland

Before 1879, oats had been the dominant crop in all the Scottish counties (M.A.F.F., 1968, p.A) except Fife and East Lothian where barley was equally important. It was not until 1964 that the barley acreage surpassed that of oats for the first time (M.A.F.F., 1968, p.36) (Figure 2.1.b), some years later than in Great Britain as a whole (Figure 2.1.a).

By 1970, barley was grown on 707,987 acres of land in Scotland (D.A.F.S., 1971) or 48.2% of the tillage and 17.0% of all the crops and grassland; oats had dropped to 309,353 acres or 21.0% of the tillage. Oats had retained its dominance in eight Scottish counties, six of which are designated 'crofting counties' (D.A.F.S., 1971, p.20).

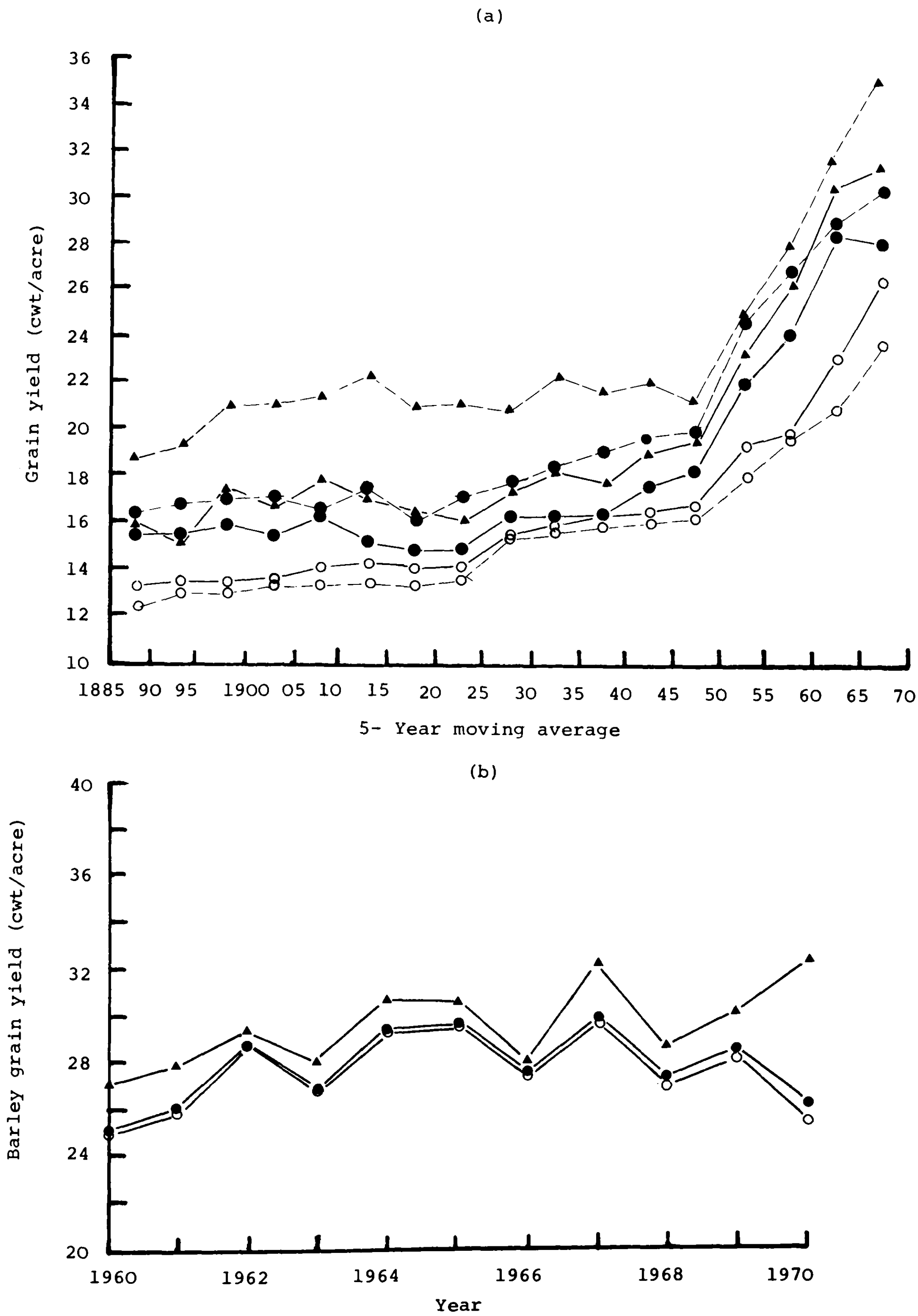


Fig. 2.2(a) Average cereal grain yields (Barley = ● , oats = ▲ , wheat = ○) from 1886 to 1970. Five year moving averages calculated from annual figures for Great Briatin (-) and Scotland (---). (b) Average barley grain yields from 1960 to 1970 for Great Britain (●), England and Wales (○) and Scotland (▲).

Source: M.A.F.F. (1968; 1970; 1971)
D.A.F.S. (1970; 1971).

The crop in Scotland is concentrated towards the eastern coast of the country, from Berwickshire to Nairnshire (Figure 2.3), although there are concentrations in Ayrshire and Galloway. This pattern of distribution arises because suitable arable land is more available in the east (M.A.F.F., 1968, p.10) and the drier and warmer summer season of the east coast assists production.

2.3 The production of barley grain in Great Britain

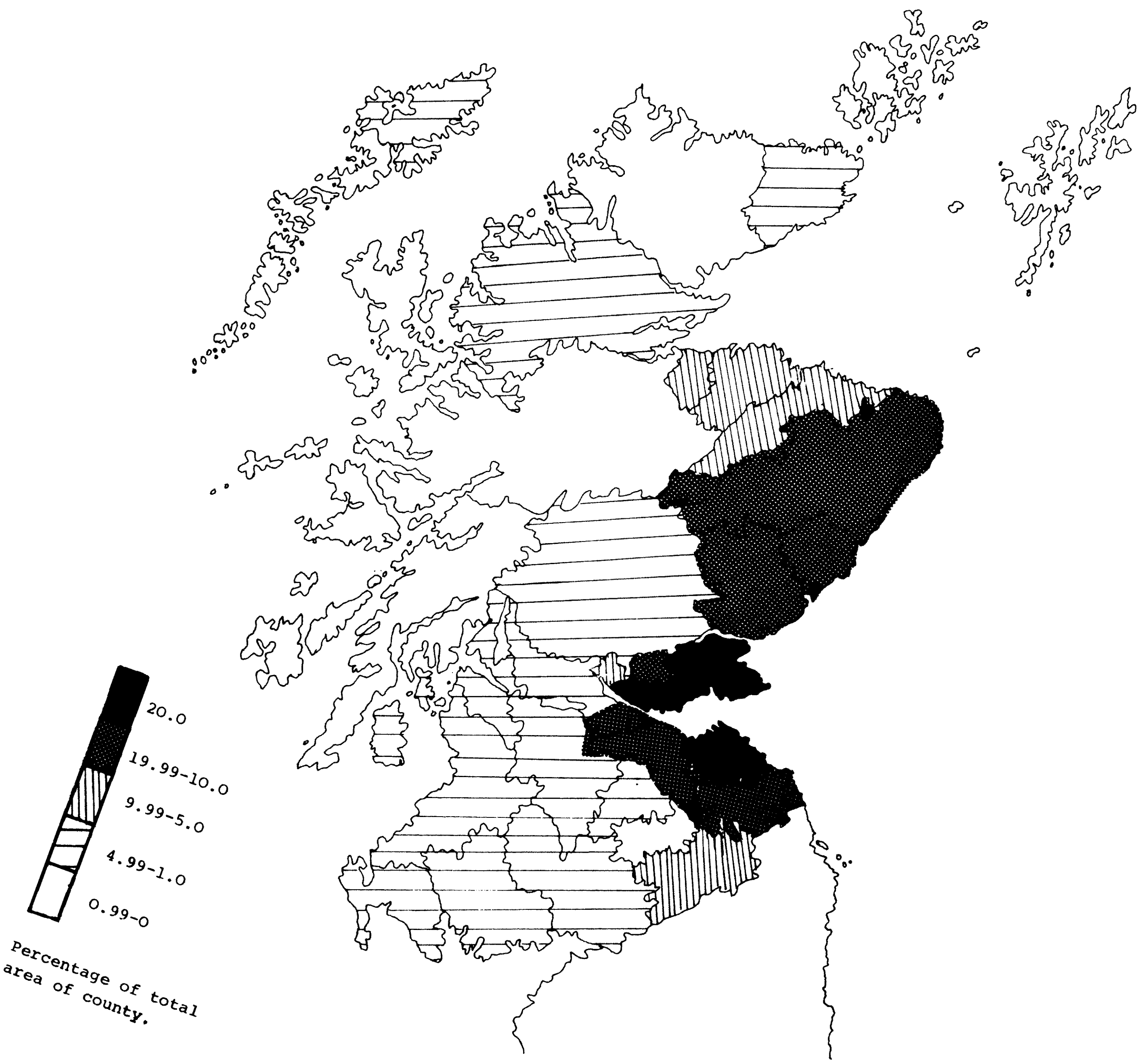
The average yield of barley grain (Figure 2.2.a) did not exceed one ton per acre until between 1945 and 1950. However, it has increased rapidly since then, so that the increase in production (Figure 2.4) has been greater than the increase in acreage over the past twenty years. By 1966, over 30 cwts per acre average yield had been attained, and the estimated average for barley in England and Wales in 1972 (Campbell, 1972) is 31 cwts per acre.

The greatest total production of barley grain yet attained in Great Britain was reached in 1967 when 8,870,000 tons of grain were produced. By 1970, this figure had fallen to 7,221,000 tons (Figure 2.4) which seems to have been due to both a drop in the total acreage grown (D.A.F.S., 1971) and to a fall in average grain yields (Figure 2.2.b).

2.4 The production of barley grain in Scotland

Scotland has followed the general pattern in Great Britain with an increase in grain production since 1959, 1,157,000 tons of grain being produced in 1970 (Figure 2.4); the largest amount ever produced in Scotland. Scotland has not followed the rest of Great Britain in the drop in production since 1967 (Figure 2.4) because the average grain yields continued to increase (Figure 2.2.b), and the total acreage grown in

Fig. 2.3 Barley acreages in Scottish counties in 1970 (percentages of total area per county), from D.A.F.S. (1971) statistics


20.0
19.99-10.0
9.99-5.0
4.99-1.0
0.99-0
Percentage of total area of county.

Scotland did not start to fall until 1970 (Figure 2.1.b).

The average grain yields have generally been higher in Scotland than in the rest of Great Britain (Figure 2.2.b) and by 1970 had attained 32.7 cwts per acre. The estimates for 1972 (Amey, 1972) suggest the highest ever average grain yield for Scotland, East Lothian crops averaging over 35 cwts per acr and 45 cwts per acre being commonly reported.

Spring barley is far more popular than winter barley in Scotland, where winter barley only reaches 4% of total barley seed sales where it is at its most popular, in the counties of Berwickshire and Roxburghshire (Table 2.1). This contrasts with some English counties where winter barley has reached more than 20% of total barley seed sales (Darlington, 1968/9).

Table 2.1 Sales of winter barley in Scottish counties as a percentage of total barley sales, 1968/9

Counties	Percentage of sales
Stirling-, Dumbarton- and Renfrewshire ..	1
Perthshire	2
Fife and Kinross-shire	0.5
Berwick- and Roxburgh-shire	4
Angus-shire	0.5
Aberdeen- and Kincardine-shire	0.5
East Lothian	No figures
All other counties	0

Source: Darlington (1969).

Britton (1969, p.83) suggested that the advantages of winter barley are much more open to doubt than those of winter wheat, which is generally acknowledged to be higher yielding than spring wheat.

2.5 Uses of the barley crop

There are three main outlets for the barley crop: animal

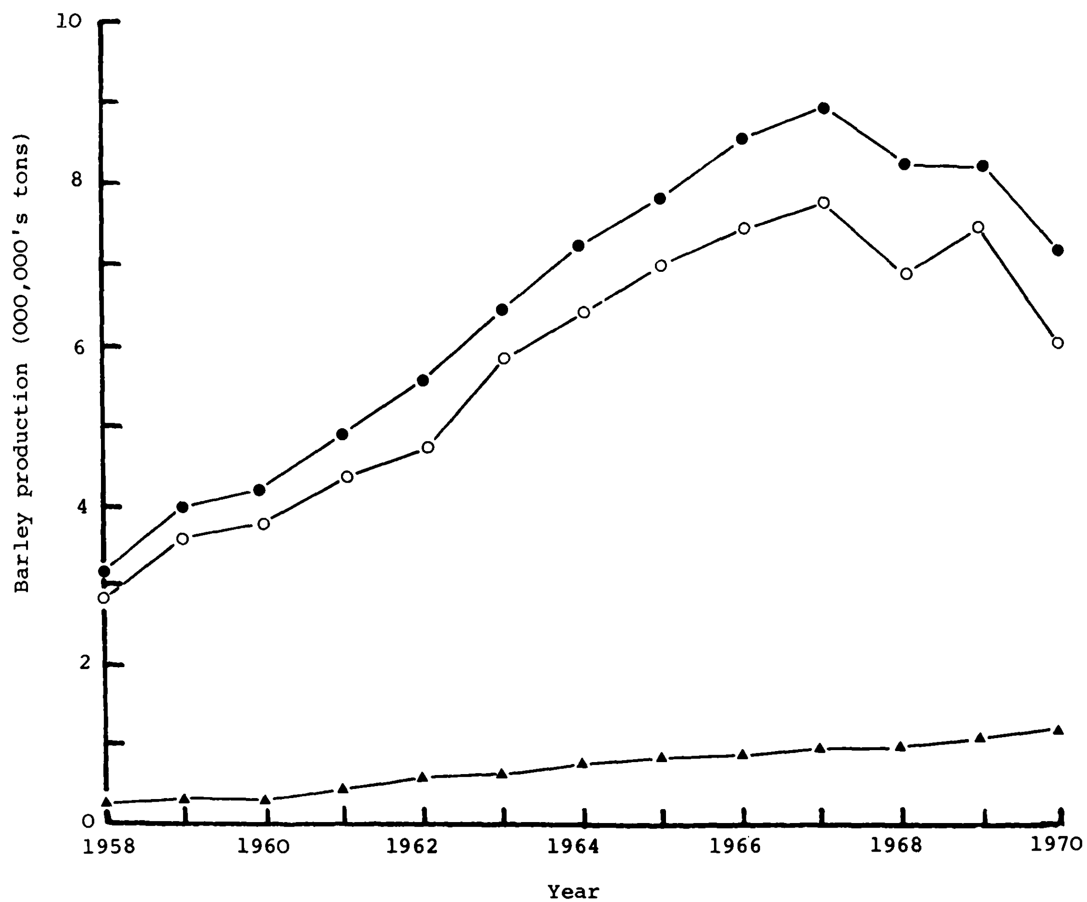


Fig. 2.4 Total annual barley grain production in Great Britain (●), England and Wales (○) and Scotland (▲) from 1958 to 1970.

Source: D.A.F.S.(1959 annually to 1971)

feed, malting - for brewing and distilling, and seed production.

The use of grain depends on its quality, as does the price the farmer receives (Britton, 1969, p.156). Grain may be produced with the aim of achieving a high enough quality for seed or malting barley, but always with the possibility that the grain can be used as animal feed.

Animal feedstuffs

All the cereals grown in Great Britain are to some extent used for animal feed (Sturgess and Reeves, 1972). The grain may be supplied to the animal in four forms: straight grain, cereal mixtures, processed grain, for example milled grain compounded into pellets, and compounded rations including a concentrate supplement of proteins, minerals and vitamins (Britton, 1969; Sturgess and Reeves, 1972).

Mixed grain, straight grain and processed grain can be grown and made up by the grower for his own livestock, if he possesses the necessary milling and mixing machines. The use of retained straights, that is own-grown grain retained on the farm of origin, makes up about a quarter of the concentrate feedstuffs used in the United Kingdom in 1969/70 (Table 2.2).

Table 2.2 Sources of feed fed to cattle, pigs and poultry*, 1960/1 to 1969/70, in the United Kingdom

June/May	1960/1	61/2	62/3	63/4	64/5	65/6	66/7	67/8	68/9	69/70
	%	%	%	%	%	%	%	%	%	%
Total:										
Compounds	59	57	57	56	55	52	53	54	54	54
Purchased straights	23	23	22	22	22	28	25	24	23	22
Retained straights	17	20	20	22	23	20	22	22	23	24

* As a proportion of starch supplied by the sources.

Source: Sturgess and Reeves (1972, p.3-12).

Sixty-six per cent of the barley crop in 1967 was used for animal feed in Great Britain as a whole (Table 2.3), of which 29.4% was retained on the farm of origin.

Table 2.3 Estimated utilization of barley in the United Kingdom in 1966/67

Production and Usage	Tonnage '000	Proportion of Production %
Crop Production Total	8586	100
Usage:		
Stockfeed sales	3162	36.8) 66.2
Stockfeed retained on farms	2523	29.4)
Malting	1078	12.5
Other human and industrial sources	272	3.2
Seed*	393	4.6
Exports	1035	12.1
Waste	123	1.4

* Includes 50% mixed corn seed requirements.

Source: Britton (1969, p.808); Sutherland and Steele (1970, p.42).

The feed barley grower has three market outlets for his crop: retaining it on his own farm, selling it to another farmer, or selling it to a merchant, compounder or grain broker.

National compounders rely mainly on merchants for their supplies of home-grown grain, of which 35.2% is barley grain (Britton, 1969, p.411-412). However, smaller compounders rely more on direct purchases of grain from the growers (Britton, 1969, p.412). Approximately 55,000 tons, or 1.7% of stockfeed sales (Table 2.3) are purchased directly by compounders from the growers (Britton, 1969, p.812).

Malting barley

Malting is the process in which barley grain is germinated under specific controlled conditions and then dried. The result is malted grain, or malt, and its principal uses are in brewing and distilling, although in some cases it goes into human food, for example malt vinegar (Britton, 1969, p.475).

In 1969/70, the production of malt for beer and whisky manufacture respectively used an estimated 760 and 500 thousand tons of home-grown barley (Sturgess and Reeves, 1972, p.131).

The process of malting is carried out by three types of 'ma tster' (Britton, 1969, p.475). Firstly, sale maltsters who make malt for sale on the open market, for the most part to brewers and distillers. These firms are usually sited in or near major grain-growing areas.

A second type is the specialist brewer maltster, attached to a brewery, and generally catering for that brewery alone. The breweries are generally sited in 'soft' water areas.

Thirdly, there are specialist distiller-maltsters, attached to distilleries. In Scotland, the whisky distilleries tend also to be in areas where a suitable water supply is available.

The smaller breweries and distilleries often find it more economical to buy their malt from sale-maltsters. Sale-maltsters took about four-fifths of the barley bought for malting in June-July, 1966/7 (Table 2.4).

Table 2.4 Estimated tonnage of barley purchased by sale maltsters and brewer maltsters in the United Kingdom from July to June, 1966/67.

	Tonnage, '000 tons		
	Sale Maltsters	Brewer Maltsters	Total
Source:			
Bought from farmers	140	6	146
Bought from merchants	670	233	902
Imported	11	-	11
Other sources	0.5	-	0.5
Total purchases	821	239	1059

Source: Britton (1969, p.482).

Distiller maltsters used more imported barley, particularly Canadian, for the quality necessary for grain distilling, although malt whisky uses mainly home-grown barley (Britton, 1969, p.502).

Forty five per cent of malting barley purchases in 1966/67 for the distilling industry was of Scottish origin (Britton, 1969, p.500). Britton suggests that distillers bought around 340,000 tons of barley in total (p.499), thus 153,000 tons must have been of Scottish origin.

There are no comparable figures for the purchases of sale and brewer maltsters given by Britton (1969).

Seed Production

The production of seed barley by a grower may either be for his own use the following season, or for sale. There are a few specialized seed producers who act as agents for plant breeders or seed merchants to multiply up stocks of certain cultivars, notably new cultivars.

The seed grower sells his grain either to another farmer, to an agricultural merchant or to a seed wholesaler. The sales of seed are to some extent influenced by the Seeds Acts which will be discussed in detail later (Chapter 3:3.3).

Britton (1969, p.301) estimated that about 5% of the grain produced in the United Kingdom is used for seed (Table 2.3). Only 2% of grain lot sales were direct to seedsmen (Table 2.5). This means that about 3% of the estimated 5% total used for seed is kept on the farm of the growers, or is part of the 70% sold to the merchants, a small proportion of which may be re-sold as seed, or is sold privately to other growers.

Table 2.5 Percentage of grain lots of barley intended for sale to be sold to different buyers in Oct./Nov., 1967

Sold to:	Percentage
Merchant	70
Miller	5
Compounder	11
Seedsman	2
Other Farmers	2
Undecided	10
Total:	100

Source: Britton (1969, p.155).

Britton suggests that 63% of the cereal seed grown is bought by agricultural merchants in Great Britain as a whole, and 71% in Scotland (p.301-303) but it is not clear whether Britton separated the seedsmen and the general merchants in this calculation.

If 5% is taken as the probable seed production figure for Scotland alone, then this represents 57,850 tons of the 1,157,000 tons of grain produced in 1970 (D.A.F.S., 1971). It is not known how much of this is retained on the farm of origin.

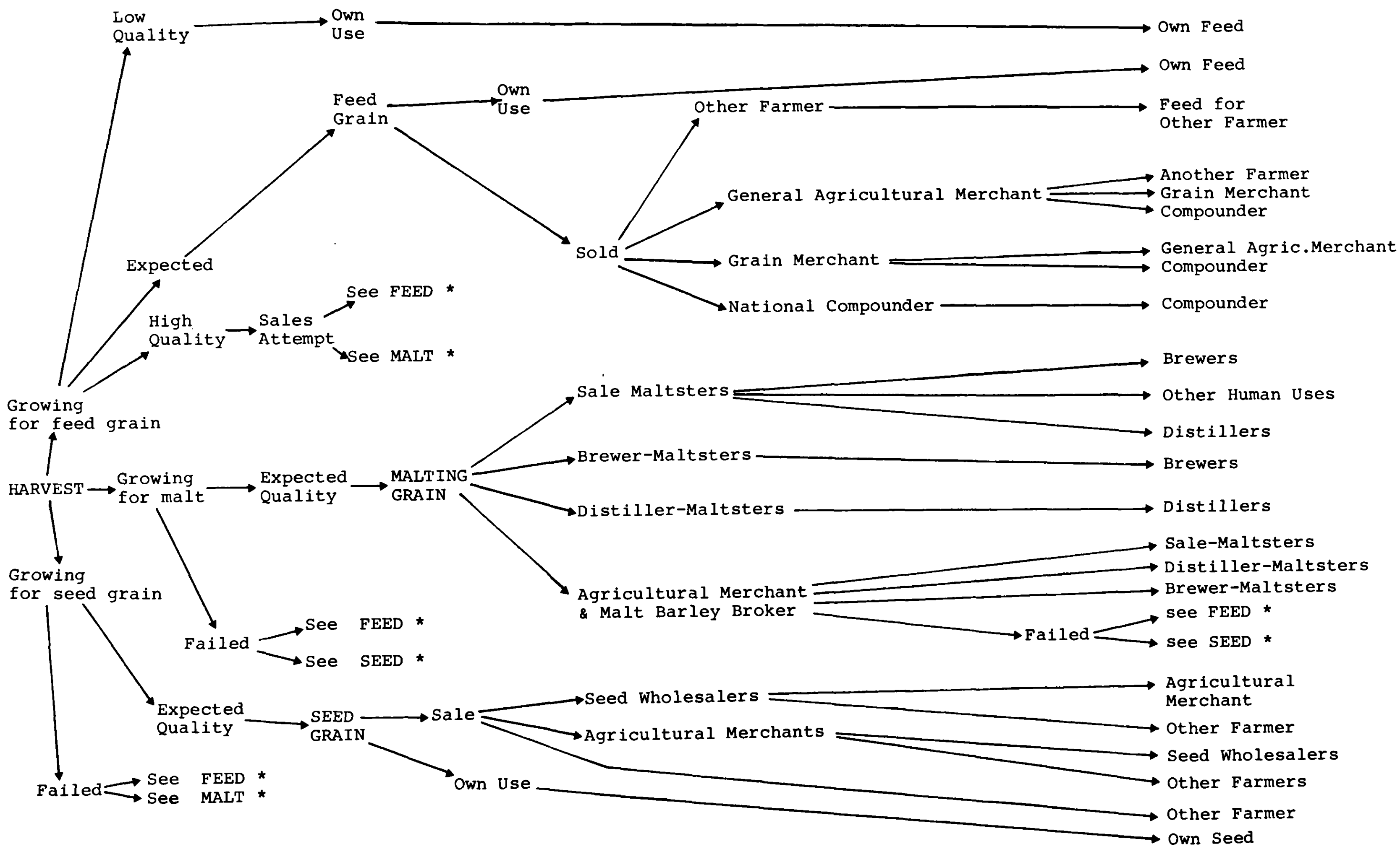
2.6 The flow of barley grain from harvest to outlets

The flow of barley grain from harvest to the eventual outlets available is summarized in Figure 2.5. The failure of grain to reach the requisite quality to be sold for seed or malting grain does not mean that the grain is useless, since it can be utilized for animal feed. Conversely, a farmer may be able to sell grain for a use he did not originally intend.

The complexity of outlets for the grower, the sales between the merchants, and the links between the merchants and processors (Figure 2.6) make it difficult to assess the relative quantities of grain flowing between each sector of the

Fig. 2.5 The flow of barley grain from the harvest to the outlets.

*See feed, malt and seed grain



HARVEST
Growing for feed grain
Low Quality
Own Use
Own Feed
Expected
Feed Grain
Own Use
Own Feed
Sold
Other Farmer
Feed for Other Farmer
General Agricultural Merchant
Another Farmer
Grain Merchant
Compounder
Grain Merchant
General Agric.Merchant
Compounder
National Compounder
Compounder
High Quality
Sales Attempt
See FEED *
See MALT *
Growing for malt
Expected Quality
MALTING GRAIN
Sale Maltsters
Brewers
Other Human Uses
Distillers
Brewer-Maltsters
Brewers
Distiller-Maltsters
Distillers
Agricultural Merchant & Malt Barley Broker
Sale-Maltsters
Distiller-Maltsters
Brewer-Maltsters
Failed
see FEED *
see SEED *
Failed
See FEED *
See SEED *
Growing for seed grain
Expected Quality
SEED GRAIN
Sale
Seed Wholesalers
Agricultural Merchant
Other Farmer
Agricultural Merchants
Seed Wholesalers
Other Farmers
Other Farmer
Own Use
Own Seed
Failed
See FEED *
See MALT *

industry.

Some of the quantities flowing within the merchant sector have been calculated by Britton (1969) (Table 2.6). Britton does not mention whether the proportion re-sold to farmers included feed and seed grain.

Table 2.6 Barley grain flows in the merchant sector in the United Kingdom, 1966/67

	Tonnage '000 tons	Proportion of Production %
Bought by merchants:		
Bought from farmers	5676	66.4
Imported	84	
Bought from other merchants	1941	
Sold by merchants:		
Sold to other merchants	1909	
Sold to farmers	1022	
Sold to compounder/millers	1455	
Sold to others and for export	1010	
Sold to maltsters/distillers	1225	
Used by merchants:		
Approximate tonnage of home-grown grain used by merchants in making compounds	1003	

Source: Britton (1969, p.815).

Trends in the merchant sector

It was estimated (Britton, 1969, p.173) that in 1967 there were over 2,050 agricultural merchandizing businesses in the United Kingdom. Many of the firms were members of the National Association of Corn and Agricultural Merchants (N.A.C.A.M.). In 1967, there were 1,661 N.A.C.A.M. members, a drop of 32% since 1947 (Britton, 1969, p.202). A similar reduction was noted by Britton in Scotland where there was a drop from 208 members to 143 members during the same period.

Although not all merchants dealing with barley seed or grain are N.A.C.A.M. members, the fall in their membership may reflect a general decline in numbers.

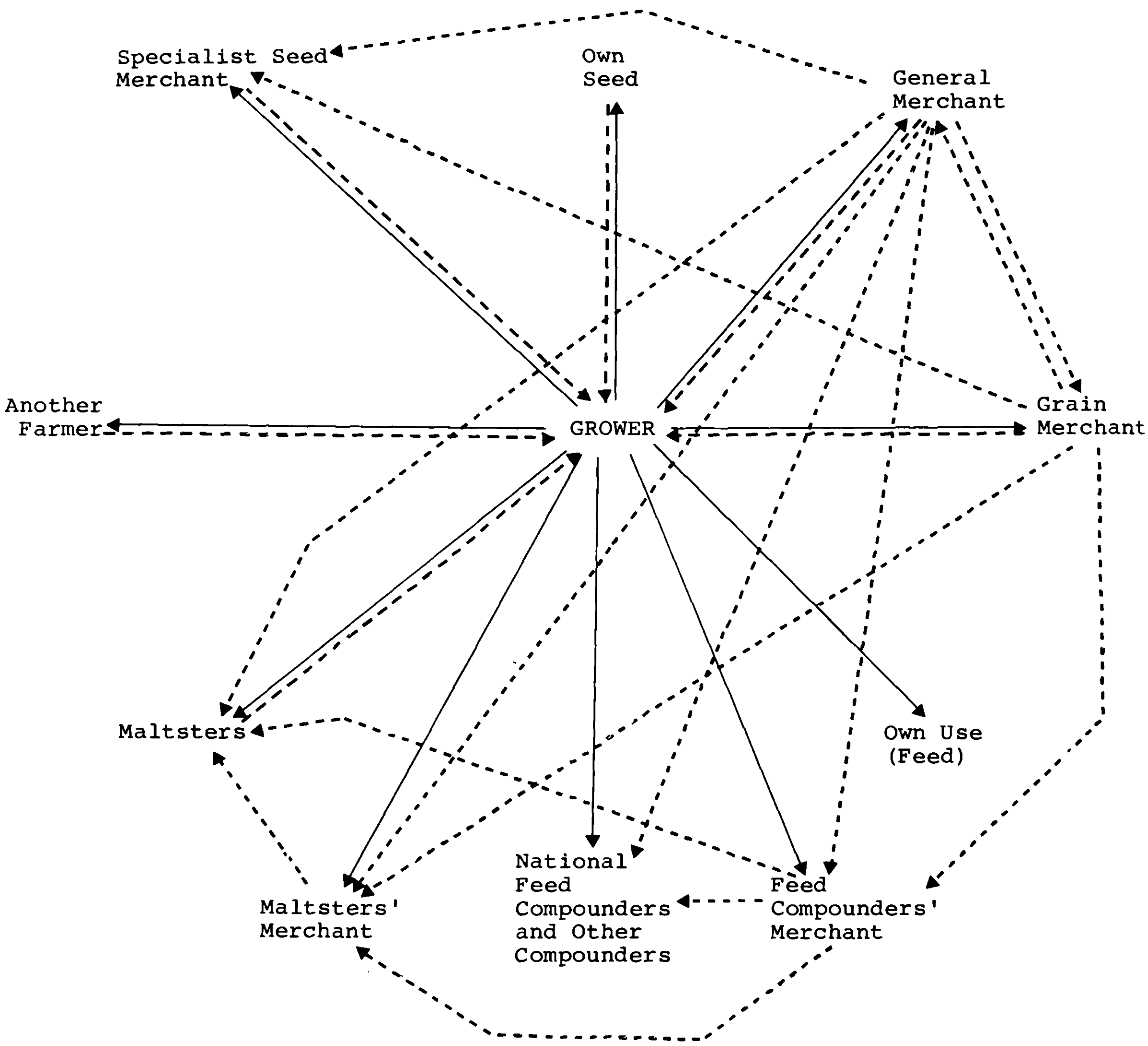


Fig. 2.6 The flow of barley grain between growers and merchants.

Britton (1969, p.203-8) suggested that certain trading pressures had reduced the numbers of merchants. Greater home production of grain had adversely affected merchants dealing mainly in imported grain. Further, the larger firms took greater control over the market, being able to better absorb increasing costs.

Tra ing in the merchant sector

In a survey of merchants conducted by Britton (1969) in 1967, it was shown that 59% of the trading (purchases and sales) was undertaken by 14% of the firms, and 21% of the firms were restricted to 1% of the trading, 6% of these being one man operations.

Britton (1969, p.177) estimated that nine-tenths of grain purchases in 1967 were undertaken by one-third of the firms. If this is true for Scotland, then it indicates that forty seven firms controlled nine-tenths of the grain purchases.

Britton further suggested (p.302) that 40% of the agricultural firms who purchased some seed from farmers purchased barley seed. However, more firms sold barley than purchased it from growers; 59% of firms, or eighty four firms in Scotland, sold barley seed. Thus, much of the agricultural seed trade is purely retail, the merchants buying their seed grain from wholesale merchants.

The merchants can be divided into four types of trader (Britton, 1969, p.170). Those specializing mainly in feed - both buying and selling; firms specializing mainly in buying grain, compounding it and then re-selling the compound feed; general merchants buying and selling all agricultural produce, but with no single main activity; and fourthly, firms specializing mainly in grain, that is, buying and selling from and to other merchants and farmers.

Britton (1969) surveyed twenty four Scottish farmers in 1967, and divided them into the categories described above Table 2.7). He gives no indication as to their respective share of the market.

Table 2.7 Specializations of merchants in Scotland, 1967

	Sp. mainly grain	Sp. mainly feed	Sp. mainly compounding	Gen. Merchants	Other*	Total
Numbers	4	3	5	6	6	24
As % of total	17	13	20	25	25	100

* Others: more than 50% of turnover in other interests.
Source: Britton (1969, p.188).

2.7 The influence of the Government on barley growing

Deficiency payment schemes

During the Second World War, under emergency measures, most of the agricultural produce of the United Kingdom was purchased by the Government. This purchasing was arranged with fixed prices and a guaranteed market, and the Government decided to review the prices it gave for the produce periodically in order to cover changes in the costs of production (Self and Storing, 1971, p.62).

Since the 1953/4 season, the market has been open to all purchasers, but for many crops Government guaranteed prices are still maintained, although prices are no longer strictly controlled. Such schemes were maintained because the British farmer had to compete with cheaper imported produce (Self and Storing, 1971, p.67). Overall, the Government's policy objective for some farm produce was to maintain low home prices so as to compete with imports, to keep food prices at a relatively low level, and to give the farmers an assured and stable income and thus help to maintain a reasonably prosperous agricultural sector (Britton, 1969, p.653).

For cereals, a system of 'deficiency payments' was introduced in 1953. Under this system, the Government paid a subsidy to the grower equivalent to the difference between the average market price and a guaranteed fixed price determined at an annual review (Self and Storing, 1971, p.70). The annual review takes into account the views of all sectors of the industry; the changes in production costs, and changes in the economy in general (M.A.F.F., et al., 1967).

The deficiency payment is made on each output unit sold; in the case of barley, this is done on an acreage basis (M.A.F.F., et al., 1967). The farmer has to make a statement as to his acreage of barley in any one year. A guaranteed price per cwt, a standard quantity per acre and a target indicator price are set out in the annual review. The production in that season is calculated by multiplying a three year average of yields in the United Kingdom by the declared acreages.

When the total production is over, the standard quantity (that is, the calculated expected production), the guarantee payment for that year is reduced proportionately, and conversely the payment is increased when the production is below the standard quantity, and the average market prices are above the target indicator level (minimum import price). (M.A.F.F. et al., 1967, p.1, 24).

If the grain is retained on the farm of origin, then there is no sales subsidy given. However, incentive payments to hold barley grain in store on the farm of origin, so that there is a staggering of the release of barley on to the market, were introduced in 1960 (Britton, 1969, p.655). The incentive was designed to encourage farmers to instal grain driers and stores. This was further stimulated by a system of 'dis-incentives', which are deductions from the acreage subsidy payments (Britton, 1969, p.656). This is used just after the harvest to prevent a swamping of the market at that time; that is, if barley is put on the market immediately after the harvest, then there is a deduction from the theoretically obtainable deficiency payment.

The system of incentives and dis-incentives that have operated since 1960 have modified the price range of barley grain through the year (Figure 2.7).

The Home-Grown Cereals Authority (H-G.C.A.)

In the early 1960s, an increasing domestic production of barley, plus a high import level of low-priced European barley caused the average market price for barley to fall occasionally to such a low level that the total subsidy bill became excessive, and the Government realized a greater control of market prices was needed (Britton, 1969, p.630).

The Government set up the H-G.C.A. in 1965, to control and improve the marketing of cereals (Britton, 1969, p.630) which would lessen the 'open-ended' nature of the subsidy commitment. The Authority consists of a board of five independent members, nine farmers and nine merchants or users, and is financed by Exchequer subsidies and a compulsory levy on all cereal growing farmers. The Authority runs several schemes which are intended to control prices and help the marketing of the grain. This includes the setting of a minimum import price which prevents the undermining of the market price in this country, which produced the low prices of the early 1960s (Figure 2.7).

The Authority also reduces the guaranteed prices whenever a certain standard quantity of home-produced barley has been exceeded. This results in a reduction in the Government's

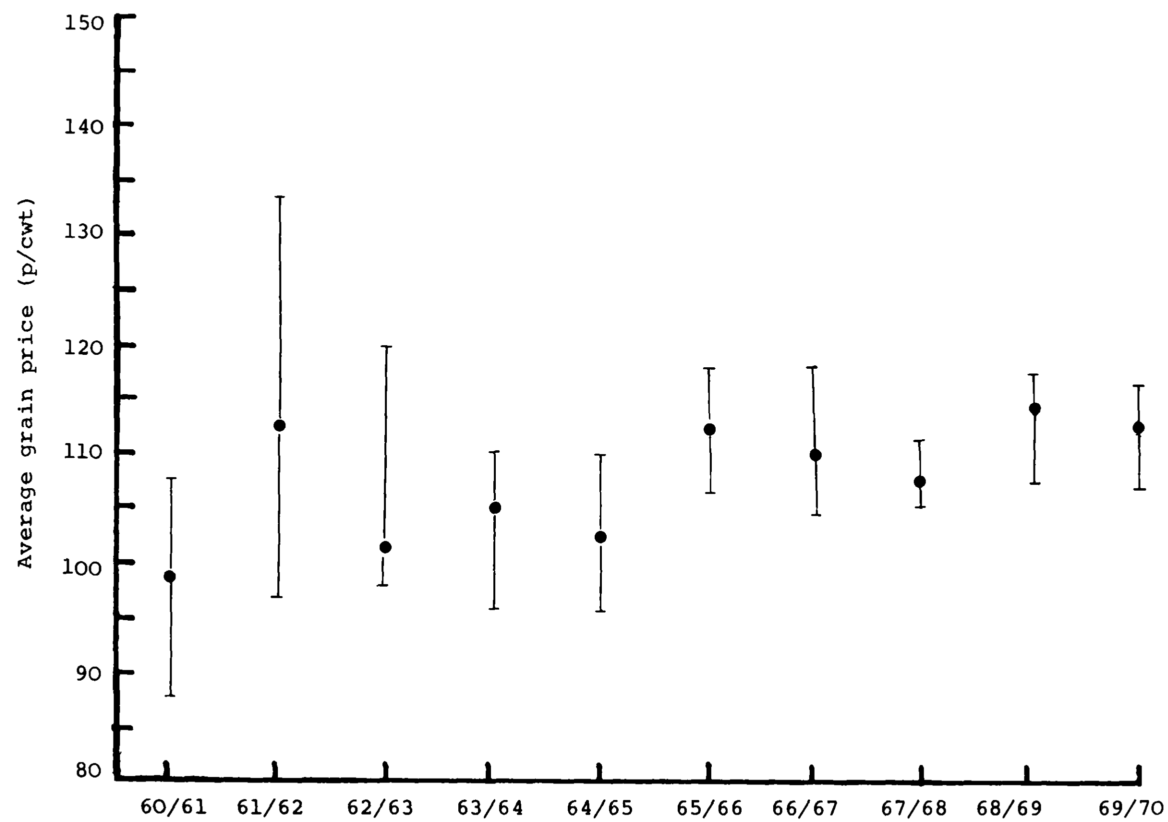


Fig. 2.7 Average yearly price for barley grain in Great Britain, from 1960/1 to 1969/70. The vertical lines represent the variation in prices over each cereal year.

subsidy bill.

There is a 'Forward Contract Bonus Scheme' which enables home-grown grain to compete more effectively against imported grain by giving the users an assured continuous supply. The money out of which the contract bonuses are paid is acquired by a compulsory levy on grain growers.

Other market-orientated schemes organized by the H-G.C.A. are a 'bonus on delivery' scheme, guaranteeing or making loans on forward contracts, improving market intelligence (including a weekly bulletin), and research into market factors (Britton, 1969, p.663-670).

Other state aids to barley growing

Besides the guaranteed pricing system and the market controls of the H-G.C.A., the Government stimulates development in the barley growing industry by providing other direct and indirect incentives, mainly in the form of subsidies but also in the form of market incentives.

An example is the de-rationing of animal feedstuffs in 1954; soon after, the Government relinquished control of the agricultural produce market. This especially stimulated the production of barley for feed compounding (Britton, 1969, p.399).

Better cultivation is encouraged by drainage grants, fertilizer subsidies and liming subsidies. These have been especially important in the introduction of barley into new areas of the country previously unfit for barley growing, including large areas of Scotland (M.A.F.F., 1968; Donaldson et al., 1972, p.30; Britton, 1969, p.24). 'Farm Improvement Scheme' grants and the 'Small Farmers Scheme' have provided money for investment in equipment and storage, thus a greater diversification of crops has been possible; especially those which could be stored for more favourable market conditions

(Britton, 1969, p.655). Grassland ploughing grants have also been a direct stimulus to crop production (Self and Storing, 1971, p.83).

Control as a reducer of uncertainty

The use of the deficiency payment schemes has meant a greater economic stability to the grower, since the Government is absorbing a large part of the price and costs fluctuations that may occur for his produce (Britton, 1969, p.653). High guaranteed prices may have had a lot to do with the increase in the popularity of barley since the War (Donaldson et al., 1972, p.162-4; Britton, 1969, p.25-7); plus the decrease in wheat guarantees which caused an original differential in returns to disappear (Britton, 1969, p.26).

Britton (1969, p.22) argues that it is doubtful whether technical developments in cereal growing would have been so rapid if it had not been for the stability offered by the Government subsidies. These reductions in uncertainty appear to have improved expectations, and thus promote the acceptance of change and innovation.

2.8 Supply and demand changes for barley

The improvements in husbandry and cultivars, and the strong Government support in the barley growing industry are reflected in the greatly increased barley production since the War, as shown in Figure 2.8 a/b.

There has been a shift in demand and supply from S_0 and D_0, the supply and demand averages from 1940 to 1949 (Figure 2.8a) to S_T and D_T, the supply and demand in 1969/70 (Figure 2.8b), the individual changes being represented by the intermediate curves (S_1, S_2 and S_3, and D_1 and D_2). The final pattern shows a marked increase in barley production, accompanied by a fall in the market price for barley grain.

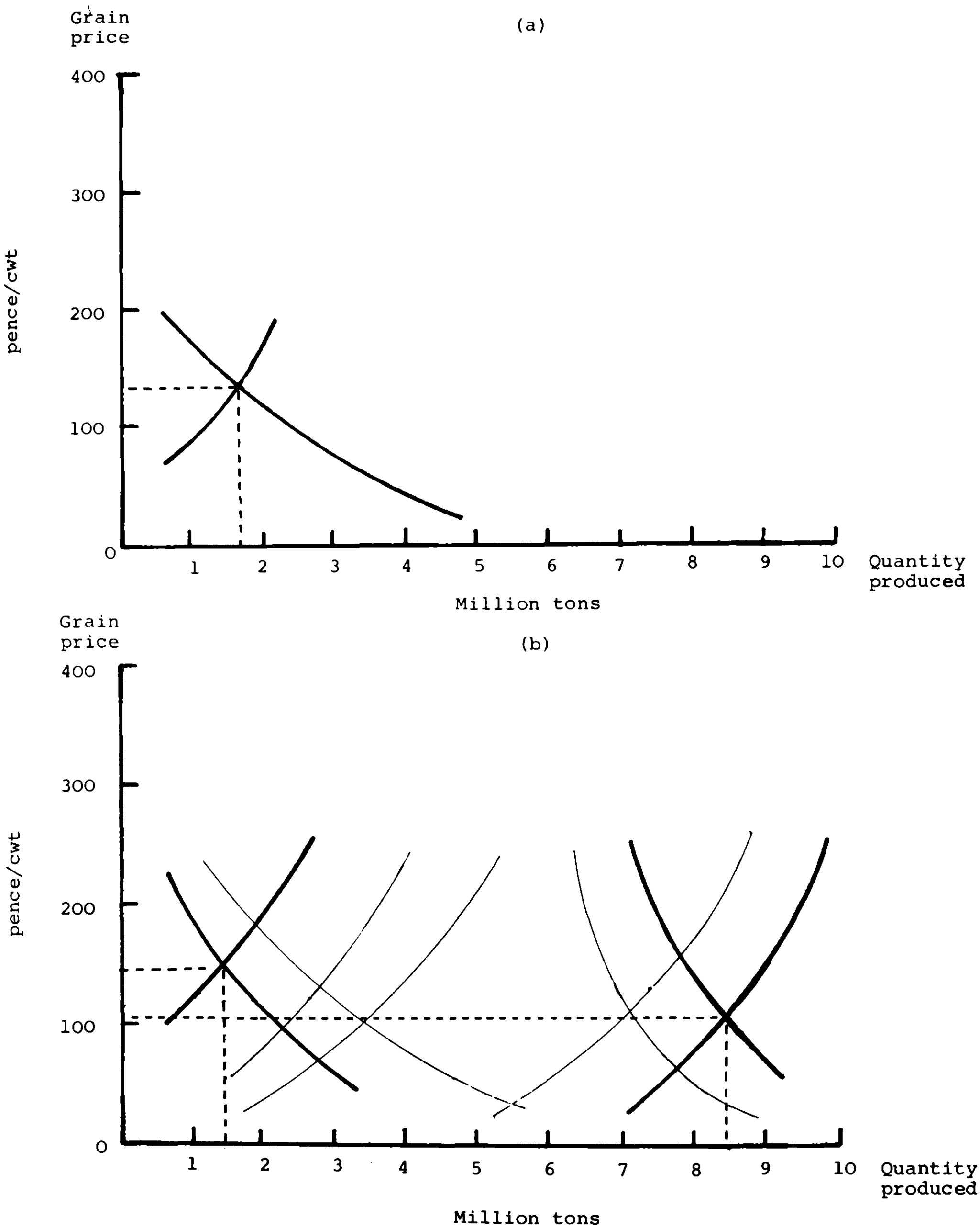


Fig. 2.8(a) Mean supply and demand situation for barley grain between 1940 and 1949 (b) A comparison of the demand and supply situations for barley grain between the 1940 to 1949 mean and that of 1969/70.

2.9 Transition to the European Economic Community (E.E.C.) marketing arrangements

The produce of the 1972 harvest will come under the influence of the E.E.C. marketing arrangements. Under these arrangements, there will be no fixed prices except for special crops grown under contract with agreed prices (Hooke, 1972). Instead, the producer will have to bargain for the best price he can get.

There will be a 'threshold price', which is a variable levy similar to the minimum import price. However, to stop prices from going down too much by over-production within the country, an official agency can buy grain at a pre-determined 'intervention price'. This is set rather lower than the threshold prices, but rises through the season (Table 2.8) with the threshold prices to encourage the storing of grain through the cereal year (Stewart, 1972; Hooke, 1972).

Table 2.8 Intervention and producer prices at Hanover, W. Germany, 1971/2, for feed barley

		Intervention price	Producer price*
	Month	D.M. per 100 kg.	
1971	August	33.10	31.00
	September	33.10	31.50
	October	33.40	33.00
	November	33.70	33.50
	December	33.90	33.50
1972	January	34.29	34.50
	February	34.59	34.50
	March	34.89	35.00
	April	35.18	36.00

* Average price received by producers combining farm-gate sold and delivered sold crops.

Source: Stewart (1972).

The agency has to buy grain offered to it at the intervention price if it is of a minimum standard of quality. The intervention price can be adjusted to suit defects in quality (Stewart, 1972).

The 'intervention price' will vary at the different cereal agency centres throughout the country. For example, in 1972/3, the intervention price will start at £25.32p. per ton of grain at Aberdeen and Leith, and £24.39p. per ton at Glasgow (Stewart, 1972).

These prices are lower than for the rest of Europe but there will be a gradual transition to European levels. However, there will be a yearly month to month increase in the 'intervention price' at a similar rate to that in Europe, of 0.36p. per ton (Stewart, 1972). An important qualification for intervention sales is that there must be at least 100 tons of barley grain offered in a single sale. This may mean that more sales will be made to the intervention agency by merchants unable to get a better price, or by farm co-operative arrangements in the same situation (Stewart, 1972). Another barrier will be that the vendor will have to bear the cost of transporting the grain to the agency, and away if its quality is below that required by law. This may make lower offers by other purchasers economically acceptable.

The change to the E.E.C. regulations will commence on February 1st, 1973; however, there will be a transition to these regulations in Britain, with the guaranteed payment system continuing through the 1972/3 season. The old system will probably be the dominating system in 1972/3 as the guaranteed price supports will be higher than those of the E.E.C. system in the first year of E.E.C. membership (Stewart, 1972).

Chapter 3

QUALITY CONTROL IN SEED SALES

3.1 Seed quality

Crop seeds are sold off the farm, and are retained and sold by the merchant, in seed lots, bulks of seed of limited weight (M.A.F.F., 1961), often from the same crop. Assessments of quality in a seed lot are made on samples drawn from the lot. Horne (1965) and Feistritzer (1969) suggest that quality assessments are no more than measured comparisons with standards of genetic purity, laboratory germination and levels of contamination with weed species and seed-borne diseases. MacKay (1965) recognizes that there are many facets to seed quality but that quality in commercial terms is its value to the grower for sowing. Even so, quality in a seed lot is measured by means of the performance of samples from the lot in the tests that are currently in use.

A laboratory germination test was the first commercially used quality control test (Wellington, 1965), but the term germination has a different meaning for seed analysts and for farmers (Heydecker, 1972). The farmer equates germination with the appearance of the aerial shoots of the plant (seedling emergence), but the seed analyst defines germination as 'the emergence from the covering structures of all essential parts which guarantee the presence of a viable seedling', which has been determined at under standardized conditions to ensure reproducible results (Wellington, 1966). Mackay (1972) has suggested that the germination test should, and often does, provide'a realistic assessment of field planting value'. This objective is not always achieved for all seed lots of all crop species, especially when seeds are subjected to harsh conditions during field establishment (Erickson and Porter, 1937).

3.2 The history of seed testing

The importance of laboratory seed testing was first realized by F. Nobbe, who established the first seed testing station at Tharandt, Saxony, in 1869 (Justice, 1965; Esbo, 1965). He demonstrated that the germinability of different seed lots could be compared by inexpensive, routine tests made on artificial substrates and under controlled conditions.

Seed testing stations soon began to appear in many parts of Europe and America, including the first British station, set up as a service to its members by the Royal Agricultural Society of England, in 1871. A few further stations were set up in the United Kingdom, mainly on commercial lines, before the First World War. The first Government controlled station was not set up in Britain until 1914, when the Department of Agriculture and Fisheries for Scotland (D.A.F.S.), then known as the Board of Agriculture for Scotland, started the Official Seed Testing Station for Scotland (O.S.T.S.S.) to test seed offered voluntarily by growers and merchants.

The food shortages of the First World War stimulated interest in the efficiency of agriculture, and one consequence was the setting up of the Official Seed Testing Station for England and Wales (O.S.T.S.) in 1917, under the Seed Testing Order, 1917 (MacKay, 1972; personal communication). The official testing of seed for seed sales was also necessary under this order.

International developments

At a Botanical Congress in Vienna, in 1905, a group of seed analysts met to discuss the formation of the European Seed Testing Association (E.S.T.A.). Further meetings were held at Hamburg, in 1906, and at Wageningen, Netherlands, in

1910, but no further meetings were possible, because of the political situation in Europe, until 1921. Professor K. Dorph-Peterson called the third meeting in 1921, at Copenhagen. It was at this meeting that the E.S.T.A. was officially constituted (Justice, 1965).

At the fourth meeting at Cambridge, in 1924, a constitution was agreed upon to form the International Seed Testing Association (I.S.T.A.) to encourage the membership of countries outside Europe.

Justice (1965) stated that the original reason for the formation of E.S.T.A. was to improve the quality of commercial seeds used in Europe and America by drawing up international codes of quality control.

The constitution of the I.S.T.A. states that 'the objectives are to further all matters concerned with accurate and uniform methods in testing and evaluating seeds in order to facilitate efficiency in production, processing, distribution and utilization of seeds to be used for sowing'. (I.S.T.A., 1922; Justice, 1965).

In its fifty years, the I.S.T.A. has achieved considerable progress in the standardization of testing techniques and international certification of test results procedures. In 1931, the I.S.T.A. set out the International Rules for seed testing (I.S.T.A., 1931), to which there have since been modifications, but the procedures laid down by the Rules are often conformed to in the seed legislation of the participating nations, including Britain. In addition, the I.S.T.A. makes recommendations governing the grading and certification of seed samples, especially for the international seed trade.

3.3 Seed legislation in the United Kingdom, I : Seeds Act, 1920

The food shortages of the First World War had made the country more conscious of its agricultural potential, and the Government more aware of the quality of produce and of agricultural productivity. One outcome of this greater awareness was legislation to increase the use of crop seeds of good quality.

The Seeds Act, 1920 (H.M.S.O., 1921) declared that some seed testing procedures were compulsory for those seed lots which were to be sold for sowing. The seller had to give the purchaser a statement containing prescribed particulars with respect to the seed cultivar, its purity and its germination.

This was an enabling Act. The Ministry of Agriculture, Fisheries and Food (M.A.F.F.) announced Orders and Regulations under the Act, with the full force of law. Thus procedures laid down by the various parts of the Act could be changed in the light of new techniques and conditions.

The Act did not lay down standards; it just required that the farmer should have trustworthy information as regards his seed purchases. Under the Orders and Regulations of the Act there is a setting down of criteria about which declarations had to be made. In the case of cereals, declarations are required in the following criteria (D.A.F.S., 1962), as set down by the Seeds Regulations, Scotland, 1961:

(a) The kind of seed - botanical species;

(b) The variety (cultivar) of the seed;

(c) The country of origin;

(d) Any treatments to the seed, and whether germination and purity tests were undertaken before or after the treatment;

(e) Percentage purity of the sample with respect to the named seed - the percentage is declarable if it is below 99%;

(f) Percentage of the seeds germinating - in barley, if this was found to be below 90%, the actual percentage has to be declared;

(g) The presence of certain specified weed species;

(h) The percentage by weight of all weed seeds present if this exceeded 0.5%.

The Seeds Act, 1920, further declared that the conducting of the testing should be by the established Government seed testing stations, and that the requirements of law were checked and re-inforced by the M.A.F.F., the D.A.F.S. and the Ministry of Agriculture, Northern Ireland (M.A., N.I.). Thus much of the official seed testing stations' work was to carry out tests specifiable under the Act for merchants and farmers who wanted to sell seed for sowing.

The testing of seed for the purposes of the Act may also be undertaken by private testing stations licensed by the Minister of Agriculture (H.M.S.O., 1920, p.497). These stations are subject to checks by the M.A.F.F., the D.A.F.S. and the M.A., N.I.

3.4 The Official Seed Testing Station for England and Wales

History

After the Government had declared that the O.S.T.S. had a statutory obligation under the Seeds Act, 1920, to test all seeds for sale (Chapter 3: 3.3), it moved from the then Ministry of Agriculture and Food (later the M.A.F.F.) in London, to Cambridge, as a branch of the newly formed National Institute of Agricultural Botany (N.I.A.B.). However, it was, and still is, considered a separate entity for administrative and accounting purposes (N.I.A.B., annual reports), although both are ultimately controlled by the N.I.A.B. Council. It also receives a development grant from the M.A.F.F. and a maintenance grant from the N.I.A.B., whilst its cash assets are held by the N.I.A.B. As from 1st April, 1973, the O.S.T.S. will be supported by a direct grant from the M.A.F.F. The new procedure recognizes the Minister's statutory responsibility for the maintenance of an O.S.T.S. (H.M.S.O., 1965, p.149).

The O.S.T.S. runs checks on the private licensed stations (Chapter 3: 3.3), of which there are 120 in England and Wales at present. Originally set up to relieve the amount of work being undertaken by the O.S.T.S., the licensed stations now account for 65% of all seed testing in England and Wales (MacKay, 1972 - personal communication).

Testing at the O.S.T.S.

The O.S.T.S. test seeds for sale under the Seeds Acts (Chapter 3: 3.4; Chapter 3: 3.6), as well as seed entered for specific seed certification schemes and other tests not under the Seeds Acts which may be requested by merchants or farmers. There is a specific price per test undertaken. Advisory tests were also carried out by the O.S.T.S. for bona fide farmers on seed for sowing on their own farms, including laboratory germination and purity tests, done at a specially low fee; however, this arrangement was cancelled in 1971. Thus figures quoted for the numbers of samples tested include samples entered for all the mentioned categories of testing.

The N.I.A.B. Annual Report (1926/7) recorded that 26,679 seed samples were tested by the O.S.T.S. in 1925/6 (Figure 3.1). The number increased slowly up to the start of the Second World War, when in 1938/9, 37,844 samples were tested (N.I.A.B., 1940). The increasing importance attached to home agriculture, accentuated by the War (Self and Storing, 1962, p.19) was

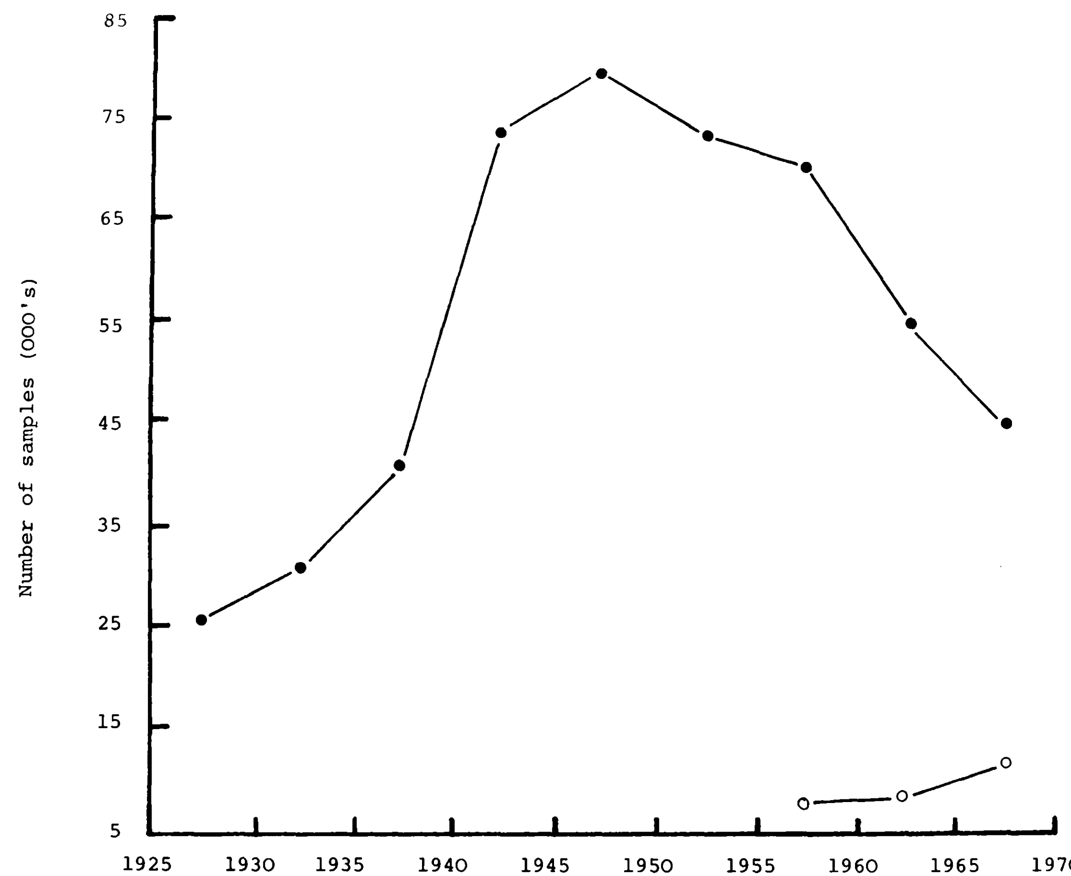


Fig. 3.1 Number of seed samples tested at the O.S.T.S. Cambridge, from 1926 to 1970; all seed samples = ● , barley samples = O (Annual figures used to calculate 5 year moving averages).

reflected in a dramatic increase in the numbers of samples tested, which rose to 75,834 by 1943/4 (N.I.A.B., 1945), of which 31,340 were cereal seed samples (Figure 3.1). By the end of the War, 1946/7, the number had risen to 80,019 (N.I.A.B., 1948), reaching its peak in 1947/8 (N.I.A.B., 1949) (Figure 3.1), when 82,737 samples were entered.

The number of samples tested by the O.S.T.S. in 1970/1 was circa 34,000, whilst the private stations tested circa 63,000 during the same year (MacKay, 1972 - personal communication). The number of private licensed stations did not change much in the ten years prior to 1970/71, suggesting that the decline in the numbers of samples tested at the O.S.T.S. had not simply resulted from a shift from the O.S.T.S. to the private licensed stations. Other factors must have effected this decline.

MacKay (1972 - personal communication) suggested four basic reasons: (a) many small merchants without licensed stations have been closed down, or amalgamated with larger companies or groups with their own licensed stations; (b) fewer transactions now take place between companies, and, as it has been commonplace in the past for tests to be undertaken each time seed changed hands, the reduction in trade has considerably reduced the need for tests; (c) seed is now handled in larger bulks, so that it has become common for a single seed sample to represent a seed lot nearer the statutory maximum bulk for a lot, for example 20 tons in the case of cereals (D.A.F.S., 1962); (d) the cost of seed testing has risen substantially, for example the farmers' low priced advisory test increased from £0.62½p. in 1961 to £1.40p. in 1971. Thus, farmers and merchants have economized by only having essential tests done.

Despite the decline in the total number of samples tested, the number of barley seed samples sent to the O.S.T.S. remained relatively steady over the period 1960/1 to 1970/1 (Figure 3.1), which may reflect the increasing popularity of barley as a crop (Chapter 2: 2.1). Since 1960/1 the number of barley samples has varied between 7,000 and 13,000 (Figure 3.1), according to the weather conditions during the harvesting of the seed and the consequent effect on the quality of the seed. The decline in the total number of samples has meant that barley seed has become an increasingly important part of seed testing efforts at the O.S.T.S., from 12.8% of samples sent in in 1955/6, to 31.6% in 1969/70.

3.5 The Official Seed Testing Station for Scotland

History

The O.S.T.S.S. performs the same seed testing functions as does the O.S.T.S. It started testing seed under the Seeds Act, 1920, in 1921, at East Craigs, Edinburgh. It obtains its maintenance and development grants from the D.A.F.S., which is also the ultimate administrator and accountant for the Station.

Seed testing at the O.S.T.S.S.

The Station had originally been established in 1914 (Chapter 3: 3.2) and had received its first seed samples, totalling 602, that year, under a voluntary scheme for merchants and farmers. By the advent of the Seeds Act, 1920, it was regularly receiving over 9000 seed samples a year, a number which remained relatively constant until 1940/1 (Figure 3.2) when, as at the O.S.T.S., the War stimulated interest in agricultural productivity, one sign of which was an increase in samples entered, from 10,315 in 1940/1 to 17,857 in 1945/6.

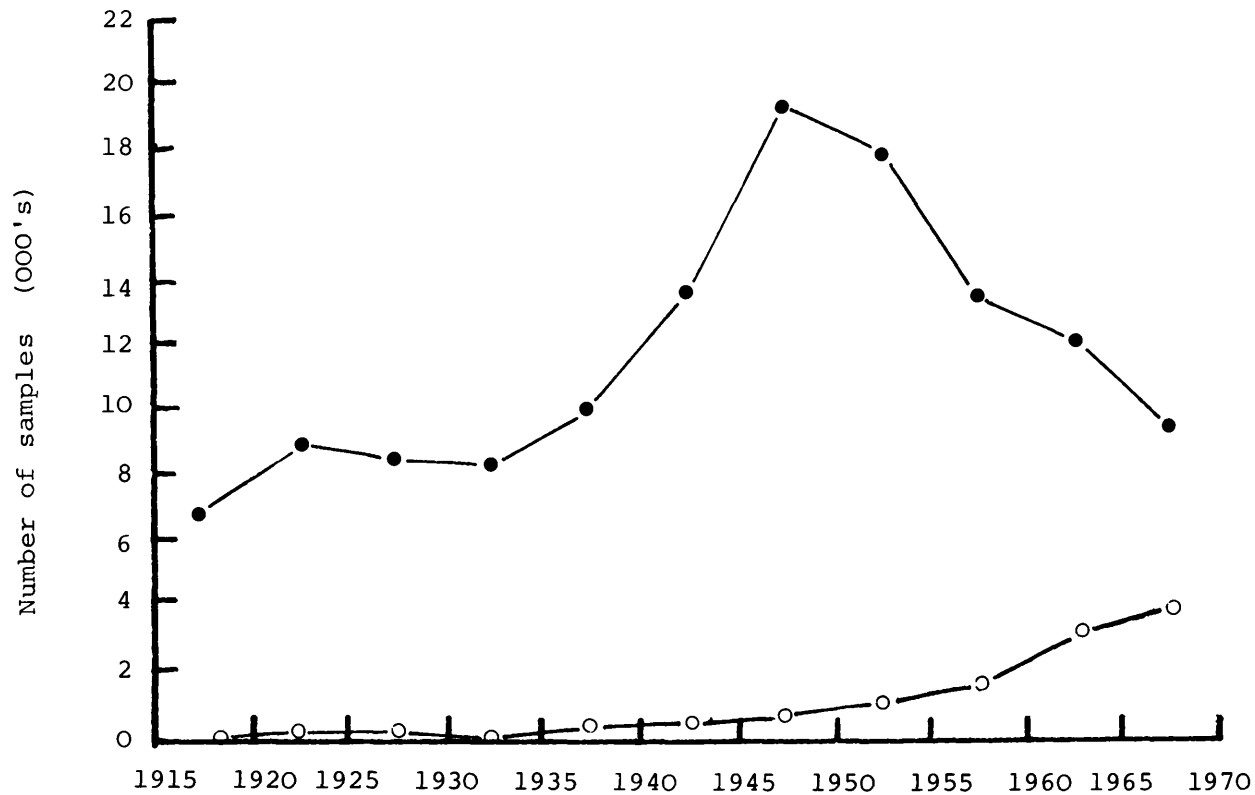


Fig. 3. 2 Number of seed samples tested at the O.S.T.S.S. East Craigs, from 1916 to 1970; all seed samples ● , barley samples ○ . (Annual figures used to calculate five year moving averages).

The number of samples received reached its peak in 1947/8 when 20554 were entered, and a high number of entries was maintained until 1953/4 (Figure 3.2). Since then, there has been a decline in numbers until in 1970/1 when only 8,887 samples were tested (Seaton, 1972 - personal communication). This was the lowest number tested in any year since 1934/5 (Figure 3.2), and it is expected that the number of samples entered in 1971/2 will be even lower (Seaton, 1972 - personal communication).

There are six private licensed stations in Scotland, which tested 42% of all the seed samples tested in Scotland in 1970/1, the rest being done at the O.S.T.S.S. (Seaton, 1972 - personal communication).

The reasons for the decline in seed testing at the O.S.T.S.S. are largely similar to those resulting in the decline in sample numbers sent to the O.S.T.S. (Chapter 3: 3.4). However, additional factors have been suggested (Seaton, 1972 - personal communication).

The fall in sample numbers may be symptomatic of the general 'squeeze' on costs due to a shortage of financial credit in the industry. Merchants who formerly sent seed to more than one testing station for verification tests now restrict themselves to a single station. Smaller Scottish firms that have been taken over by English firms now send their seed to the licensed station of the parent company in England. It was also suggested that there was a general reluctance to send in samples of all seed lots as a preliminary to buying or selling, because of an increasing belief in the certainty that most of the seed lots for sale were of high quality after years of strict control (Chapter 3: 3.8).

~~It is also possible that with present Government cereal policies (Chapter 2: 2.7) stimulating the storing of cereals throughout the cereal year, seed is often brought on to the market later in the year, so there is less time for thorough testing before it is sold (———, 1972 - personal communication).~~

Barley seed represented a very small proportion of the total numbers of seed samples received at the O.S.T.S.S. until comparatively recently. The number of barley seed samples received did not reach 1000 (5.9% of the total number received) until 1951/2 (Figure 3.2). It was not until 1958/9 that barley exceeded 10% of the seed samples received. However, since 1958/9, the number of barley samples has increased, whilst the total number of seed samples has decreased, so that the barley seed samples received in 1970/1 (Figure 3.2) represented 46.5% of all the seed samples tested at the O.S.T.S.S.

3.6 <u>Seed legislation in the United Kingdom, II : The Plant Varieties and Seeds Act, 1964</u>

The 1920 Seeds Act will be replaced by 1974 by an Act controlling cultivar breeding and seed sales and testing, the Plant Varieties and Seeds Act (H.M.S.O., 1964, p. 113-226). So far this Act affects only the plant breeders' rights and regulations; for seed quality control, the 1920 Act and the 1961 Regulations (D.A.F.S., 1962) continue to function until 1974. Nevertheless, the Act maintains the right of the Minister for Agriculture to make such regulations as are deemed expedient with changing techniques and conditions, as laid down in the Seeds Act, 1920, but not only for seed testing and sales, but also for the control of cultivar breeding and the entitlement of breeders to establish royalty rights on their plant cultivars. T[illegible] Administration is controlled by the Plant Variety Rights Office. The purpose behind this section of the Act was to make plant breeding a more worthwhile investment by enabling the breeders to gain a financial return on their breeding programmes.

In practice, this is an enabling Act, and the resulting regulations on cereal seed testing and sales can be regarded as largely similar to those of the Seeds Act, 1920, as are the regulations concerning the maintenance and control of the official and licensed seed testing stations.

3.7 The development of seed certification schemes

Schemes to assist the production of quality seed have been developed alongside the refinements in seed testing. One such scheme that is currently in operation is the British Cereal Seed Scheme (B.C.S.S.) which controls and describes the quality of cereal seed. It has been in operation since the harvest of 1969, but its origins can be traced back through a series of earlier schemes (Figure 3.3) to the increasing concern for agriculture during and after the Second World War.

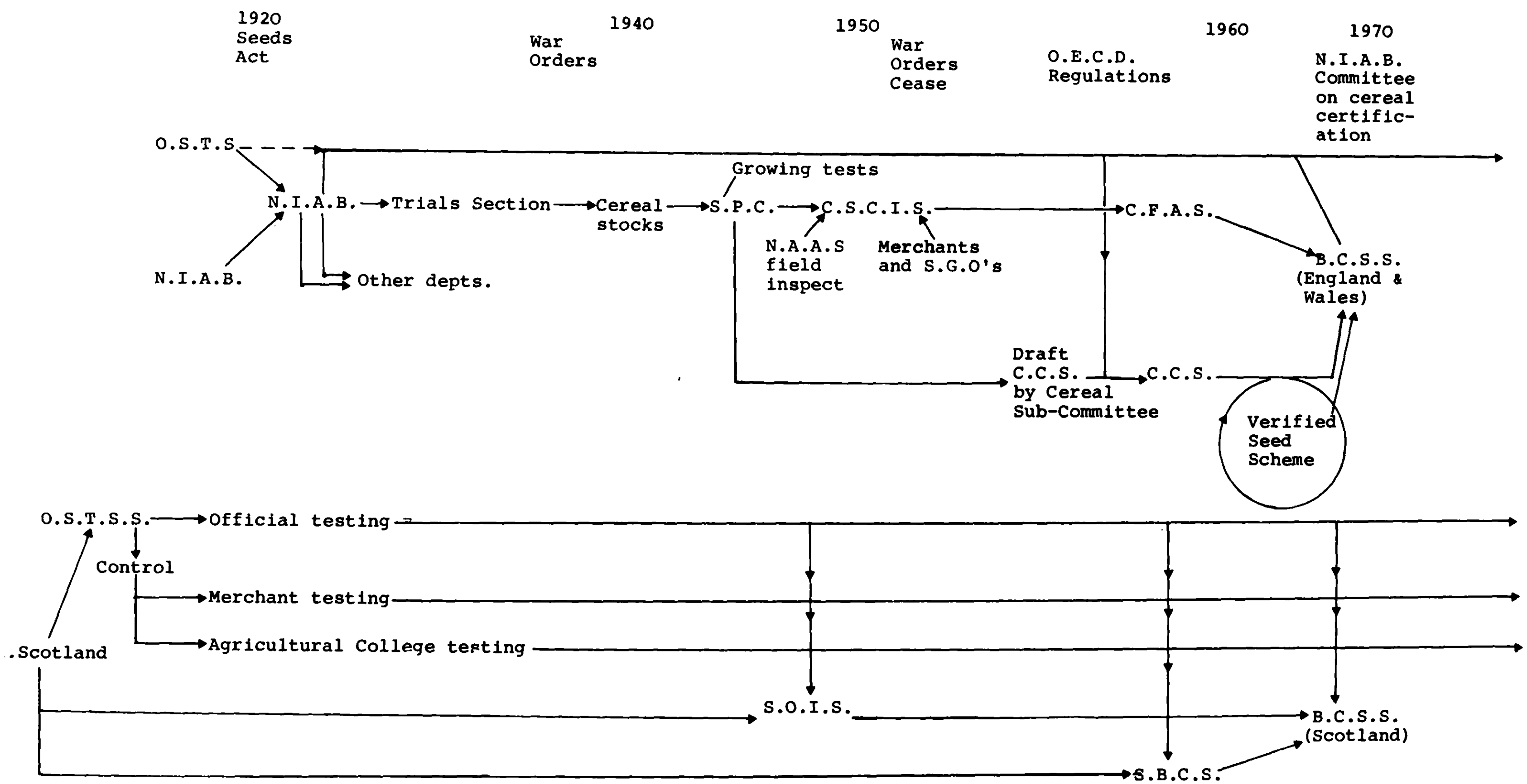
The Seed Production Committee

Under a Government war orders measure, a Seed Production Committee (S.P.C.) was set up in 1942 (Figure 3.3), at the N.I.A.B., Cambridge, to represent the interests of growers, seedsmen, farmers, the M.A.F.F. and the N.I.A.B. (N.I.A.B., 1942). The aims of the S.P.C. were: (a) to approve and co-ordinate inspection schemes for seed crops, and to undertake any other action to assist the production of high quality seed; (b) to advise on the production of agricultural and horticultural seeds in relation with home requirements, and to

Fig. 3.3 History and evolution of cereal seed certification schemes in Great Britain.

Annotations:

O.S.T.S.:	Official Seed Testing Station for England and Wales
N.I.A.B.:	National Institute of Agricultural Botany
S.P.C.:	Seed Production Committee
N.A.A.S.:	National Agricultural Advisory Service
C.S.C.I.S.:	Cereal Seed Crop Inspection Scheme.
C.C.S.:	Cereal Certification Scheme
C.F.A.S.:	Cereal Field Approval Scheme
B.C.S.S.:	British Cereal Seed Scheme
B.A., Scotland:	Board of Agriculture for Scotland, later the Department for Agriculture and Fisheries, Scotland.
S.O.I.S.:	Scottish Oat Inspection Scheme
S.B.C.S.:	Scottish Barley Certification Scheme


1920
Seeds
Act
War
Orders
1940
1950
War
Orders
Cease
O.E.C.D.
Regulations
1960
1970
N.I.A.B.
Committee
on cereal
certific-
ation
O.S.T.S.
N.I.A.B.
N.I.A.B.
Trials Section
Cereal
stocks
Other depts.
Growing tests
S.P.C.
C.S.C.I.S.
N.A.A.S
field
inspect
Merchants
and S.G.O's
C.F.A.S.
B.C.S.S.
(England &
Wales)
Draft
C.C.S.
by Cereal
Sub-Committee
C.C.S.
Verified
Seed
Scheme
O.S.T.S.S.
Official testing
Control
Merchant testing
Agricultural College testing
Scotland
S.O.I.S.
B.C.S.S.
(Scotland)
S.B.C.S.

imports and exports; (c) to look into methods of seed production, and (d) to act as a liaison body between plant breeders and other research stations producing 'certified mother seed' (that is, first and second generation from the breeders' stocks), and the growers, and the distribution of the resulting 'commercial seed crops' (seed which has not been tested for a grading scheme).

The S.P.C. performed these functions throughout the remaining years of the War, but a controlled crop inspection scheme was not initiated until 1947, when the S.P.C. inaugurated a 'Cereal Seed Crop Inspection Scheme' (C.S.C.I.S.) (Figure 3.3), in which the crops of mother seed were inspected in situ.

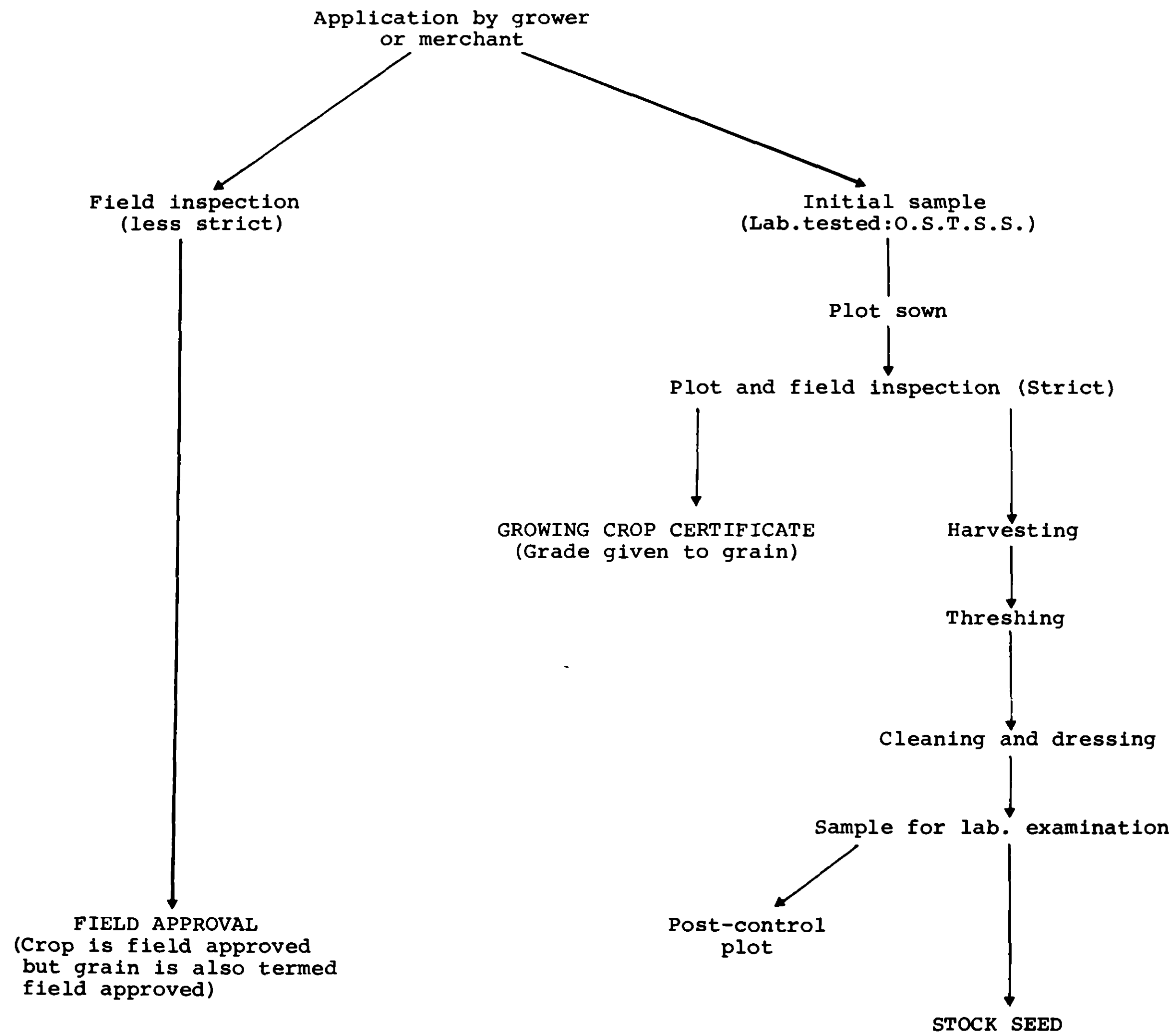
Individual merchants were asked to co-operate in the C.S.C.I.S. for the 1947 harvest, and 45 firms were approved as inspectors. Twenty seven thousand acres of cereals were inspected that season.

The Oat Inspection Scheme in Scotland

Meanwhile, the D.A.F.S. had started a trial Oat Inspection Scheme (O.I.S.) in Scotland, later known as the Oat Certification Scheme (O.C.S.),in 1947/8 (Figure 3.3). Under the O.I.S. (Figure 3.4) growing crops could be examined by official inspectors for weeds, genetical purity and disease. If the crop passed these quality control tests, it received a Field Approved Certificate and the grain could be merchandized as Field Approved. However, for higher grading of seed, a sample of the seed was sent to the O.S.T.S.S., where it was examined for weeds and diseases and then sown in an experimental plot. This plot was inspected in the same way as the crop grown from that seed lot. If they were both satisfactory, the crop was

Fig. 3.4 Schematic flow diagram of the Oat Inspection Scheme for Scotland.

Source: Thompson, 1963.


Application by grower or merchant
Field inspection (less strict)
Initial sample (Lab.tested:O.S.T.S.S.)
Plot sown
Plot and field inspection (Strict)
GROWING CROP CERTIFICATE (Grade given to grain)
Harvesting
Threshing
Cleaning and dressing
Sample for lab. examination
Post-control plot
STOCK SEED
FIELD APPROVAL (Crop is field approved but grain is also termed field approved)

given a Growing Crop Certificate and the seed from that crop could be sold with this Certification. For the highest seed grade, Stock Seed (Figure 3.4), the harvested grain was further examined in the laboratory after cleaning and dressing (the coating of seed with a pesticide or fungicide). A post-control plot was also sown the following spring to show up any errors made in the laboratory tests.

Breeders', or mother seed, and Growing Crop Certificate seed were eligible for entry into Stock Seed certification; however, seed harvested from a Field Approved crop could not be further multiplied within the Scheme. The O.I.S. was eventually put into full operation in 1950.

<u>The Comprehensive Certification Scheme for England and Wales</u>

In 1947, the Lincolnshire Seed Growers' Association (L.S.G.A.) asked the N.I.A.B. Council to formulate a scheme for the certification of pedigree herbage seed, that is, mother seed and its pure progenitors (N.I.A.B., 1947). The S.P.C. put forward a scheme for the 1948 harvest (N.I.A.B., 1948) which allowed for the complete certification of seeds as opposed to field inspection only. The seed would also be laboratory tested either by the O.S.T.S. or by licensed stations.

In 1949, the S.P.C. inaugurated 'growing-on' tests for the L.S.G.A.'s recommended scheme (N.I.A.B., 1949), where a plot of the field approved material was compared with either stock seed or breeders' seed. However, no further developments were undertaken until 1952/3 (N.I.A.B., 1954) when the S.P.C., which had continued to function although the war order ceased in 1952 (N.I.A.B., 1952), put up a draft scheme for a Comprehensive Certification Scheme (C.C.S.) for herbage seeds.

The C.C.S. was finally used on a limited scale to provide authentic certified cereal stocks for further seed multiplication in 1955 (N.I.A.B., 1956) (Figure 3.3) based on two categories of certification:

(a) Foundation seed (F.S.) - the first general increase of breeders' seed, and called the 'basic material' (N.I.A.B., 1955).

(b) Registered seed (R.S.) - the produce of F.S., and breeders' seed which did not reach the F.S. standards.

The C.C.S. administration was undertaken by a Cereal Seeds Sub-Committee, and the S.P.C. undertook the supervision and inspection of the Scheme. The Scheme implied the application of certain standards to the growing crop, seed samples and varietal and stock identity.

The Cereal Field Approval Scheme for England and Wales

In 1955, the S.P.C. started a Cereal Field Approval Scheme (C.F.A.S.) (Figure 3.3) which evolved from the C.S.C.I.S. and was run on much the same lines except that it could accept seed for multiplication from the C.C.S. (N.I.A.B., 1956). By 1959, 187 licensed merchants and five licensed S.G.A. were participating in the C.F.A.S. (N.I.A.B., 1960), inspecting 241,869 acres of cereals, of which 20% was of barley.

In 1964, the S.P.C. introduced new rules for the C.F.A.S., especially for crops intended for the production of seed designated as multiplication seed, and suitable for the sowing of crops to be entered in the C.F.A.S. the following season. Thus the field approved seed became the graded seed for general use, and could not be re-entered for the C.F.A.S. in the following season. In 1965, it was further decided that multiplication seed could only be re-entered into the C.F.A.S. if samples of the seed were sent to the N.I.A.B. for verification tests (Verified Seed Scheme, Figure 3.3).

The Scottish Barley Certification Scheme

Although there had been an O.I.C. (later the O.C.S.) since 1950 (Figure 3.3), barley and wheat remained outside any form of seed grading scheme until 1959, when the D.A.F.S. inaugurated the Scottish Barley Certification Scheme (S.B.C.S.) (Figure 3.3) following a similar design to the O.C.S. (Figure 3.4). The main difference between the Schemes was that to reach field approved standard, the harvested grain had to pass a test for loose smut (Ustilago nuda) disease of barley (Thomson, 1963).

The purpose of the Scheme was to raise the standard of uncertified seed sold to the farmers by producing a small quantity of very high quality seed which could be used by seed growers for multiplication out of the Scheme (Thomson, 1963).

3.8 The British Cereal Seed Scheme

In 1966, the N.I.A.B. Council approved a special sub-committee (Figure 3.3) to consider the cultivars of cereals and other crops in relation to the requirements for certification and field approval of seed crops. It reviewed the principle which governed the acceptance of cereal seed stocks for the C.F.A.S. and the C.C.S., and noted procedures used in the Scottish schemes (N.I.A.B., 1967).

The recommendations made were that the C.F.A.S. should be revised and amalgamated with the C.C.S. and the Verified Seed Scheme (Figure 3.3), and that the new scheme should take over the individual schemes for England and Wales, Scotland and Northern Ireland. The new scheme, the B.C.S.S. (Chapter 3: 3.7), used nomenclature and structures suggested by the Organization for Economic Co-operation and Development (O.E.C.D.) (N.I.A.B., 1967; Horne, 1965; Thomson, 1969), and was started with the harvest of 1969 and immediately included all cereal species grown in the United Kingdom.

Structure of the B.C.S.S.

The Scheme consists of four stages (Figure 3.5) (N.I.A.B., 1967):

Stage 1) The production of Basic Seed (B.S.) by breeders, or their agents, in close co-operation with the N.I.A.B., to ensure its acceptability for further multiplication.

Stage 2) The production of Certified Seed (C.S.) eligible for the O.E.C.D. blue or red labels (signs of international recognition of standards set up by the O.E.C.D.), by approved seed merchants and growers.

Stage 3) The production of Multiplication Stock (M.S.) seed for the further multiplication of the Scheme's seed.

Stage 4) The production of Field Approved (F.A.) seed under simple field inspection arrangements.

The C.S. grade has procedures and standards equivalent to the top grade of the S.B.C.S. and the O.C.S. (Thomson, 1963). The M.S. grade takes aspects from the C.C.S., the S.B.C.S. and the O.C.S.'s multiplication seed and stock seed grades. The F.A. grade uses procedures similar to, but of a slightly lower standard than the C.F.A.S.

In England and Wales, the B.C.S.S. is operated by the N.I.A.B. through the Cereal Seeds Committee, whilst in Scotland it is controlled by the D.A.F.S., and in Northern Ireland, by the Ministry of Agriculture (Thomson, 1969).

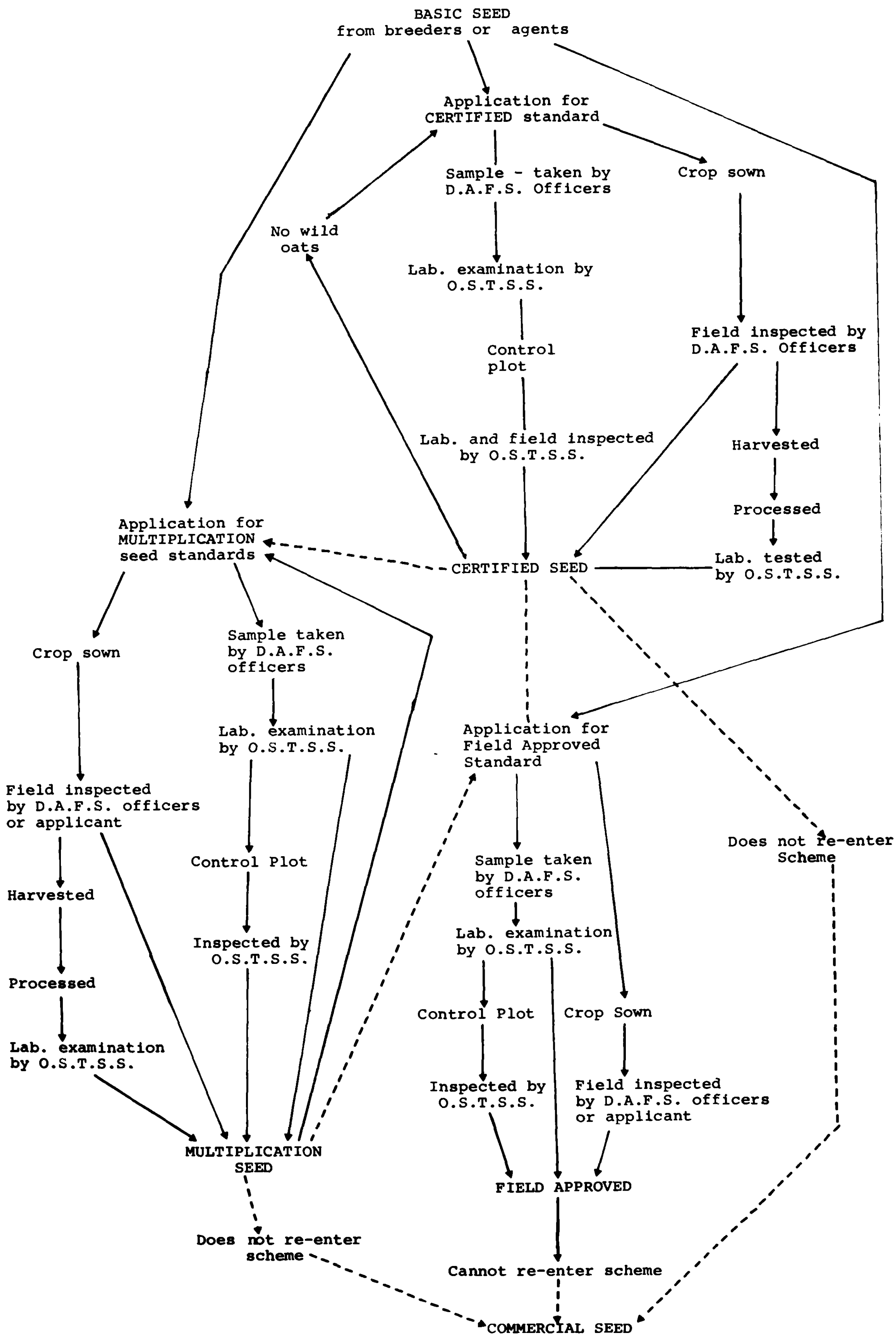
The B.C.S.C.S. in practice

In practice, the seed graded under the B.C.S.S. are used for the following purposes (Thomson, 1969). Certified seed is used solely for the production of seed to be distributed

Fig. 3.5 Schematic flow diagram of the British Cereal Seed Scheme in Scotland.

Annotations: O.S.T.S.S. - Official Seed Testing Station for Scotland

D.A.F.S. - Department of Agriculture and Fisheries for Scotland.


BASIC SEED
from breeders or agents
Application for
CERTIFIED standard
Sample - taken by
D.A.F.S. Officers
Crop sown
No wild
oats
Lab. examination by
O.S.T.S.S.
Control
plot
Field inspected by
D.A.F.S. Officers
Lab. and field inspected
by O.S.T.S.S.
Harvested
Processed
Application for
MULTIPLICATION
seed standards
CERTIFIED SEED
Lab. tested
by O.S.T.S.S.
Crop sown
Sample taken
by D.A.F.S.
officers
Lab. examination
by O.S.T.S.S.
Application for
Field Approved
Standard
Field inspected
by D.A.F.S. officers
or applicant
Control Plot
Sample taken
by D.A.F.S.
officers
Does not re-enter
Scheme
Harvested
Inspected by
O.S.T.S.S.
Lab. examination
by O.S.T.S.S.
Processed
Control Plot
Crop Sown
Lab. examination
by O.S.T.S.S.
Inspected by
O.S.T.S.S.
Field inspected
by D.A.F.S. officers
or applicant
MULTIPLICATION
SEED
FIELD APPROVED
Does not re-enter
scheme
Cannot re-enter scheme
COMMERCIAL SEED

within the seed trade. The quantity is limited to that adequate for the ultimate production, two generations later, of sufficient seed in the F.A. grade to satisfy the estimated demands of the commercial farmers. Multiplication seed is used for the regular multiplication of seed stocks. Field Approved seed is used for sale to farmers for the production of high quality crops for feed, malt and milling, but not for further seed for sale.

Figure 3.5 shows the structure of the Scheme as operated in Scotland. D.A.F.S. officials supervise the field inspection within the Scheme, and the O.S.T.S.S. undertakes the laboratory inspections and the growing of control plots (Thomson, 1969).

The Scheme is voluntary so that crops or seed lots may be withdrawn and sold, or used as commercial seed, from any point within the Scheme. Once, however, a seed lot reaches F.A. grade, or leaves the Scheme, it cannot be re-entered into the Scheme.

Table 3.1 shows the tests involved in the B.C.S.S. For the C.S. and M.S. grades, the original sample, and the harvested seed are laboratory inspected, and the crop in situ and the control plot are field inspected. For the F.A. grade, the original sample of seed is inspected in the laboratory and the crop and control plot are field inspected.

The two systems of inspection guarantee the grower definite standards of purity and the absence of diseases in his seed, plus other qualities, for example the germination test, which are designed to be related to the ability of the seed lot to produce viable plants.

Table 3.1 B.C.S.S. field and laboratory tests in Scotland

INSPECTION SITE	
LABORATORY (SEED)	FIELD (CROP)
Other Cereals	Other Cereals
Weeds	Wild Oats
Loose Smut (Ustilago nuda)	Other Weeds
Germination	Diseases
Colour and appearance	Other Barley cultivars
Size and grading	Lodging
Moisture content	Growth
Fungicidal treatment	
Ergot, detritus, etc.	

Source: Seaton (1970, personal communication)

The use of the B.C.S.S. for barley growing in Scotland

There had been a steady number of entries (circa 475 crops) into the S.B.C.S. each year since 1965 (~~Figure 3.6~~). In 1968, the year before the B.C.S.S. started, there had been 465 entries (O.S.T.S., 1968), with the majority being entered for a Growing Crop Certificate (Table 3.2). However, the advent of the B.C.S.S. was coupled with an increase in the total number of entries which reached 813 in 1971 (~~Figure 3.6~~) (O.S.T.S., 1972).

Table 3.2 Entries and percentage of crops passed at field inspection of each grade of the S.B.C.S. and the B.C.S.S. in Scotland since 1965

S.B.C.S. GRADE	YEAR			
	1965		1966	
	Entries	% Passed	Entries	% Passed
S.S.	90	67.8	82	74.4
G.C.	345	67.1	336	75.0
F.A.	No data	-	56	71.4
	1967		1968	
	Entries	% Passed	Entries	% Passed
S.S.	58	75.9	96	61.5
G.C.	337	75.1	325	77.5
F.A.	66	72.7	44	50.0

continued...

Table 3.2 (continued)

B.C.S.S. GRADE	YEAR					
	1969		1970		1971	
	Entries	% Passed	Entries	% Passed	Entries	% Passed
C.S.	35	94.3	29	100	36	94.4
M.S.	283	93.0	294	90.5	345	87.8
F.A.	146	89.4	218	95.9	381	95.6

Sources: D.A.F.S. Seed Section Annual Reports (1917-1963)
Seaton, 1972, personal communication.

The increase in crop entries was particularly evident for the F.A. grade which replaced the field approved grade of the S.B.C.S. This increase may reflect the easing of standards as compared to those of the S.B.C.S. (Table 3.2), and, possibly, the increasing use of the F.A. grading to denote high quality seed for crops to be grown for high quality feed and malt grain (Keppy, 1972 - personal communication). It is possible that some merchants may be using the grade as an advertizing feature.

The decline in numbers entered for the C.S. grade as compared with the stock seed grade of the S.B.C.S. (~~Figure 3.6~~) is less easily explained. It is possible that much of the supply of C.S. for Scotland is being produced and certified in England (Seaton, 1972 - personal communication) and then multiplied in Scotland.

The actual acreage of crops within the B.C.S.S. is a very small proportion of the barley grown in Scotland (Table 3.3). However, it is the production of seed from those crops that would show the influence of the B.C.S.S.; these figures do not include importations of B.C.S.S. graded grain, particularly from England.

Table 3.3 Barley acreage that passed field inspection grades, expressed as a percentage of the total barley acreage in Scotland, 1970

	ACRES	PERCENTAGE OF ACREAGE
Estimated total barley crop	708,000	100.0
C.S. grade acreage	524.6	0.07
M.S. grade acreage	5,293.1	0.75
F.A. grade acreage	4,353.2	0.61

Sources: D.A.F.S. (1971); O.S.T.S.S. (1970).

Thomson (1969) notes that the original aim of the Scheme was to produce a small quantity of tightly controlled, high quality seed for sale to seed producers, who would multiply it out of the Scheme and sell the produce to commercial farmers. The ultimate product would thus be raised in standard, although it would remain uncertified, by passing through the Scheme during its early generations.

3.9 Influence of the European Economic Community

When Britain becomes a member of the European Economic Community (E.E.C.) in 1973, there will be changes in the control of seed sales (M.A.F.F., 1971, Internal memorandum). There will be a ban on the sale of uncertified cereal seed, and a certification system will be used which, for cereals, will only certify seed one and two generations from the breeders' basic seed. There will be compulsory minimum standards for genetical purity, laboratory germination levels, and freedom from weeds and diseases in the certification arrangements similar to those in present use in the B.C.S.S. The complete changeover to the E.E.C. system will be undertaken by July, 1976, but present British restrictions on E.E.C. certified seed would be removed by 1st July, 1973.

The E.E.C. system may result in a greater amount of 'own-grown' seed being produced (Seaton, 1971 - personal communication) particularly by those growers having their own adequate storage facilities. Those farmers without such facilities would have to buy seed, possibly at a higher price (Seaton, 1971 - personal communication; Keppy, 1972 - personal communication; Harley, 1971 - personal communication) because of the costs of certification, and the changing market situation.

Chapter 4

SEED AS A PRODUCTION FACTOR: SURVEY WORK IN SCOTLAND

4.1 Introduction

As a preliminary to evaluating the agronomic and economic feasibility of reducing sowing densities in spring barley in Scotland, a description of the present use of seed by Scottish barley growers is necessary. Some information on this is given in Britton's report on the production, marketing and utilization of cereals (Britton, 1969), which describes the position for all cereals grown in the United Kingdom in 1967.

Britton's report, because of its comprehensive coverage, contains little specific data on the use of seed barley in Scotland, and describes the situation five years ago.

Some information regarding the popularity of spring barley cultivars and the use of certified seed (also termed graded seed) is available from the B.C.S.S. field inspection figures for Scotland (Chapter 3:3.8).

Because of the paucity of information on the use of seed barley in Scotland, two surveys were undertaken, one in 1970 (survey A) and the other in 1971 (survey B).

These surveys were intended to give a clearer picture of a) the present use of barley cultivars by the grower, b) the sowing densities used, c) the seed costs incurred, d) the choice of seed grade by the farmer, and e) the attitudes of farmers to their seed as a production factor.

The first survey (A) served as a pilot for the second (B), and the details of the methodology of both surveys are given in Appendix A.

Survey A

Postal questionnaires were sent to a group of 100 barley growers in December, 1969. The growers were not selected on a random basis (Appendix A). Most of the recipients were located in the east and south-east of Scotland. Enquiries concerning the two previous growing seasons for spring barley, 1968 and 1969, were made. Sixty-six per cent of the questionnaires were completed and returned.

Survey B

After survey A, a second questionnaire was prepared (Appendix A) and distributed by post in January, 1971, to a sample of 200 growers. The growers were not selected at random from all the growers of barley in Scotland, but the sample size differed between counties according to the proportion of the total barley acreage in Scotland grown in each county. The appropriate number of growers were randomly selected from all the growers within each county. This method of selection was an attempt to counteract the skew distribution of acreage sizes whereby there are a large number of growers growing small acreages of barley. In Scotland, in 1970, circa 51% of the barley growers grew only 13% of the barley acreage (D.A.F.S., 1971).

In the sampling method, there would be a tendency to over-sample the larger acreage growers of barley, since the sample size varied between counties according to the acreage grown in those counties, and not the number of barley growers.

The questions covered the whole of the 1970 season and certain points concerning the 1969 and 1971 seasons. The response was lower than that for survey A, 38% of the questionnaires distributed being completed and returned.

Most of the following tables were based on survey B, but some points are made from information accruing from survey A. In addition, comparisons are made with other sources of information.

One of the respondents, henceforth known as AB farm, grew an acreage of spring barley which represented 26.9% of the total barley acreage surveyed in 1971. Table 4.1 contains data both with and without the inclusion of AB farm.

4.2 Choice of cultivars

The response to survey B included information on sixteen cultivars grown over the seasons 1970 and 1971. The popularity of each barley cultivar as a percentage of the total barley acreage surveyed is shown in Table 4.1.

Table 4.1 Percentage of total barley acreage sown with different barley cultivars, in survey B, during 1970 and 1971.

Cultivar	1970 With AB farm %	1970 Without AB farm %	1971 With AB farm %	1971 Without AB farm %
Golden Promise	28.3	37.1	29.7	38.8
Zephyr	28.1	14.1	33.1	21.2
Ymer	18.6	25.5	15.1	20.7
Sultan	10.6	14.6	7.3	9.9
Julia	9.6	2.2	8.9	1.4
Maris Baldric	1.6	2.2	0.5	0.6
Vada	1.4	2.0	1.5	2.1
Freja	0.8	1.0	-	-
Crusader	0.4	0.4	0.5	0.6
Cambrinus	0.2	0.4	-	-
Akka	0.2	0.2	0.5	0.6
Deba Abed	0.2	0.3	-	-
Midas	-	-	1.5	2.2
Berac	-	-	0.5	0.6
Clermont	-	-	0.7	1.0
Gerkra	-	-	0.2	0.3
Total	100.0	100.0	100.0	100.0

The most popular cultivar was Golden Promise when AB farm was excluded, but the large acreage of Zephyr grown by AB farm put Zephyr at the top of the full list in 1971. Similarly, the high level of popularity of Julia was accounted for by AB farm's preference for that cultivar.

B.C.S.S. (Chapter 3:3.8) field inspection statistics (Table 4.2) showed that Golden Promise was the dominant cultivar in Scotland in both 1970 and 1971. Ymer showed a similar share in survey B as in the B.C.S.S. data, but Zephyr represented a much lower proportion in the latter data.

Table 4.2 Proportion of acreages of named cultivars based on acreages field inspected for the S.B.C.S. and the B.C.S.S. , from 1965 to 1971

		Cultivar*							
		Ymer	Golden Promise	Man's Baldric	Pallas	Freja	Sultan	Zephyr	Midas
Scheme	Year	%	%	%	%	%	%	%	%
SBCS	1965	50.7	0	13.2	9.3	9.5	0	0	0
"	1966	62.2	0	19.8	3.2	5.1	0	0	0
"	1967	69.9	2.3	14.8	4.9	2.9	0	0	0
"	1968	46.7	37.3	8.1	3.9	1.9	0	0	0
BCSCS	1969	32.8	44.6	3.8	2.2	0.2	6.6	5.0	0
"	1970	25.6	42.9	2.7	1.3	0	7.3	8.1	7.4
"	1971	17.2	54.0	0.4	0.3	0	5.9	8.9	7.6

* Other cultivars that did not attain 7.0% of the acreage inspected are excluded.

Source: S.B.C.S. and B.C.S.S. unpublished data (Chapter 3: 3.7).

Firmly established cultivars tended to be less well represented in the B.C.S.S. data, especially in the seed certification levels of the scheme (Chapter 3:3.8). These data did not take into account seed from crops grown in the rest of the United Kingdom and brought into Scotland. This may have affected the Scottish statistics for Zephyr and Sultan which were both commonly grown in England (Darlington, 1969).

The overall trends in the use of cultivars over the past seven years are also evident from Table 4.2, which shows that Golden Promise supplanted Ymer as the dominant cultivar in 1969, and also records the decline and arrival of other popular cultivars.

Britton (1969, p.70) noted that the choice of cultivar by growers was associated with the cereal acreage of the growers, and that the larger growers were those with a greater tendency to use newer cultivars (Table 4.3), in this case Zephyr and Impala.

Table 4.3 Cultivars of barley grown in the United Kingdom in 1967

	Percentage of farmers who grow some:							
	Proctor %	Zephyr %	Impala %	Vada %	Ymer %	Rika %	Dea %	Man's Badger %
Cereal acreage:								
0-49 acres	31	17	13	9	12	9	5	4
50-99 acres	31	31	16	14	12	11	8	9
100-299 acres	28	34	26	13	12	3	16	7
300+ acres	36	44	23	13	11	4	27	19
Participation class:								
A	24	36	33	12	12	13	17	11
B	31	26	16	12	12	7	7	6
C	32	22	11	11	12	9	9	6

Source: Britton (1969, p.79).

Using the cereal acreage groups suggested by Britton (Table 4.4) amongst the respondents to survey B, a tendency for the larger growers to use the newer cultivars was seen (Table 4.4). For example, Golden Promise, in 1970, was significantly associated, as measured by chi-square (X^2) analysis, with the larger acreage growers (Appendix A). Ymer, an older cultivar (O.S.T.S.S. annual data), showed a tendency towards being favoured by the smaller growers (Table 4.4). Although this tendency was not significant for any of the years covered by the survey (Appendix A), Ymer was the dominant cultivar for the smallest growers in each year.

Table 4.4 Choice of cultivars in four acreage size groups*

in survey B, in 1969, 1970 and 1971

	No. of Growers	Ymer %	Golden Promise %	Zephyr %	Sultan %	Midas %	Julia %	Maris Baldric %
		Percentage of growers who grew some: **						
Total, 1969:	71	47	43	27	24	0	3	4
Acreage group: ***								
0- 49 acres	22	63.6	9.1	22.7	13.6	0	0	0
50- 99 acres	18	44.4	50.0	22.2	11.1	0	0	5.6
100-299 acres	28	42.9	60.7	28.6	35.7	0	3.6	7.1
300+ acres	3	0	100.0	33.3	0	0	33.3	0
Total, 1970:	73	47	47	27	22	0	9	3
Acreage group:								
0- 49 acres	26	61.3	19.2	3.8	15.4	0	3.8	0
50- 99 acres	21	38.1	52.4	42.9	9.5	0	4.8	9.5
100-299 acres	22	40.9	68.2	36.4	45.5	0	9.1	0
300+ acres	4	25.0	75.0	25.0	0	0	25.0	0
Total, 1971:	72	42	57	31	17	11	6	1
Acreage group:								
0- 49 acres	23	52.2	30.4	8.7	4.3	4.3	4.3	0
50- 99 acres	17	35.3	76.5	35.3	5.9	0	5.9	0
100-299 acres	31	38.7	64.5	41.9	32.3	19.4	3.2	3.2
300+ acres	1	0	100.0	100.0	0	100.0	100.0	0

* As a percentage of the number of growers in each acreage group.

** Cultivars not attaining 3.0% are excluded.

*** Extrapolated from mean of 1970 and 1971.

Britton (1969, p.70) graded growers into three categories of 'participation' in the industry (A, B and C) depending on various peripheral agricultural activities and views, such as their membership of farmers' associations and views regarding the grading of seed. He found (Table 4.5) that the class A farmers, with the higher 'participation' index, were, in general those growing the larger acreages of cereals, who were also those growers using the newer cultivars (Table 4.3). This suggests that the use of new cultivars is associated with the degree of 'participation' in the industry.

Table 4.5 Distribution of farmers in each 'participation' index class by cereal acreages, in the United Kingdom, 1967.

Participation class	A%	B%	C%	Total %
All farmers:	14	34	52	100
Acreage groups:				
0-49 acres	6	30	64	100
50-99 acres	18	36	46	100
100-299 acres	30	45	25	100
300+ acres	48	36	16	100

Source: Britton (1969, p.71).

It is apparent from Table 4.4 that, since the totals exceed 100%, growers often used more than one cultivar. The number of cultivars used per grower increased with increasing barley acreages (Table 4.6) in both 1970 and 1971, and the mean number of cultivars used in each acreage group was significantly different from each other except for the 0-49 and 50-99 acreage groups in 1970 (Table 4.6, Appendix A). For the purposes of this analysis, the 100-299 and the 300 plus acreage growers have been grouped together as 100 plus acreage growers.

Table 4.6 Average numbers of cultivars per grower in each of three acreage groups (0-49, 50-99 and 100 plus acres) in survey B, 1970 and 1971

	1970		1971	
	Number of growers	Number of cultivars	Number of growers	Number of cultivars
Acr age group:				
0-49 acres	26	1.12 a*	23	1.13 a
50-99 acres	21	1.67 a	17	1.82 b
100+ acres	26	2.31 b	32	2.34 c

* Any two means with a letter in common are not significantly different, as measured by the Duncan's multiple range test.

Britton (1969) also found that the larger growers grew more cultivars (Table 4.7). However, the average number of cultivars used by growers in survey B was much higher than that found by Britton, except in the lowest acreage groups. It is not possible to say whether this was due to sampling or regional differences, or to the fact that survey B was taken three years later than Britton's survey.

Table 4.7 Average numbers of cultivars per grower in each of four acreage groups, in the United Kingdom, in 1967

	Number of cultivars		Number of cultivars
All farmers:	1.56		
Acreage group:		Participation class:	
0-49 acres	1.28	A	1.89
50-99 acres	1.68	B	1.53
100-299 acres	1.82	C	1.43
300+ acres	2.20		

Source: Britton (1969, p.77).

Britton (1969, p.77) suggested that the growing of a greater number of cultivars by the larger acreage growers was to be expected, and directly due to the size of the acreages involved, and to the greater awareness of the class A 'participating' growers.

In industry, larger firms are more amenable to the uptake of innovation than smaller firms (~~Chapter [illegible]~~.) partially because they are able to try new materials and ideas on a smaller scale relative to the size of their total enterprise. This may be a factor in the use of recently bred cultivars by larger growers (Jones, 1972: personal communication).

4.3 Seed sources

Three sources of seed were defined within the scope of the main survey (B) questionnaire:

(a) The seed merchant,

(b) Other farmers,

(c) Own seed, from one's own previous harvest.

The respondents received seed from one or more of these sources, but the majority (87.3%) obtained seed from seed merchants(Table 4.8). Nearly half the respondents only used seed bought in from seed merchants. There was no significant difference between the acreage groups in the use of merchants as a seed source, as measured by χ^2 analysis (Appendix A). The larger the barley acreage, the greater the number of seed sources used (Table 4.8). Thus 51.4% of the 100-299 acreage growers used seed from more than one source, compared with 25.0% of the 50-99 acreage growers and 4.0% of the 0-49 acreage growers.

The significantly greater use of 'own seed' by the larger acreage growers (Appendix I), as measured by χ^2 analysis, may have resulted from these growers being more likely to have adequate storage facilities (Table 4.9), and some form of drying equipment. There was a significant association, as

Table 4.8 Sources of barley seed used by growers in survey B, 1971, in four acreage groups*

	No. of growers	Seed sources:** M %	F %	O %	M + F %	M + O %	F + O %	M + F + O %	Only M %	Only F %	Only O %	Total %
All growers:	71	87.3	15.8	39.4	5.3	23.7	1.3	2.6	50.7	6.6	11.8	100.0
Acreage group:												
0- 49 acres	23	69.6	21.7	13.0	4.0	0	0	0	65.2	17.7	13.1	100.0
50- 99 acres	16	87.5	0	37.5	0	25.0	0	0	62.5	0	12.5	100.0
100-299 acres	31	77.4	12.9	61.3	3.2	35.4	6.5	6.5	32.3	3.2	12.4	100.0
300+ acres	1	100.0	0	0	0	0	0	0	100.0	0	0	100.0

* As a percentage of total respondents giving sufficient information.

** Annotations: M : merchant
F : another farmer
O : own-grown

Table 4.9 Seed storage and drying facilities on survey B farms in 1970*

Characteristic:	Acreage group (acres): 0-49	50-99	100+	Total
Storage bins (with or without driers)	23.1	55.0	76.9	51.4
Floor of barn or loft (with or without driers)	73.1	60.0	42.3	58.3
Granaries and silos	7.7	0	15.4	8.3
Hot air driers available	23.1	35.0	73.1	44.4
Ventilation and cold air driers available	0	30.0	23.1	16.7
No driers on farm, but uses outside driers	23.1	0	0	8.3
No driers and not drying grain	53.8	35.0	15.4	34.9
Farms with some form of grain drier	46.2	65.0	96.2	69.4
Number of growers	26	20	26	72

* As a percentage of respondents in each acreage group, and of all respondents, giving enough information.

measured by χ^2 analysis, between the larger acreage growers and the use of storage bins, but not for the availability of drying facilities (Appendix A).

Many of the small acreage growers did not have adequate storage facilities, and there was a tendency (Table 4.9), although not significant (Appendix A) for them not to dry their grain.

4.4 Choice of seed grade

Barley growers can choose from four types of seed. These are:

(a) Seed purchased straight from the breeders, termed basic or mother seed, which is usually used for seed multiplication purposes (Chapter 3:3.7).

(b) Seed graded within the B.C.S.S. (Chapter 3:3.8). A further choice can be made between the grades of this seed.

(i) Certified seed (C.S.) - for further multiplication of breeders' seed;

(ii) Multiplication seed (M.S.) - for further high quality seed multiplication;

(iii) Field approved seed (F.A.). The standing crop from which the seed was obtained was approved; the seed is used for multiplication outside the B.C.S.S. and high quality feed and malt crops;

(c) Commercial seed - covering the whole range of purchased uncertified and non-breeders' seed, which is used for all purposes. This group includes seed bought in direct from other growers.

(d) Own seed - if available, in which case it may have been graded within the B.C.S.S. or it may be ungraded.

The choice of seed depends on the quality of the grain being produced, and the purposes for which it is being grown.

In survey B, there was a significant association, as measured by χ^2 analysis (Appendix A), between the larger growers and the use of graded seed (Table 4.10). This may have been because these growers tended to grow barley for a wider range of purposes, or it may have been a factor associated with their greater 'participation' in the industry, that is, their greater 'awareness' of the importance of the grading of seed grain (Britton, 1969, p.70).

Table 4.10 Choice of seed grades on survey B farms in 1971*

	Acreage group (acres):			
	0-49	50-99	100+	Total
Seed grade:				
(a) Basic seed	0	0	3.2	1.4
(b) B.C.S.S. graded seed	16.7	56.4	67.7	47.9
(i) Certified	4.2	6.3	16.1	9.9
(ii) Multiplication	0	6.3	19.3	9.9
(iii) Field approved	12.5	43.8	32.3	27.8
(c) Commercial seed	75.0	31.3	29.0	45.1
(d) Own seed	16.7	18.8	51.6	32.4
% of own seed grown from graded seed the previous year	0	0	48.4	21.1
Number of growers	24	16	31	71

* As a percentage of the respondents in each acreage group, and of all the respondents, giving enough information.

The generally better storage conditions of the larger acreage farms (Chapter 4:4.2) may have enabled growers in that group to use seed graded for further seed multiplication in the production of their own seed for the next season, and thus saving in seed costs.

The lower demand for ungraded commercial seed by the larger growers (that is, 100 plus acreages) may also reflect a greater concern about seed quality (Chapter 3:3.1). The larger growers were more likely to buy B.C.S.S. graded seed, and their seed was often one generation grown from bought in graded seed.

On the smaller acreage farms, there appeared to be less concern as to seed quality; this was reflected in the type of seed used, as smaller growers were significantly associated with the use of commercial ungraded seed (Table 4.10; Appendix A). The reason for this may have been the greater proportion of grain being used for feeding their own livestock. This was suggested by Britton (1969) (Table 4.11) who showed that more small growers than large growers sold none, or little, of their grain. Thus one assumes they used their grain for homestead feed alone, few keeping it for further seed.

Table 4.11 Number of sales of cereals from the 1967 crop by cereal acreages grown*

	Cereal acreages, 1967 (acres):				
	All farms %	0-49 %	50-99 %	100-299 %	300+ %
Percentage of cereal growers making:					
No sales	21	33	14	5	-
One	22	28	21	12	3
Two	25	24	28	21	19
Three	15	8	8	25	16
Four	7	4	9	12	14
Five	5	1	5	15	19
Six - eight	4	1	5	8	17
Nine or more	1	-	-	3	11
Average number of sales per farm	2.6	1.8	2.7	3.6	4.7

* Figures from a survey of the whole of the United Kingdom.
Source: Britton (1969, p.151).

The smaller growers made greater use of the cultivar Ymer, largely a feed barley (Table 4.5). This suggests that they primarily used the barley they produced as feed for their own livestock.

4.5 Sowing densities and field establishment

Sowing densities

Before possible changes in sowing densities in spring barley in Scotland can be suggested, some information on sowing densities in current use is required. Britton (1969, p.826) mentions an average sowing density for barley in Scotland as 1.65 cwts per acre. He does not divulge the source of the data. No further details are available from M.A.F.F. and D.A.F.S. statistics.

In survey B, sowing densities used by each acreage group of growers (Table 4.12) and for each of the main cultivars in use (Table 4.13) were ascertained. In 1971, the mean sowing density was 1.56 cwts per acre (Table 4.12), which was very similar for each acreage group, except for the two growers growing more than 300 acres. There also appeared to be little difference between the acreage groups in the range of sowing densities they used.

Table 4.12 Sowing densities used in four acreage groups of growers and the proportion of crops sown at four sowing density ranges, in survey B, 1971

	Acreage group (acres):				
	0-49	50-99	100-299	300+	Overall
Average sowing density:	1.57	1.58	1.55	1.38	1.56
Sowing density range:	%	%	%	%	%
1.1 -1.25 cwts per acre	17.9	8.0	9.7	50.0	11.6
1.26-1.5 " " "	57.1	56.0	62.9	50.0	56.9
1.51-1.75 " " "	3.6	24.0	24.2	0	20.7
1.76-2.0 " " "	21.4	12.0	3.2	0	10.8
Total:	100.0	100.0	100.0	100.0	100.0
Number of crops:	28	26	62	2	118

Table 4.13 Sowing densities for the main cultivars in use, in survey B, 1971

Cultivar	Number of crops	Average sowing density cwts per acre
Golden Promise	41	1.71 a*
Sultan	12	1.55 b
Ymer	29	1.52 b
Zephyr	27	1.43 c
Midas	7	1.54
Clermont	5	1.55

* Any two means with a letter in common are not significantly different, as measured by the Duncan's multiple range test. Midas and Clermont were not included.

The crops of the cultivars Golden Promise, Ymer and Zephyr were sown at significantly different densities (Table 4.13; Appendix A), and Sultan crops were sown at similar densities to those of Ymer, but at significantly different densities to those of the other cultivars (Table 4.13; Appendix A). The average sowing density used for Golden Promise was noticeably higher than that of any of the other major cultivars (Table 4.13).

One source of variation in sowing densities between cultivars is that there is some variation in seed weight between cultivars (Chapter 9:9). Golden Promise has generally a lighter seed than, for example, Ymer; thus, to obtain a corresponding number of seeds one should sow less by weight of Golden Promise than Ymer. Keppy (1972, personal communication) suggested that there had been no experimental evidence to show that Golden Promise required a higher plant density to achieve better yields, but that growers generally believed that to be the case. The basis of this belief is unknown, but it has not been on the advice of the advisory services.

Interestingly, survey B showed that the high sowing density of 1.75 cwts per acre, which was the most popular density for Golden Promise, gave a higher average yield than lower and higher sowing densities of Golden Promise (Table 4.14).

Table 4.14 Sowing density and grain yield in Golden Promise cultivar, 1970

Sowing density cwts per acre	Number of crops	Average grain yield cwts per acre
1.25	1	34.0
1.38	1	30.0
1.5	11	35.6
1.7	1	39.0
1.75	14	39.4
2.0	7	34.2

Boyd (1952) claimed that 1.5 cwts per acre was a common sowing density in the United Kingdom, which suggests that there has been little change in the average sowing density (1.56 cwts per acre in 1970 and 1971 in survey B) over the past twenty years.

Field establishment

The replies to a question in survey A showed that the respondents know very little about the kind of plant population or density they were aiming for. Only six gave a reply of any kind; the remaining sixty respondents did not reply to that question, or replied that they did not know.

In discussions with six farmers in Fife and the Lothians in 1970, three basic reasons were given for the use of current sowing densities: (a) common practice, (b) suit the types of land - most suggested the lighter the land the lower the sowing density, and (c) the advice of seed merchants. However, when each farmer was asked about the plant populations they were aiming for, only two replied, when pressed, with 2 million and

2 to 3 million plants per acre. The other replies included a 'fair stand' and stands with no irregular spaces between plants. Thus, there appeared to be a general inability to express quantitatively the plant stands aimed for by growers.

4.6 Yields in relation to sowing densities

There was an increase in average yields with increasing sowing densities, up to 1.75 cwts per acre (Table 4.15). The highest yields occurred in the 1.51 to 1.75 cwts per acre sowing density range, reflecting the large number of Golden Promise crops sown at this density, since this cultivar had the highest average yield per acre of the main cultivars (Table 4.15).

4.7 Seed costs in 1970

The choice of seed depends on the use to which the crop will be put (Chapter 4:4.3) and the availability of the seed. For higher quality crops, such as are needed for malt grain and seed grain for sale, a higher quality of seed is bought (Chapter 3:3.1); usually a quality signified by a B.C.S.S. grading. Naturally the higher the quality of the seed, the more expensive it was (Table 4.16). Basic seed was generally more expensive than even B.C.S.C.S. graded seed, but there is usually only a limited amount available, and this is often the case with seed for further high quality seed multiplication (Harley, 1970, personal communication).

Some cultivars are generally more expensive than others. Ymer is one of the cheapest cultivars. This is due in part to the fact that there is no plant variety levy on this cultivar (Chapter 3:3.6) since it was bred and in commercial use before 1964, the starting date for breeders' rights legislation. There is a levy which was, in 1970, £0.15p. (Inglis and Son Ltd., 1970) per cwt

Table 4.15 Sowing densities and grain yields in the main cultivars, in survey B, 1970

	Main cultivars									
	Golden Promise		Ymer		Zephyr		Sultan			
Sowing density range cwts per acre	Av. yield cwts/acre	(No. of samples)	Av. yield cwts/acre	(No. of samples)	Av. yield cwts/acre	(No. of samples)	Av. yield cwts/acre	(No. of samples)	(Total No. of Samples)	Total Av. yield cwts/acre
1.1 - 1.25	34.0	(1)	31.2	(5)	32.7	(3)	30.0	(1)	(10)	31.8
1.26 - 1.5	35.2	(12)	32.7	(22)	35.4	(14)	35.6	(11)	(59)	33.8
1.51 - 1.75	39.0	(13)	32.0	(3)	43.5	(2)	36.7	(3)	(21)	38.6
1.76 - 2.0	34.7	(8)	34.0	(2)	-	-	34.0	(1)	(11)	34.9
Total average: 1.56	36.8	(34)	32.5	(32)	35.8	(19)	35.3	(16)	(101)	

of seed, payable by the grower, on the more recent cultivars.

Table 4.16 Seed purchase costs of the main cultivars grown, in survey B, 1970

	Seed grade				
	Commercial and estimates for own-seed	Field approved	Multi-plication seed	Certi-fied seed	Basic seed
Cultivar	£.p. per cwt				
Golden Promise	(15)*1.78½	(8) 2.35½	(5) 3.35	-	(1) 6.30
Ymer	(19) 1.87½	(2) 1.82½	(2) 4.10	-	(1) 6.30
Zephyr	(4) 1.98	(7) 2.66	-	(1) 4.50	(1) 6.30
Sultan	(4) 2.09	(2) 3.35	(1) 3.00	(1) 3.10	-
Average**	(47) 1.90½	(23) 2.36½	(11) 3.53	(4) 3.80	(3) 6.30

* (No.) denotes the number of seed purchases.

**Including information on all seed purchases covered by survey B.

The size of the market for the seed and its availability may also influence the average cost of the seed. Thus very new cultivars, which may be limited in supply, may be more costly. For example, two new cultivars in 1971, Clermont and Midas, show generally higher seed costs at all seed grades (Table 4.17).

Table 4.17 Seed costs of the cultivars Clermont and Midas, in survey B, 1971

	Seed grade			
	Commercial seed	Field approved	Multiplication seed	Certified seed
Cultivar	£.p. per cwt			
Clermont	-	-	-	(5) 4.51
Midas	(2)* 3.22½	(1) 4.50	(2) 4.56½	-

* (No.) denotes the number of seed purchases.

4.8 Returns on seed investment

A comparison can be made of the efficiency of seed use between growers by calculating the returns made on seed investment. That is, the difference between the grain output and the seed costs.

The returns on seed investment were calculated for each cro- grown by every grower responding to survey B, including crops using own-grown seed and/or producing grain that was not sold. Where seed costs and grain prices were not given by the respondent, estimated values were included based on the opportunity costs foregone by using own-grown seed or retaining the grain. The opportunity costs were based on the market prices for the grain had it been sold (M.A.F.F. and D.A.F.S. statistics) and seed prices for the different grain grades (Chapter 4:4.6; D.A.F.S. statistics).

Table 4.18 shows the seed costs per acre and the returns on that seed investment averaged for all the growers in each acreage group. The growers in the lowest acreage group obtained the lowest returns, largely as a result of a lower average grain yield per acre and a poor grain price per cwt. Interestingly, these growers used slightly more expensive seed than the second group (50-99 acreage growers). This may be due to a greater use of own-grown seed by the 50-99 acreage growers (Table 4.8).

The 100-299 acreage growers obtained a marginally lower return on their seed investment than the 50-99 acreage growers, although the average grain yields and grain prices were relatively similar. This may reflect the greater use of the more expensive graded seeds (Table 4.10), including, it was observed, of graded own-grown seed.

The 300 plus acreage group was represented by only four growers. However, this group achieved the highest returns on investment, although at a lower grain price, due to high average yields and lower average seed costs per acre. The lower seed costs are partially a result of lower sowing densities (Table 4.12).

Table 4.18 Seed investment and returns per acre: averages for four acreage groups in survey B, 1970

	Seed costs £.p./acre*	Yield cwts/acre	Grain return £.p./cwt*	Return on investment £.p./acre*
Acreage group:				
0- 49 acres	3.26½	31.9	1.34½	39.52½
50- 99 acres	3.19½	35.5	1.42	47.03½
100-299 acres	3.99½	34.5	1.45	45.52½
300+ acres	2.71½	38.0	1.34½	48.15

* Calculated to the nearest half-penny.

4.9 Conclusions

One conclusion evident from the analysis of survey B is that there are distinctions between growers of small and large acreages of barley. These differences are reflected in certain characteristics. Larger acreage growers tended to use newer barley cultivars, make greater use of B.C.S.S. graded seed (that is, higher quality seed), have better facilities for storing and drying seed grain for use the following year, have higher average yields, and, in general, obtain a better return on their seed investment.

The smaller growers were characterized by their use of older cultivars, and ungraded seed; an inability to undertake much grain drying and storing, the obtaining of lower average yields and, on the smallest barley acreage farms, the getting of lower returns on their seed investment.

Distinctions between larger and smaller growers were noted by Britton (1969), but were largely based on interests in organizations and ideas within agriculture. He termed the distinctions as a greater or lesser 'participation' in the industry, and found that the larger growers were, in general, the greater 'participators'. The results of survey B further point to the distinction, but on the basis of seed use and facilities.

The lowest returns on seed investment were found in the smallest acreage group (0-49 acres), due to low grain yields and grain prices, and the greatest returns in the largest acreage group (300 plus acres) who ~~used~~ had the cheapest seed costs and achieved the best grain yields.

The 50-99 and 100-299 acreage growers achieved similar returns on very different seed costs. The 100-299 acreage growers' average seed cost was £0.80p. higher per acre than the lower acreage group but with a similar grain yield, and only a marginally higher average grain price achieved. This may suggest that the 100-299 acreage growers are spending more on their seed than need be necessary.

Thomson (1969) suggested that certified seed, then from the S.B.C.S. (Chapter 3:3.7), was being overproduced, and being sold to sow for lower quality crops. As this was the most expensive seed, this represented a cost the farmer need not undertake. He suggested that the use of this seed could lower their profit margin. The results of survey B suggest that this could be a characteristic of the 100-299 acreage growers, the 'middle' group.

The overall average sowing density average was 1.56 cwts per acre which indicated that there had been little change in the densities for, at least, twenty years. There was also little appreciation of plant population and density and their effects on grain yield amongst the barley growers. There was little difference between the larger growers and the smaller growers in these respects. However, there seems to have been some influence on the sowing density of one cultivar, Golden Promise. The source of the influence that has resulted in this cultivar having a higher average sowing density than any of the other major cultivars is unknown.

Section III

A biological analysis of the possibilities of using lower sowing densities than those in current use is presented in two chapters. The first includes an experiment undertaken at Stirling in which the relationship between sowing density and yield in spring barley was examined. The second chapter reviews all the available data on sowing density/grain yield field trials undertaken in England and Wales, and, separately, in Scotland, since 1960, and with reference to earlier trials. A third chapter will describe experimental work at Stirling on field emergence levels, and its relationship to laboratory germination.

Chapter 5

THE EFFECT OF PLANT DENSITY AND SOWING DATE ON SPRING BARLEY

5.1 Introduction

In general, three approaches to the study of the relationship between plant density and grain yield in cereals can be recognised. Firstly, the results of experimental work have been used to produce mathematical expressions of the yield/density relationship. This work will be reviewed only briefly in this chapter. Secondly, analyses of the reaction to density of the various components of yield have been undertaken. This developmental approach has been used in the experimental work of this chapter, and will be discussed in detail. The third approach has been more agronomic, involving sowing a crop at a range of densities and determining the relationship between density and yield in situations close to that of commercial growers. Agronomic work of this type will be considered in the next chapter.

Holliday (1960) reviewing experimental data on crops in which the yield was a product of the reproductive phase of the crop's growth as in cereals, suggested that the relationship between yield and plant density conformed to a parabolic curve when presented graphically. Some researchers have found that the yeild/density parabola for wheat (Hudson, 1941; Willey, 1965) and barley (Willey, 1965; Kirby, 1967, 1969), was flat-topped with only small decreases in yield at each side of the optimum density. The parabolic relationship has been defined mathematically by a number of workers (Shinozaki and Kira, 1956; Holliday, 1960) for crops where yield is a function of reproductive growth. All the expressions depict an increase in yield with increasing plant density up to an optimum density, after which the yield falls with further increases in density.

The equations put forward by Shinozaki and Kira (1956) and Holliday (1960) are based on the mathematical relationships between the reciprocal of mean yield and plant density, and basically the relationships describe a situation where the size of an individual plant falls as the density of the plants per unit area increases (Willey and Heath, 1969). This decline in size is explained biologically as the effect of increased competition for nutrients, water, light, carbon dioxide and physical space (Harper, 1961; Donald, 1963).

The accurate mathematical definition of the relationship between plant density and crop yield aids the agronomist, in predicting from the minimum of data, yields from a large range of sowing densities.

In cereals, the relationship between plant density and yield is complicated by their extreme morphological plasticity (Engledow, 1928; Sprague and Farris, 1931; Donald, 1963; Cannell, 1969), which is reflected in changes in the yield components. In barley, for instance, the number of ears per plant, the number of grains per ear and the average weight per grain (Kirby, 1967) all change with the increasing competition that accompanies an increase in plant density.

Recent developmental work on the yield/density relationship in barley has been concerned with the yield reduction in above-optimum densities, and, to some extent, with the yield compensation ability of low plant densities. Willey and Holliday (1971a) and Kirby (1967; 1969) found that yield reduction above the optimum could be explained by decreases in grains per ear and the average weight of individual grains. Willey and Holliday (1971a) focussed attention on the number of grains produced per ear and suggested that shading in high density crops, early in the growth of the crop, reduced the number of grains initiated and thereby reduced the capacity of the ear to store carbohydrate assimilates. This they confirmed by reducing the grain yield and the number of grains per ear after shading plants artificially during ear development.

Kirby (1967, 1969) appeared to consider grain weight to be the more important influence and attempted to explain the decline in grain yield at high plant densities in terms of a fall in the efficiency of dry matter production, particularly after anthesis (flowering). This is not in accord with more recent observations (Willey and Holliday, 1971a) that shading after anthesis did not reduce yields, and had little effect on grain weight, which suggests that carbohydrate supply during grain filling is not an important factor in the decline in yield at high plant densities.

Barley plant densities below the optimum have attracted less attention. Kirby (1969) noted considerable yield compensation at low densities in an autumn and early spring sowing, but not in a later sowing. From his data, he suggested that the main compensation came from an increase in grain weight accompanied by an increase in grains per ear and ears per m^2. The lack of compensation in the late sowing was attributed to the production of only small grains at the lower densities.

The work of this chapter is largely concerned with the ability of low densities of plants to compensate, but the results will be discussed in relation to ideas put forward in considerations of the yield reduction in above-optimum densities (Willey and Holliday, 1971a; Kirby, 1967).

Another aspect of yield/density developmental studies has been the influence of various agronomic factors, such as sowing date, spatial arrangement of plants, cultivars and levels of fertilizer application on the yield/density relationship. The marked effect that sowing date can have on this relationship has already been mentioned (Kirby, 1969).

Droughty and Engledow (1928) found that irregularities in plant distribution in wheat had an important effect on grain yield, and on the yield components, notably by decreasing tillering. However, Sprague and Farris (1931) found that the yield of barley grain from a deliberately variable plant distribution along rows was greater than from a regularly spaced distribution along rows. It has been noted that plant spatial arrangement may vary within a single plant density (Willey and Heath, 1969), and that few workers have separated rectangular arrangements and constant row arrangements of plant densities. However, when comparisons are being made with commercial practice in mind, as in this work, it is perhaps appropriate to use constant row methods.

A significant cultivar x plant density interaction was noted by Kirby (1967) for four barley cultivars, indicating that not all the cultivars responded to density in the same way. Differences in the development of vegetative and fertile (ear) tillers between cultivars have been pointed out by Cannell (1969), and in ear production by Pollhamer (1967). Pollhamer (1967), in Hungary, also found cultivar differences in 1000 grain weights and grains per ear, confirming Forbes' (1960) findings at Boxworth on six barley cultivars, and Willey and Holliday's (1971a) results for wheat cultivars.

Work on the effect of additional nitrogenous applications on the response of yield to plant density has been reviewed by Boyd (1952) and Holliday (1960). They noted some positive interactions in winter wheat for sowing density and nitrogen level, but found less evidence of interaction for spring wheat and barley. In barley, there is evidence of increased lodging at high plant densities after nitrogen applications (Glynne and Slope, 1957) which may obscure the true yield development. Several workers have shown that there was no consistent effect of increasing nitrogen levels in barley yield/density relationships (Jackson and Page, 1957; Glynne and Slope, 1957; Mundy and Page, 1972), although Rennie (1957) showed that the addition of nitrogen always increased the yield at each sowing density. Rennie's (1957) data also indicates that there was little difference between the yield/density response curve with increased nitrogen levels.

No known studies on the influence of plant density on the development of the yield components and eventual grain yield have been undertaken in Scotland. That growing conditions in Scotland are different from those in England, where much of the recent developmental work has been done (Willey, 1965; Kirby, 1967, 1969; Willey and Holliday, 1971a), is borne out by the fact that the two most popular cultivars grown in Scotland up to 1969 (Ymer and Golden Promise) were seldom grown south of the border (Darlington, 1969).

An experiment was undertaken at the experimental gardens, University of Stirling, in 1971. It was designed to look at yield compensation at low densities, and to examine the effect of cultivars and sowing dates on this compensation.

5.2 Materials and methods

Certified grade seed of the two cultivars, Golden Promise and Ymer, was obtained from a seed merchant (Harley and Son Ltd., Milnathort, Kinross-shire). Both samples were treated with fungicide (Cotol with panogen) by the merchant.

The experiment was laid out as a split plot in four replicate blocks, with the two cultivars as the main plot treatments. Within each main plot, three sowing dates and five sowing densities were completely randomized. Thus the sub-plot treatments were the combinations of sowing date and sowing density, and were sown as plots of ten rows of 4 ft (1.22 m) long and 6 in (15.24 cm) apart. The seed was sown into furrows of 1.5 in (3.77 cm) depth, at densities equivalent to 0.25 (i), 0.75 (ii), 1.5 (iii), 2.25 (iv) and 3.0 cwts per acre (v) (3.84, 94.2, 188.3, 282.5 and 376.6 kg per ha, respectively), (Table 5.1).

Table 5.1 Weights of sowing density treatments and approximate equivalent commercial sowing densities

Density treatment	Sown plot weight $g/20ft^2$	Sown plot weight g/m^2	Equivalent commercial weight: cwt/acre	Equivalent commercial weight: kg/ha
i	5.83	5.13	0.25	38.4
ii	17.46	9.39	0.75	94.2
iii	34.92	19.78	1.5	188.3
iv	52.47	28.17	2.25	282.5
v	69.84	39.56	3.0	376.6

Table 5.2 gives the number of seeds sown per plot, and the equivalent numbers per acre and per hectare. The three sowing dates were: 13th to 16th March (S1), 7th to 9th April (S2), and 11th to 14th May (S3). The S1 and S2 sowings were undertaken during the period when most of the adjacent farm crops

Table 5.2 Seed density treatments and approximate equivalent commercial seed densities

Y m e r

Density treatment	Seeds per: Plot (20ft^2)	m^2	acre	ha
			'000	'000
i	117	63	254.83	630.0
ii	350	187	762.3	1870.0
iii	702	374	1528.96	3740.0
iv	1050	561	2286.9	5610.0
v	1397	748	3042.67	7480.0

Golden Promise

Density treatment	Seeds per: Plot (20ft^2)	m^2	acre	ha
			'000	'000
i	130	70	283.14	700.0
ii	390	210	849.42	2100.0
iii	780	420	1698.84	4200.0
iv	1166	630	2539.55	6300.0
v	1560	840	3397.68	8480.0

were sown, but the S3 was sown after the normal time for sowing.

The plots were covered with netting to prevent bird damage. The soil was a uniform medium loam, dressed with 20 : 10 : 10, N : P : K, and the tilth was good on each sowing occasion. The plants were infected by a mildew attack in late May, especially the S1 and S2 sowings; but several applications of Karathane prevented extensive spread. The plots were hand-weeded throughout the experiment. Some lodging, due to heavy rain occurred from 5th to 7th August and in late September; this was not excessive but Ymer was more affected than Golden Promise.

The S1 plots were harvested from 8th to 9th September, S2 from 10th to 11th September and S3 from 13th to 15th October. The lateness of the S3 harvest was due to a prolonged wet and cloudy period in late September resulting in late maturity and late suitable harvest conditions.

The harvest sample from each plot consisted of two samples of 1ft (30.5 cm) in length from each of the middle six rows of the sub-plot, excluding 6in (15.24 cm) from each end of the rows. The two 1ft (30.5 cm) samples were randomly selected from the middle 3ft (91.4 cm) of each row. The plants were pulled by hand from the soil when the grain was fully matured and dry. They were retained in dry storage in loose sheaths for a month, at 21°C. After plant and fertile tiller (ear) counts for each plot, the roots were removed, and the plants were threshed on a small laboratory threshing machine (F. Walter - H. Wintersteiger, K. G. LD 180 ST 4) and the grain sample from each plot was weighed. The weight of 1000 grains from each plot was determined.

5.3 Results

Plant numbers at harvest

Details of the mean plant densities for each cultivar and sowing date are given in Table 5.3. The plant number data is used in calculating ear numbers per plant and as the assessment of plant density. Differences in eventual plant numbers between sowing dates may be due to differences in soil conditions at sowing time.

Grain yield

The S1 and S2 sowings significantly outyielded the S3 sowing (Table 5.5) at all densities for both cultivars (Figure 5.1 a/b) which reveals itself as a significant main effect of sowing date on grain yield (Table 5.4). Plant density had a significant effect on yield, and there was

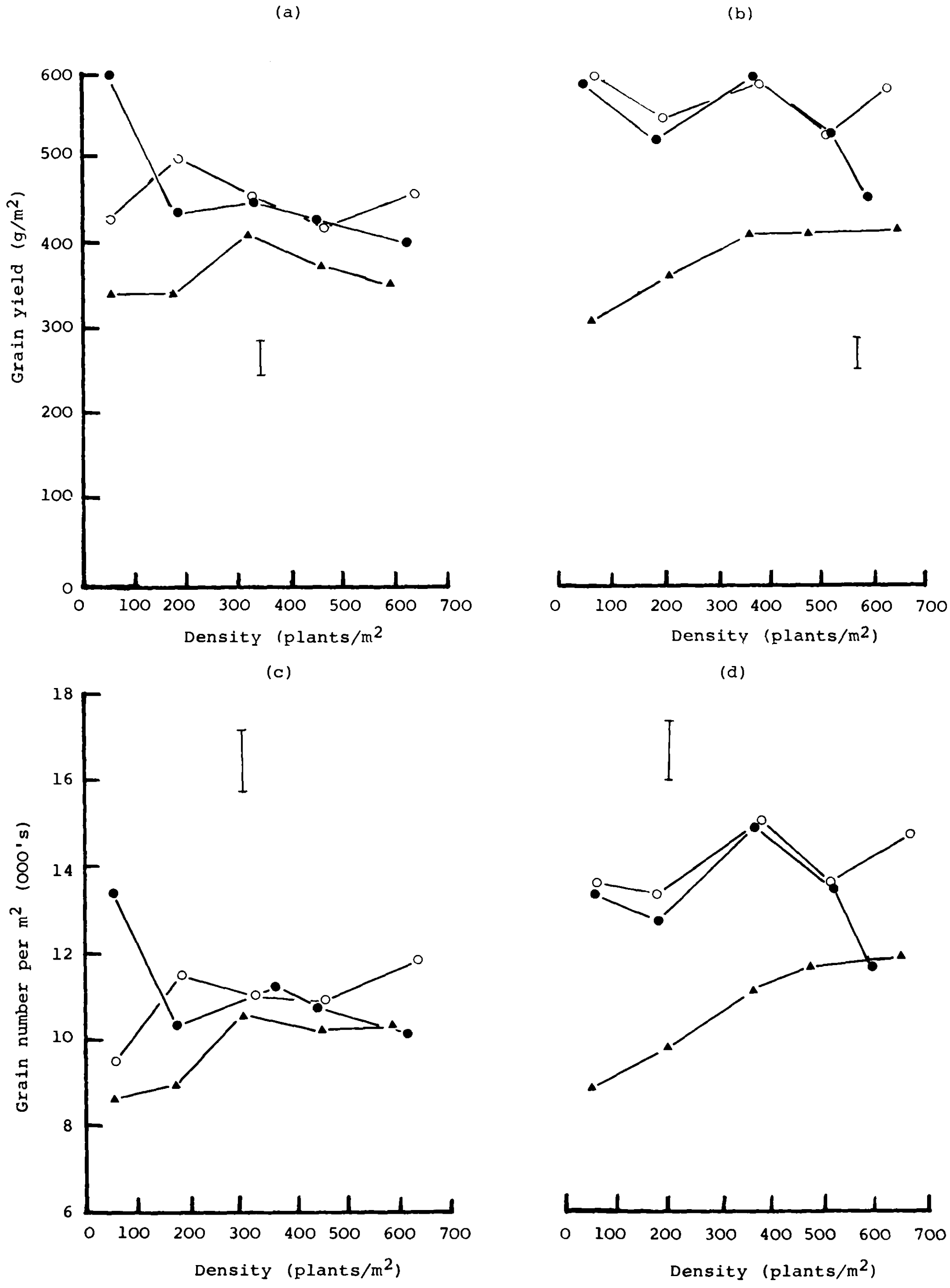


Fig. 5.1 The response of grain yield (a, b) and grains per m^2 (c, d) to plant density for Ymer (a, c) and Golden Promise (b, d), for three sowing dates: S1 = ●, S2 = ○, S3 = ▲. The vertical lines represent the L.S.D's (0.05), calculated following an analysis of variance. Each point is a mean of samples from four replicate plots.

a significant interaction between plant density and sowing date (Table 5.4), which is seen in Figure 5.1 a/b in the relationships between density and yield for the S1 and S2 sowings as opposed to the S3 sowing. There was also a significant plant density x cultivar interaction (Table 5.4).

Table 5.3 Mean plant densities (m^2) for each cultivar and sowing date

Density treatment:		i	ii	iii	iv	v
Sowing date treatment:						
Ymer	S1	59	183	334	449	626
	S2	54	187	330	470	639
	S3	54	180	316	456	596
Golden Promise	S1	63	187	372	519	596
	S2	65	194	382	513	634
	S3	61	203	364	481	652

Ear production

There was a marked decrease in the number of ears per plant with increasing plant density (Table 5.4; Figure 5.2 a/b). There is some difference between the cultivars as to the number of ears produced, Ymer producing a significantly higher mean number of ears per plant (Table 5.5) than Golden Promise in the S1 and S3 sowings.

However, the greater production of ears per plant at low densities does not make up the number of ears produced per unit area to the level of production at higher plant densities (Figure 5.2 c/d). There was a significant increase in the number of ears per m^2 with increasing plant density in both cultivars (Figure 5.2 c/d). However, the significant interaction between cultivar and plant density (Table 5.4) indicates a different relationship for the two cultivars, which is seen particularly in Figure 5.2 c/d in the low level of ears per m^2

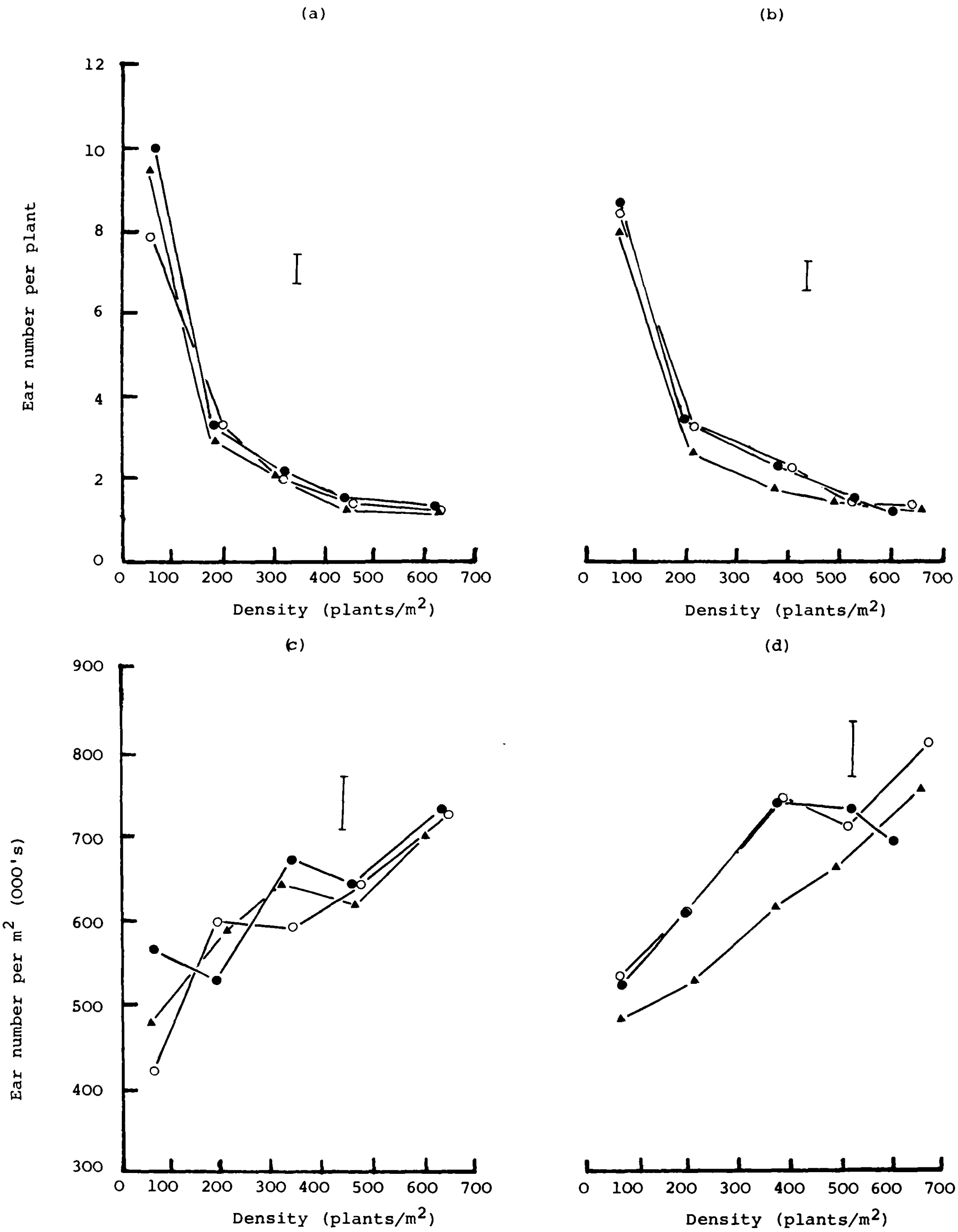


Fig.5.2 The response of number of ears per plant (a, b) and per m^2 (c,d) to plant density for Ymer (a,c) and Golden Promise (b,d), for three sowing dates: S1 = ● , S2 = ○ , S3 = ▲ . The vertical lines represent the L.S.D's (0.05), calculated following an analysis of variance. Each point is a mean of samples from four replicate plots.

in the S3 sowing of Golden Promise, but not for Ymer. This also results in a sowing date x plant density x cultivar interaction (Table 5.4).

Grains per ear

There was a decrease in the number of grains per ear in the S1 and S2 sowings with increasing plant density (Figure 5.3 a/b), and a significant difference in the mean numbers of grains per ear between the cultivars (Table 5.4; 5.5). The S3 sowing of both cultivars had a lower mean number of grains per ear than the S1 and S2 sowings (Table 5.5), which was reflected in the significant sowing date x plant density interaction (Table 5.4). There was not such a marked response to plant density in the S3 sowings (Figure 5.3 a/b).

1000 grain weight

One thousand grain weight decreased with increasing plant density in the S1 and S2 of both cultivars (Figure 5.3 c/d), although this was not as evident in the S3 sowings. The mean 1000 grain weights of the S3 sowings were significantly lower than those of the earlier sowings (Table 5.5). These responses were reflected in the main effect of sowing date and plant density (Table 5.4), and in the sowing date x plant density interaction. Although there was no significant difference between the cultivars in their mean 1000 grain weight (Table 5.5), the second order interaction of sowing date x plant density x cultivar was significant (Table 5.4), which is seen as a significant decrease in 1000 grain weight at the low densities in the S3 of Golden Promise (Figure 5.3 d).

Grain number per m^2

Figure 5.1 c/d shows the influence of grain numbers per

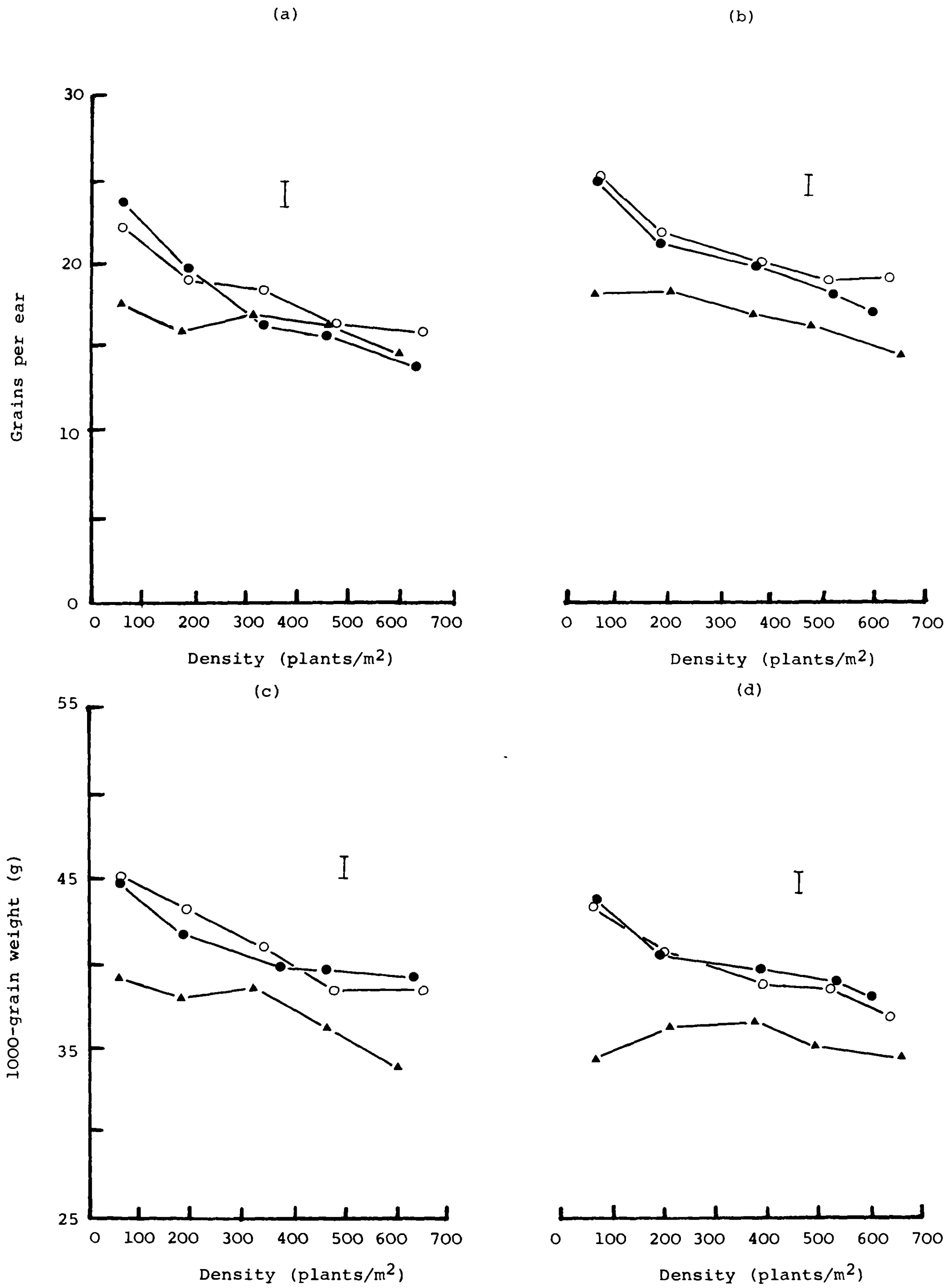


Fig.5.3 The response of number of grains per ear (a,b) and 1000-grain weight (c,d) to plant density for Ymer (a,c) and Golden Promise (b,d) for three sowing dates: S1 = ● , S2 = o , S3 = ▲ . The vertical lines represent the L.S.D's (0.05), calculated following an analysis of variance. Each point is a mean of samples from four replicate plots.

Table 5.4 Variance ratios of the treatments and interactions for the yield and yield components, and their significances.

Source of variation	Characteristic: Grain yield	Grains/m^2	Ears/plant	Ears/m^2	1000 grain wt.	Grains/ear
Cultivar	134.6594 **	121.9908 ***	4.6958 *	24.8200 *	2.8893 NS	3.5652 *
Sowing dates	208.0772 ***	31.7871 ***	2.4604 NS	44.7025 ***	175.3997 ***	2.7505 NS
Plant density	21.7152 ***	3.5583 *	43.0495 ***	62.7936 ***	54.3038 ***	456.3654 ***
Sowing date x density	4.5295 ***	4.4625 ***	1.2812 NS	8.2514 ***	6.3632 ***	0.9136 NS
Sowing date x density x cultivar	9.3517 ***	4.3572 ***	3.1442 **	1.6762 NS	3.8054 **	2.3870 *
Sowing date x cultivar	17.8567 ***	9.0140 ***	4.7008 *	2.7625 NS	1.0187 NS	2.2790 NS
Plant density x cultivar	3.4895 *	1.2308 NS	0.5459 NS	0.3893 NS	2.1033 NS	1.1591 NS

*** : Significant at $p < 0.001$
** : " " $p < 0.01$
* : " " $p < 0.05$
NS : Not significant

Table 5.5 Means of cultivar and sowing date treatments and significances of the differences between the means

Characteristic	Sowing date	Cultivars: Ymer	Cultivars: Golden Promise	$p < 0.05$ Significance
			*	**
Grain yield (g/m^2)	S1	493.3 a	394.5 b	NS
	S2	506.6 a	308.7 a	NS
	S3	388.2 b	348.7 c	S
Grains/m^2	S1	11064 a	13185 b	S
	S2	11247 a	14255 a	S
	S3	9856 b	10699 c	S
Ears/m^2	S1	603 a	661 ab	S
	S2	598 a	684 a	S
	S3	618 a	610 b	NS
Ears/plant	S1	3.55 a	3.37 a	S
	S2	3.01 c	3.19 a	NS
	S3	3.39 b	2.94 b	S
Grains/ear	S1	18.0 b	20.3 b	S
	S2	18.5 a	21.2 a	S
	S3	16.4 c	17.7 c	S
1000 grain weight (g)	S1	41.3 a	40.4 a	NS
	S2	41.4 a	39.9 b	NS
	S3	36.7 b	35.6 c	NS

* Any means with the same letter, for each characteristic and cultivar, are not significantly different from one another, at the p 0.05 level, as measured by Duncan's multiple range test.

** NS - not significantly different at $p < 0.05$

S - significantly different at $p < 0.05$.

m^2 against plant density in each cultivar, for each sowing. This is strikingly similar to the influence of plant density on grain yield (Figure 5.1 a/b).

Plant density had a significant effect on grain numbers per m^2 (Table 5.4), as did the interaction with cultivar and sowing date treatments, and the second order interactions of plant density x sowing date, sowing date x cultivar and plant density x sowing date x cultivar. These interactions are reflected in the significantly higher grain numbers per m^2 obtained in the S1 and S2 sowings, of both cultivars, compared with the S3 sowing (Table 5.5), and the significantly higher grain numbers per m^2 observed in Golden Promise than in Ymer for each sowing date (Table 5.5).

Yield components in relation to grain yield

Grain yield and the number of ears produced per plant, and produced per m^2 of crop, were not significantly correlated (Table 5.6). However, the number of grains per ear, 1000 grain weights and the number of grains produced per m^2 of crop were all significantly, and positively, correlated with grain yield.

The relationship between grain yield and grain numbers per m^2 of crop, which showed a significant correlation, is depicted in Figure 5.4 a/b. A highly significant linear regression was noted for both cultivars.

The S3 sowings of both cultivars showed a reduction in yield at low plant densities, in contrast to the yield compensation at low densities observed in the S1 and S2 sowings (Figure 5.1 a/b). The failure to compensate is reflected in the significantly lower numbers of ears per plant, grains per

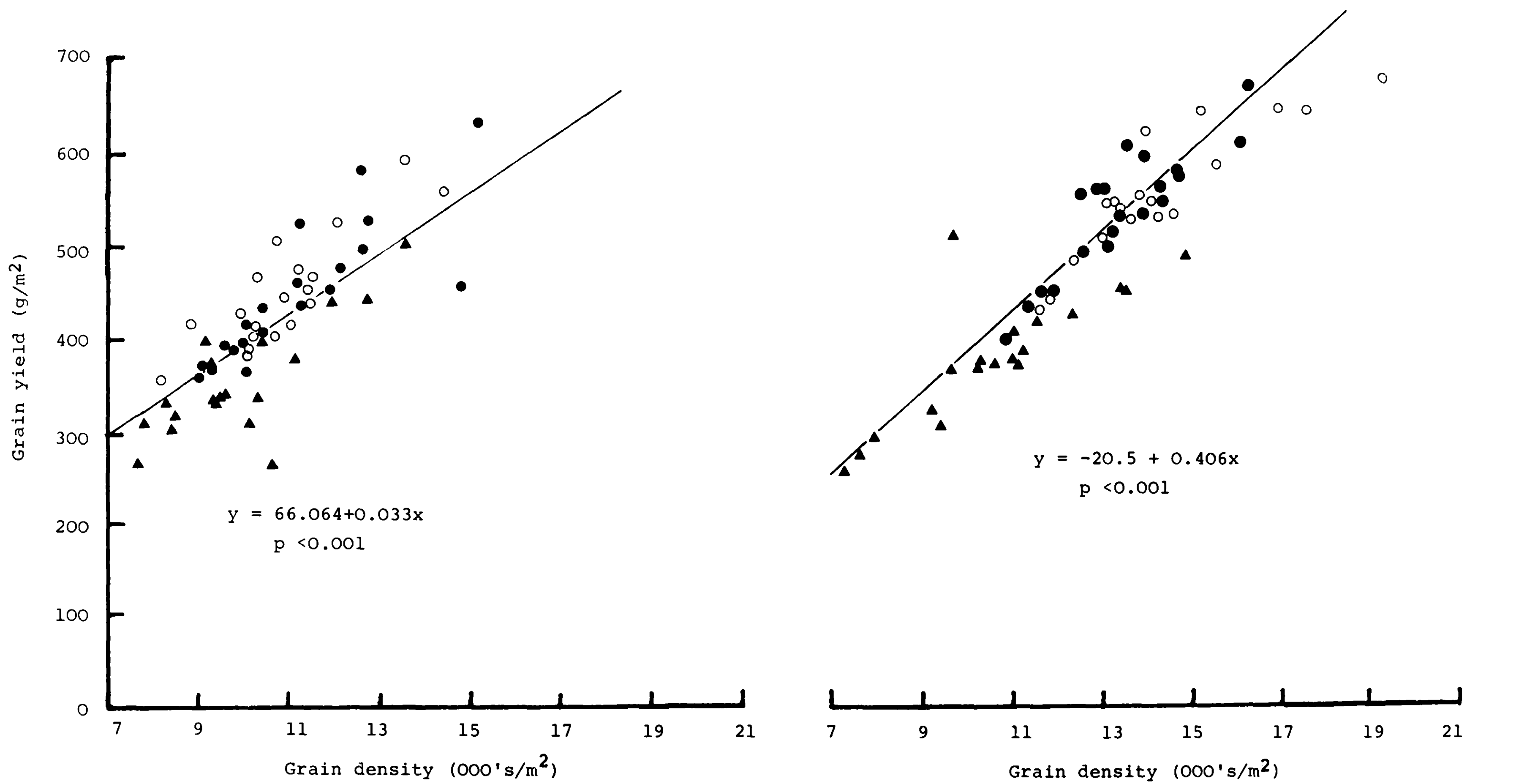


Fig. **5.4** Relationship of grain yield with grain density for Ymer (a) and Golden Promise (b) for three sowing dates:

S1 = ●, S2 = O, S3 = ▲ .

ear, and, therefore, grains per m^2, and in the 1000 grain weight obtained in the S3 sowings (Table 5.5), compared with the earlier sowings.

Table 5.6 Relationships between grain yield and yield components as measured by the correlation coefficient (r)

Yield component	Correlation coefficient r	Significance level +
Grains per m^2	0.4814	* * *
Ears per plant	0.0955	NS
Ears per m^2	0.0061	NS
1000 grain weight	0.4784	* * *
Grains per ear	0.6182	* * *

* * * = significant at $p < 0.001$
* * = " " $p < 0.01$
* = " " $p < 0.05$
NS = not significantly correlated.

5.4 Discussion

Two major effects of plant density and sowing date on grain yield are noticeable for both cultivars from the results presented in Figure 5.1 a/b. Firstly, yield compensation at the low plant densities in the early sowings was such that the yields obtained were as great, and on occasion greater, than those obtained from higher plant densities. Secondly, in the S3 sowing the yield compensation at low plant densities is not evident, and grain yield was lower than in the earlier sowings at all plant densities.

The yield responses to density for the two cultivars and for the different sowing dates will be discussed in terms of the responses of three yield components to different plant densities: ear production, grain weight and grains per ear.

Ear production

The number of ears produced per plant decreased with increasing plant density (Figure 5.2 a/b) for all three sowing dates and both cultivars; but, the number of ears produced per m^2 of crop increased with increasing plant density (Figure 5.2 c/d). Therefore, the increased production of ears per plant at low densities was insufficient to compensate for the increase in plant numbers at high plant densities. The number of ears per plant and ears per m^2 were significantly reduced in the S3 sowing of Golden Promise, although not in Ymer.

A reduction in ears per plant with increasing density has been noted by a number of workers (Engledow, 1928; Cannell, 1969; Kirby, 1969). Dale, Felippe and Fletcher (1972) have shown that unfavourable conditions imposed by shading the first and second leaves reduced the number of fertile tillers (ears) produced per plant. They, and Dale and Felippe (1972) proposed that shading may lead to shortages of either carbohydrate assimilate or nitrogen compounds to the apex, which thus, curtailed tiller development.

Kirby (1969) also noted the increase in ear numbers per m^2 with increasing density for all sowing dates. However, his data shows a greater number of ears produced in the later spring sowing than in the early sowing, which is the converse of the Stirling results for Golden Promise. There was a significant cultivar effect on ear numbers in both Kirby's experiment (1969) and the experiment reported here.

Although ear compensation is recognized as important in yield compensation at low plant densities (Kirby, 1969), its lack of effect in aiding yield compensation in the S3 of Ymer indicates that it is not the major contributor to yield compensation. Kirby (1969) also noticed that ear production at low densities was not the major compensating factor at low densities.

<u>Grain weight</u>

One thousand grain weight consistently increased as plant density decreased in the early sowings (Figure 5.3 c/d). However, in the S3 sowing, the 1000 grain weight only increased with decreasing plant density down to the intermediate plant densities, after which there was little change in the Ymer grain weight, but, in Golden Promise, there was a decrease in grain weight. These results are in accord with those of Kirby (1969) who considered individual grain weight was the most important influence on yield compensation at low densities. Further, in Kirby's (1969) late sowing, where there was no yield compensation at low densities, 1000 grain weight did not increase at the low densities as in the earlier sowings. Both Kirby's (1969) results and those at Stirling showed a strong correlation of grain weight with grain yield.

Grain weight is dependent on the filling of the grain with carbohydrate assimilates. Thorne (1963 a, b) showed that the carbohydrate for grain filling was produced largely by the photosynthesis from four sites on the fertile tiller: the flag leaf, its sheath, the rachis and peduncle, and the ear itself. On shading these parts of the tillers during grain filling, Thorne (1963b) noted a reduction in grain yield. In his discussion of yield reduction at high plant densities, Kirby (1969) suggested that the grain yield is determined by the capacity of the sites of photosynthesis to produce sufficient products to fill the grains after anthesis (flowering). Less competition for light and nutrients at low densities allows greater filling of the grain (Kirby, 1969) and thus facilitates yield compensation.

However, when Willey (1965) shaded barley plants after anthesis, he found no reduction in yield. Willey and Dent (1969) considered, from a review of wheat and barley experiments, including those of Willey (1965), that the carbohydrate potential of the photosynthetic areas is often much greater than is actually moved to the ear.

Willey and Holliday (1971a) showed from experiments undertaken by Willey, from 1961 to 1964, that some reduction in grain weight occurred when plants were shaded during ear initiation. They also noted (Willey and Holliday, 1971b) that, in wheat, thinning of plants at anthesis, which reduced the inter-plant shading, had little effect on grain weight, even though, in wheat, grain weight was markedly reduced by shading after anthesis. From both these observations, they suggested that grain weight could be reduced by shading before anthesis, through an effect on the capacity of the grains to fill. However, the evidence for an effect of shading on the capacity of barley grains to fill needs much more substantiation.

In this work, and in Kirby's (1969) work, it has been pointed out that in late sowings, the grain weight does not increase at low densities. Kirby (1969) suggests that this is a photoperiod effect on the various stages of plant development. Increased light periods during ear initiation have been shown (Guitard, 1960; Kirby and Eisenberg, 1966) to hasten anthesis and reduce the leaf number produced before anthesis, and Kirby (1969) has noted a reduction in photosynthetic area per tiller in a late sowing, which he thought may cause a reduction in grain filling and, therefore, grain weight. However, it has been suggested that an excess of photosynthetic assimilates are generally available for ear filling, thus a reduction in leaf area may not have a great effect. Alternatively, a reduced leaf area may have an effect at the stage of ear initiation which leads to a reduction in the capacity of the grains to fill. A similar suggestion has been outlined above to explain the density effect on grain weight.

If Kirby's (1969) suggestion is accepted, then the grain weight reduction in the low densities of the late sowing is due to a photoperiod effect on leaf area, and consequently on carbohydrate supply to the filling grain. However, it may be due to a pre-anthesis effect which reduced the capacity of the grains to fill.

Grains per ear

Holliday and Willey (1969), in a review of wheat and barley experiments, showed that some of the most successful cultivars not only had the capacity to produce large grains, but more importantly, in their opinion, they produced high grain numbers per unit area of crop. This, they suggested, shows the importance to grain yield of the ability of a plant to produce storage space for assimilates. Ear storage space, or capacity, has been suggested to be a function of the capacity of the grains to fill, and, more importantly, of the number of grains produced per ear (Holliday and Willey, 1969; Willey and Dent, 1969).

In the Stirling experiment there was a general increase in the number of grains per ear with decreasing plant density in the early sowings (Figure 5.3 a/b). However, in the S3 sowing of both cultivars, there was an increase in the number of grains down to intermediate plant densities, but at lower densities there was little change in numbers. The results of the early sowings are in accord with Willey and Holliday's (1971 a, b) findings in wheat and barley, and there are some similarities in the difference in response shown by the early and late sowings as noted by Kirby (1969). Kirby (1969), however, only found a small interaction for sowing date x plant density in grains per ear, whereas in the present experiment a very significant interaction was found (Table 5.4). A very significant positive correlation between grain yield and grains per ear was also found (Table 5.6). This indicates that grains per ear is an important factor associated with yield compensation at low densities, and, since the lower grain yields were associated with lower grain numbers per ear, the reduction in grain numbers per ear may be associated with the lack of compensation in the low densities of the third sowing.

Although Kirby (1969) did not consider grains per ear to be the main determinant of grain yield, Willey and Holliday (1971a, b), in shading experiments on wheat and barley, found that grain numbers followed grain yield closely, both decreased with increasing shading, particularly when shaded from ear initiation to anthesis. They suggested that shading, either artificially or by other plants in high density crops, during this period reduced floral development and thereby reduced the number of grains produced.

Willey and Holliday (1971a) explained the effect of shading during ear initiation on grain numbers in terms of the availability of total dry matter during ear development. They attributed the lower production of total dry matter at high densities to the crop growth rates having reached their peak and then having declined before the end of the ear development period.

An alternative hypothesis for the reduction in grains per ear at high plant densities has been put forward by Kirby and Faris (1970). They found that increased shading, due to increasing plant density, led to an earlier and shorter period of ear development, and to a reduction in leaf area and number per plant. They postulated that the increasing plant density and thus shading, led to a greater giberellin concentration in the plant tissues, as shown by Brian (1959) (vide: Kirby and Faris, 1970). Consequently, ear development was stimulated earlier in the crop's development, and the duration of development was shortened. It was further noted by Kirby and Faris (1970) that, at high densities, the vascular tissue supply to the young ear apex was reduced, which might reduce the carbohydrate and nutrient flow to the growing apex. The consequent reduction in assimilates could, they suggested, lead to the starvation and death of the growing apex, which would therefore curtail further grain production by the apex. Puckeridge (1968) (vide: Kirby and Faris, 1970) has suggested that giberellin activity may be disrupted at low plant densities due to increased light intensity. Thus yield compensation at low densities may be closely associated with the lessening of giberellin activity following destruction by light, and its influence on grain production.

Willey and Holliday (1971a) suggested, however, that it is not just the number of grain initials produced that is important, but the number produced that can fill with assimilates. Therefore, the grain initials must also develop to a certain stage before filling if they are to develop into grains.

Low grain production per ear at low densities of late sowings has been explained by Guitard (1960) and Kirby and Eisenberg (1966) as a photoperiod effect on the early development of the plant. A longer photoperiod regime during the period from sowing to internode elongation, as would be found in a late sowing, has been shown to stimulate rapid ear formation, and shorten the duration of grain initial formation without increased meristematic activity, and, thus, cause a reduction in the number of grains produced per ear. The decrease in overall grain numbers in the S3 sowing of the Stirling experiment may, therefore, be an effect of an increased photoperiod regime during early plant development. The decrease in ear grain numbers in above-intermediate plant densities suggests that the density effect (Kirby and Faris, 1970) is reducing further the grain numbers produced per ear.

Grains per unit area

Holliday and Willey (1969) conclude from a review of experimental work in cereals, that the storage capacity of the crop is linked to the storage capacity of the ear by the number of grains produced per unit area of crop. It has been shown since (Willey and Holliday, 1971a) that there is a very high correlation between grain yield and grains per unit area.

The results of the Stirling experiment confirm those of Willey and Holliday (1971a). Figure 5.1 shows the markedly similar response to plant density of both grains per m^2, and yield per m^2 (Figure 5.1 a/b).

It is suggested, therefore, that compensation at low plant densities in the early sowings must be in large part a function of grain production per unit area of crop. Grain production per unit area is dependent on the number of ears produced and, especially, the number of grains produced per ear. The effect of the late sowing was to generally reduce the mean grain numbers produced, but at the low densities the compensation by grains per ear was reduced drastically. Ear compensation per plant was insufficient to increase the yield to that comparable with higher plant densities. The decrease in yield at high densities in the S3 of Ymer does not compare with the stable number of grains per m^2 produced. The conclusion must be reached, therefore, that if the number of grains per unit area remains static with increasing density, then the yield may drop due to decreases in the 1000 grain weight.

The paraboloid response curve noted by Holliday (1960), and others, for the yield/plant density relationship, is not clearly seen from the Stirling results. Possibly this is due to not a wide enough range of plant densities being studied.

Grain yield in relation to equivalent commercial sowing densities

The sowing density/grain yield relationship from the experiment in equivalent cwt per acre figures is presented in Figure 5.5 The two early sowings have been combined, as have the results for both cultivars.

A decline in yield per acre can be seen in both relationships for densities above the normal of circa 1.5 cwt per acre (188.3 kg per ha) (Chapter 4). However, in the case of the early sowings, 1.5 cwt per acre is by no means a clear physical optimum density since there is relatively little difference between the yields from 0.25, 0.75 and 1.5 cwts per acre (3.84, 94.2 and 188.3 kg per ha), and the highest yield is in fact that obtained from the lowest density (0.25 cwt per acre). In the late sowing, 1.5 cwt per acre is clearly the optimum density.

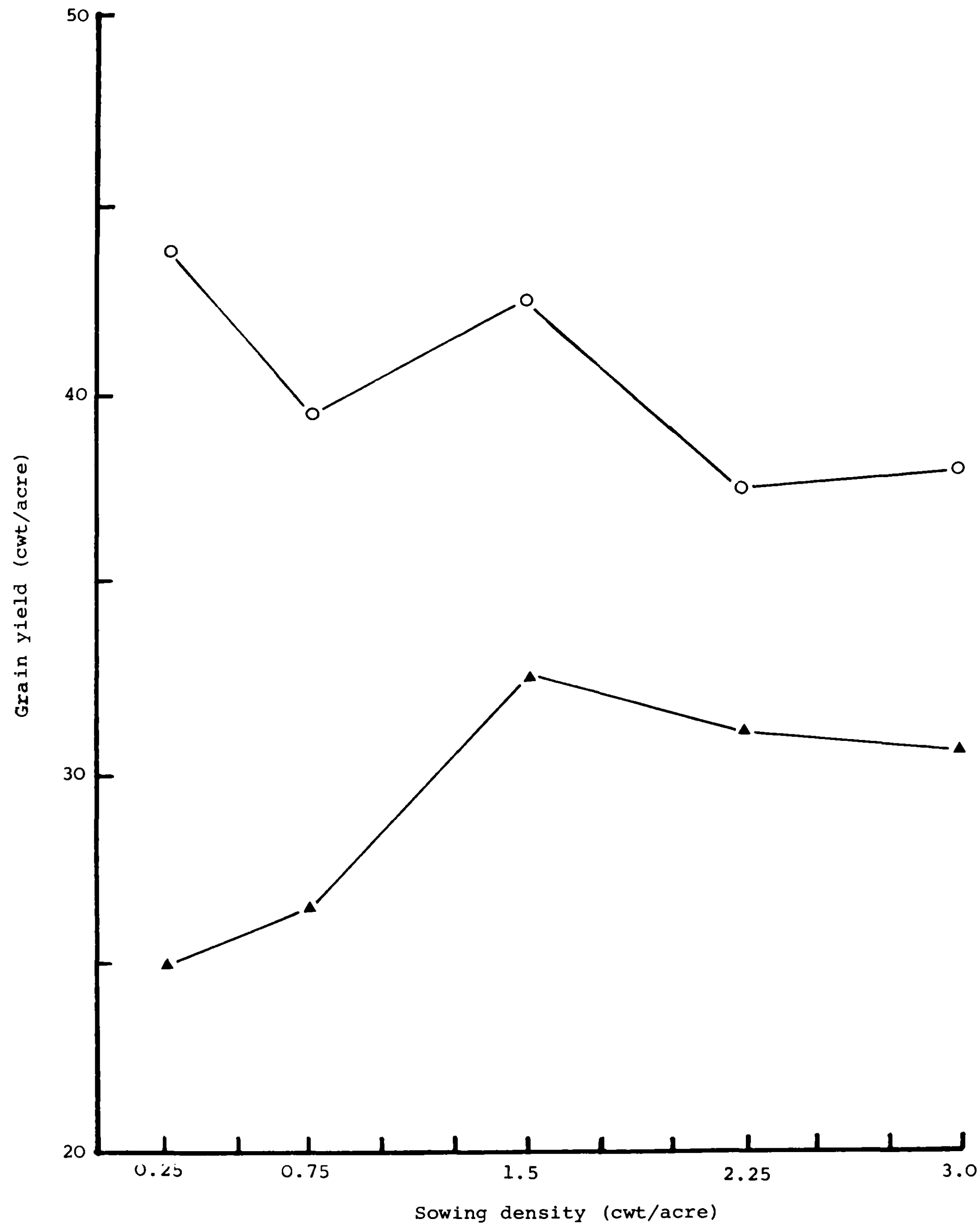


Fig. 5.5 Relationship between sowing density and yield in cwt per acre calculated from the results of the 1971 experiment. The combined results of sowing dates S1 and S2 = O; sowing date S3 = ▲ . Both Ymer and Golden Promise cultivars are combined for each point.

Chapter 6

A REVIEW OF GRAIN YIELD/SOWING DENSITY RELATIONSHIPS IN SPRING BARLEY TRIALS IN BRITAIN

6.1 Introduction

The Stirling experiment showed that, under certain conditions, yield compensation at low sowing densities of spring barley may be such that there is little difference in the yields obtained from densities ranging from 0.25 to 3.0 cwt per acre (Chapter 5: 5.4). However, the experiment only looked at one year on one site. A large number of trials have been undertaken throughout Britain which have looked at the relationship between sowing density and yield under conditions closer to those found in commercial barley growing. This chapter will review most of those experiments, presenting the optimum sowing densities that have been found under various environmental conditions, and show the magnitude of the differences in yields that can be obtained from different sowing densities.

The review will be divided into two sections: experiments undertaken before 1952, which were reviewed by Boyd (1952), and those undertaken since 1952. The latter section will further look at the effects of four types of agronomic factors on the sowing density/yield relationship: the level of nitrogen application, different sowing dates, different cultivars and year to year differences due to mainly meteorological factors. Experiments from Scotland and the rest of Britain will be discussed separately. Finally, the optimum densities from the experiments reviewed will be summarized in an attempt to pick out the optima under a range of circumstances and to examine the effect on yields of reducing sowing densities below the normal densities used at the present time, particularly in Scotland where the normal density is around

1.5 cwt per acre (188.31 kg per ha).

6.2 Sowing density trials: before 1952

Boyd (1952) summarized all the traceable results of experiments in Britain on cereals, involving sowing density as a variable factor, from the reports of experimental farms and county trials since 1900. His review included sixteen English experiments on spring barley. These showed an average optimum sowing density of circa 1.0 cwt per acre (125.54 kg per ha), but he noted that only a quarter of the experiments showed a substantial loss in yield when 0.5 cwt per acre (62.77 kg per ha) was sown.

The effects of two environmental factors were also reviewed by Boyd (1952). He found that row width had little effect on the yield obtained, and did not affect the optimum sowing density. There was little information on the effect of the second factor, applications of nitrogen fertilizer. He reviewed, however, some data from Danish experiments on barley which showed that each sowing density used responded to a similar degree to each additional application of nitrogen.

Experiments on wheat at Rothamsted (Rothamsted, 1946-51), which included nitrogen as a variable, proved rather inconclusive. However, Hudson (1941) suggested from a survey of sowing density optima for wheat in different world climatic zones that the higher the potential yield, the higher the sowing density physical optimum. That is, the greater the environmental resources available the higher the potential yield maximum, and the higher the sowing density required to achieve that maximum yield. Hudson (1941) considered that water supply was a key factor.

Boyd (1952) concluded from his review that there was some indication, in the cereals he looked at, that lower densities were more successful in conditions of high fertility. He also considered there was a good case for reducing the sowing density of spring barley below the normal level in Britain at that time of 1.5 cwt per acre (188.31 kg per ha).

6.3 Sowing density trials: since 1952

Holliday (1960) included the results of Boyd's (1952) review in a further review which also included three more experiments undertaken between 1952 and 1960. The present review will include the experiments noted by Holliday (1960), plus National Agricultural Advisory Service (N.A.A.S.) (now the Agricultural Development and Advisory Service, A.D.A.S.) experimental farm results, along with published long term experiments and unpublished data from trials undertaken by the three Scottish agricultural colleges.

The effect of nitrogen fertilizer application on the yield/density relationship

The addition of nitrogen is considered an environmental resource addition (Holliday, 1960) and, thus, according to Hudson (1941) and Crowther, Tomforde and Mahmoud (1935-6), should increase the optimum seed densities, since there is an increase in yield potential. Several series of experiments in England since 1952 (Jackson and Page, 1957; Glynne and Slope, 1957; Rennie, 1957) have examined the influence of applications of nitrogen fertilizer on the spring barley yield/density relationship. The combined data, a total of thirteen trials, are summarized in Table 6.1.

Table 6.1 Effect of increasing nitrogen applications on the optimum sowing density in trials in England from 1952 to 1957

Experiment	Jackson and Page	Glynne and Slope	Rennie
Number of trials	8	2	3
Change in optimum density with increased N*:			
Increase	0	0	0
Decrease	5	0	2
No clear change	3	2	1

*N = nitrogen fertilizer

In seven of the trials an increased nitrogen level gave rise to a lowering of the optimum sowing density. The other six trials showed no discernible pattern, or the optimum was the same for each nitrogen level used.

In Scotland, twenty four trials were undertaken by the West of Scotland Agricultural College (W.S.A.C., 1962-1970; unpublished data, and Annual Reports) from 1961 to 1969 on a number of farms. In two of the trials there was an increase in the optimum sowing density with increasing nitrogen applications (Table 6.2), and in two trials there was a decrease in the optimum. In the remainder of the trials there were no clear patterns, or no change in the optimum density at different levels of nitrogen application. However, as high levels of nitrogen have been shown (Glynne and Slope, 1957) to possibly lead to lodging and a consequent loss in yield, the effect of the intermediate applications alone are also given in Table 6.2. The amended results show that in six trials increased nitrogen levels resulted in an increase in the optimum sowing density, and in four trials a decrease in optimum.

Table 6.2 Effect of increasing nitrogen applications on the optimum sowing density in trials in Scotland from 1961 to 1969

Year	1961	1962	1963	1964	1965	1966	1967	1968	1969
Number of trials	1	4	3	4	3	4	3	1	1
Change in optimum density with increased N*:									
Increase	0(0)**	1(1)	1(1)	0(2)	0(1)	0(1)	0(0)	0(1)	0(0)
Decrease	0(0)	1(1)	0(0)	1(1)	0(0)	0(1)	0(1)	0(0)	0(0)
No clear change	1(1)	2(2)	2(2)	3(1)	3(2)	4(2)	3(2)	1(0)	1(1)

*N: nitrogen fertilizer

**: excluding the highest nitrogen addition (90 units)

Some differences between the results of the English and Scottish trials are evident. The English trials show a tendency towards a negative optimum sowing density reaction to increased nitrogen levels. The Scottish results are less clear, no discernible pattern could be seen in over half of the trials, and, in the other trials, in seven there was an increase, and in four, a decrease, in the optimum sowing density with increased nitrogen levels.

Although increased nitrogen levels did not consistently affect the optimum sowing densities, there was nearly always a positive yield response to increases in the nitrogen supply. In the English experiments, in only three of nineteen nitrogen additions was the mean yield lower than the lowest nitrogen level in the same trial. In the Scottish trials, in only four of seventy four nitrogen additions was there no increase in mean yield with an increased nitrogen level. The yield responses to increased nitrogen levels ranged from - 1.2 to + 5.5 cwt per acre in the English data, and from - 1.8 to + 17.3 cwt per acre in the Scottish trials.

The effect of sowing date on the yield/density relationship

Kirby's (1969) experimental results indicated that an earlier sowing of spring barley leads to a lower optimum sowing density. He further showed that low densities sown late in the season were liable to result in a very marked decrease in yield not apparent in early sowings. However, Mundy and Page (1972), in field trials, noted that there was little change in the optimum sowing density for three different sowing dates (Table 6.3), although the latest sowing did result in a lower mean yield (Table 6.4).

Table 6.3 Optimum sowing densities for three sowing dates

	Experiment	
Sowing date	1965/6	1966/8
March	0.75, 1.25	0.75
Early April		0.75
Late April	1.25	0.75

Source: Mundy and Page, 1972 data.

Table 6.4 Yield responses to different sowing dates

	Experiment	
Sowing date	1965/6	1966/8
March	31.7	26.9
Early April		22.5
Late April	25.5	18.5

Source: Mundy and Page, 1972 data.

No data is available from Scottish sources apart from the results of the Stirling experiment in 1971 (Chapter 5 : 5.4) which confirmed Kirby's (1969) results.

The effect of cultivar differences on the yield/density relationship

In England, Mundy and Page (1972) compared two cultivars, Proctor and Impala at one sowing density, in trials over three seasons. Proctor's mean yield was greater than that of Impala by 1.6 cwt per acre (200.86 kg per ha) overall. Both cultivars had an increase in yields obtained as nitrogen levels increased, but Proctor attained its maximum yield at a lower nitrogen level than Impala (Table 6.5). Both cultivars had a reduction in mean yield with increasing lateness of sowing.

Jackson and Page (1957) included four sowing densities in trials on the cultivars Kenia and Earl in Lindsey and Kesteven, Lincolnshire (Table 6.6), from 1952 to 1954. There was little difference in mean yield between the cultivars except in 1954 at Kesteven, when Kenia significantly outyielded Earl. However, the optimum sowing density was always lower in Kenia than Earl, except in 1954 at Lindsey, when there was a similar optimum for the two cultivars. Rennie (1957) at High Mowthorpe, Yorkshire, used Kenia and Earl in trials from 1952 to 1954 (Table 5.7), and showed that in two of the three years the optimum sowing density was higher for Kenia than for Earl, and in the third year it was the same for both cultivars.

The N.A.A.S. carried out trials at four experimental farms in 1969 and 1970 (M.A.F.F., 1970, 1971) (Table 6.8), using a number of cultivars over several sowing densities. Few discernible patterns can be seen in the results. Possibly Vada and Midas tended to have a lower optimum sowing density than the other cultivars tested, whilst Zephyr tended to

Table 6.5 Yield responses (cwt per acre) of Proctor and Impala barley to the addition of nitrogen fertilizer

Cultivar	Nitrogen addition: 0	30	60	90
Proctor	0	+4.1	+6.4	+6.0
Impala	0	+3.8	+5.8	+6.4

Source: Mundy and Page, 1972, data.

Table 6.6 Grain yield response to sowing densities for Kenia and Earl cultivars in Lindsey and Kesteven, 1952 to 1954

	EXPERIMENT											
	Lindsey 1952		Kesteven 1953		Lindsey 1953		Kesteven 1954		Lindsey 1954		Mean	
Cultivar	K	E	K	E	K	E	K	E	K	E	K	E
Sowing density cwt per acre	cwt per acre											
1.0	30.6	29.1	36.8*	37.2	37.4	37.2	35.8	31.8	23.7	22.1	32.8	31.5
1.5	29.9	31.7	36.7	38.3*	37.6*	37.1	35.8	32.5	20.4	22.0	32.1	32.3
2.0	32.4*	32.1	36.2	35.9	37.1	36.5	35.9*	32.5	25.0	23.8	33.3*	32.1
2.5	31.4	32.3*	35.5	36.8	37.1	37.3*	35.8	33.5*	25.4*	24.8*	33.0	33.1*
Mean	31.1	31.5	36.3	37.0	37.3	37.0	35.7	32.6	23.6	23.2	32.8	32.2

* Maximum grain yield

produce its maximum yields at the higher densities.

Table 6.7 Grain yield response (cwt per acre) to sowing density for Kenia and Earl cultivars at High Mowthorpe, 1952-54

	Year					
	1952		1953		1954	
Sowing density	Kenia	Earl	Kenia	Earl	Kenia	Earl
1 cwt per acre	32.1	33.8*	34.9*	32.3*	21.6	19.2
1½ " " "	32.4	32.9	33.9	32.1	20.5	20.2*
2 " " "	33.0	32.7	33.0	31.0	22.1*	19.5
2½ " " "	33.2*	32.4	-	-	-	-

* Maximum grain yield
Source: Rennie, 1957.

In Scotland, the East of Scotland College of Agriculture (E.S.C.A.) undertook trials on Ymer and Golden Promise cultivars on three farms in 1968 (Table 6.9). There was no consistent trend, with Ymer having a lower optimum density on one farm, and Golden Promise on another. On the third farm, the two cultivars had the same optimum density.

Table 6.9 Grain yield response (cwt per acre) to sowing density for Ymer and Golden Promise cultivars in eastern Scotland, 1968

Site:	St. Martins		Corstorphine		Midcalder	
Cultivar:	Ymer	Golden Promise	Ymer	Golden Promise	Ymer	Golden Promise
Sowing density:						
1 cwt per acre	31.4	29.2	30.6	26.3	32.8	40.4
1.5 cwt per acre	32.1	33.0	30.7*	28.7	34.9	43.2*
2 cwt per acre	32.8*	34.2*	30.4	29.0*	38.3*	41.8

* Maximum grain yield
Source: E.S.C.A., 1969.

Table 6.8 Cultivars sown and densities used in trials on A.D.A.S. experimental farms, 1969 and 1970

Site	Boxworth, 1969			Boxworth, 1970			Drayton, 1970			Gleadthorpes, 1969			Gleadthorpes, 1970			High Mowthorpe, 1970		
Sowing density (lbs/acre):	98	126	154	98	126	154	126	154	168	63	88	110	73	92	125	70	98	126
Cultivar:																		
Proctor			+			+			+			+		+			+	
Zephyr			+			+			+			+		+				+
Julia	+					+						+		+				
Sultan		+				+			+			+			+		+	
Midas			+			+		+			+		+				+	
Deba Abed			+			+												
Berac			+			+			+			+			+		+	
Clermont		+			+	+		+			+				+			+
Vada											+			+		+		
Gerbra																	+	

+ Optimum sowing density

Although there seems to be little consistent effect of cultivar differences on optimum sowing densities, the possibilities of response differences are still present. The differences in response to density between cultivars may well be influenced through the effect of other factors on the cultivars, for instance the susceptibility of cultivars to disease, pests and lodging.

Differences in the yield/density relationship from year to year

There are yearly differences in the sowing density optima and in the yield levels attained due to uncontrolled factors such as meteorological differences, disease outbreaks and weed infestation. When experiments are carried out over a number of years not all factors can be fixed and their effects assessed; thus, there can be yearly differences due to many uncontrolled factors.

Jackson and Page (1957) noted a yearly variation in mean yields attained, and in the relative yields, of different cultivars. They found, on two experimental sites, that the poorest yields were obtained in 1954 (Table 6.6), and, interestingly, in that year there was a tendency for the optimum sowing density to be higher than in two other more favourable growing years. Similarly, Rennie (1957), at High Mowthorpe, found a yearly difference in mean yield (Table 6.10); further, in 1954, the lowest yielding season, the optimum sowing density was twice that of the two previous years, possibly showing a lack of yield compensation in a season of generally low yields.

Table 6.10 Grain yield response to sowing density, 1952 to 1954, at High Mowthorpe (cultivars combined)

Sowing density cwt per acre	Year 1952 cwt/acre	1953 cwt/acre	1954 cwt/acre
1.0	31.4	32.4*	19.9
1.5	31.1	31.9	19.9
2.0	31.1	30.8	20.7*
2.5	31.1	-	-
Mean	31.2	31.6	20.2

* Maximum grain yield

Source: Rennie, 1957.

Trials at Auchencruive, Scotland (W.S.A.C., 1962 to 1968) on Ymer barley showed changes in the optimum sowing density from year to year (Table 6.11). In four of the seven years, the optimum sowing density was also the highest density tested, but in the other three years there was some variation in the optimum.

Table 6.11 Mean grain yield response to sowing density, 1961 to 1967, for Ymer barley at Auchencruive

	Year						
	1961	1962	1963	1964	1965	1966	1967
Sowing density:							
0.5 cwts/acre	-	-	-	-	-	-	42.8
0.75 " "	-	-	-	-	-	-	44.3
1.0 " "	24.7	39.9	33.4*	24.8	34.2	39.1	44.3
1.25 " "	-	-	-	-	-	-	45.3*
1.5 " "	-	-	-	27.0	36.1	40.2*	43.9
2.0 " "	31.1	43.6	32.0	28.0	35.8	40.0	-
2.5 " "	-	-	-	28.7*	36.8*	40.0	-
3.0 " "	34.7*	44.9*	31.7	-	-	-	-

*Maximum grain yield

Source: W.S.A.C., 1962 to 1968, unpublished data

These results suggest that yearly differences, which are not precisely accounted for, occur in the optimum sowing density on one site for any barley cultivar. There is a suggestion from Jackson and Page's (1957) and Rennie's (1957) results that in a year of poorer growing conditions, there is a tendency for the optimum sowing density to be higher.

6.4 Summary of the sowing density/grain yield relationship data

Changing environmental factors have been shown to result in changes both in the mean yields obtained and in the optimum sowing densities. Table 6.12 summarizes the data from all the English trials reviewed, and shows how the optimum sowing density may vary under the wide range of conditions represented.

Table 6.12 Range of sowing density physical optima* for all the reviewed English trials, and mean yields for each sowing density

Sowing density cwt per acre (a)	No. of trials (a) is used (b)	Mean yield cwt/acre	No. of times (a) is optimum sowing density(c)	(c) as a % of (b)
0.5	8	37.4	0	0
0.75	48	28.4	10	20.8
1.0	67	30.7	19	28.4
1.25	68	30.5	17	25.0
1.5	44	35.8	28	63.6
1.75	12	29.1	3	25.0
2.0	12	36.9	4	33.0
2.25	9	29.7	2	22.2
2.5	7	34.0	4	57.1
2.75	1	28.3	1	100.0
3.0	3	29.7	2	66.6

* Sowing densities taken to the nearest 0.25 cwt.

The sowing density most frequently optimum was 1.5 cwt per acre (188.31 kg per ha), and it was optimum on over 60% of the occasions it was used. However, the two lower densities, that is 1.0 and 1.25 cwt per acre (125.54 and 156.93 kg per ha), were optimum on thirty six occasions, and optimum on over 25% of the occasions they were used. Fewer trials are available for the other densities, but all were optimum on some occasion except for 0.5 cwt per acre (62.77 kg per ha).

There was some variation in the mean yield (Table 6.12) obtained from each density, but there was no trend towards lower yields from the lower densities.

The Scottish data is similarly presented in Table 6.13. However, as distinct from the English results, 2.0 cwt per acre (251.05 kg per ha) was most frequently optimum, and optimum on 40% of the occasions it was used. However, the lower densities, excepting 0.5 cwt per acre (62.77 kg per ha), were all very frequently optima, and 1.25 cwt per acre (156.93 kg per ha) was optimum on over 50% of the occasions it was used.

Table 6.13 Range of sowing density physical optima* for all the reviewed Scottish trials, and mean yields for each sowing density

Sowing density cwt per acre (a)	No.of trials (a) is used (b)	Mean yield cwt per acre	No. of times (a) is optimum density (c)	(c) as a % of (b) %
0.5	9	37.3	0	0
0.75	23	34.5	4	17.4
1.0	99	30.8	16	16.2
1.25	17	33.9	10	58.8
1.5	71	33.0	13	18.3
1.75	6	28.3	3	50.0
2.0	110	31.9	44	40.0
2.25	1	28.3	0	0
2.5	40	29.6	17	42.5
3.0	48	32.4	17	35.4

*Sowing densities taken to the nearest 0.25 cwt.

There is a tendency for the mean yields to be higher at the lower sowing densities (Table 6.13) in the Scottish data. However, the variation is not great considering the wide range of conditions represented.

The Scottish data have been analyzed further. It has been noted that circa 1.5 cwt per acre (188.31 kg per ha) is the mean sowing density used in Scotland at the present (Chapter 4: 4.5); therefore, yield comparisons have been made (Table 6.14) with three lower sowing densities to see how different the yields obtained have been in the lower densities in the trials from the 1.5 cwt per acre trial results. The mean yield differences are a mean of comparisons within trials in which a measure of the comparisons are possible. Further, the proportion of occasions when each sowing density outyielded the other, or equalled the yield of the other, is also presented in Table 6.14.

Table 6.14 <u>Yield comparisons for a number of sowing densities from the Scottish trials</u>

Sowing density comparison cwt/acre		cwt/acre	Number of comparisons	Proportion of occasions	Mean yield difference cwt/acre
1.5	outyielded	0.75	23	0.70	1.76
0.75	"	1.5			
1.5	"	1.0	51	0.76	2.08
1.0	"	1.5		0.22	0.96
1.5	equalled	1.0		0.02	0
1.5	outyielded	1.25	14	0.29	2.08
1.25	"	1.5		0.71	1.22

Table 6.14 shows that 1.5 cwt per acre (188.31 kg per ha) generally outyielded densities of 0.75 and 1.0 cwt per acre (94.16 and 125.54 kg per ha), but 1.25 cwt per acre (156.93 kg per ha) generally outyielded 1.5 cwt per acre when present in the same trial. This suggests that 1.25 cwt per acre (156.93 kg per ha) is most frequently the optimum sowing density when compared under similar conditions to the other sowing densities reviewed in Table 6.14. Furthermore, mean differences in yield were not great, even when 1.5 cwt per

acre (188.31 kg per ha) was compared with the lowest density of 0.75 cwt per acre (94.16 kg per ha), the mean difference being 1.03 cwt per acre (129.31 kg per ha).

Chapter 7

SOME COMPARISONS OF FIELD EMERGENCE IN SEED LOTS OF SPRING BARLEY

7.1 Introduction

Examination of the relationship between plant density and yield in spring barley (Chapters 5 and 6) suggested that, under many circumstances, a reduction in plant density does not result in a fall in yield, and where a reduction in yield is found, it is seldom a drastic one. The utilization of such information in the advocation of a reduction in sowing densities below the normal density of 1.5 cwt per acre, depends on the grower being able to achieve the plant densities that are intended.

The achievement of a particular plant density depends on the existence, detection and use of seed lots capable of producing a plant from nearly every seed sown over a wide range of sowing conditions, and a sowing technique capable of rigorously controlling sowing density. The emergence ability of seed barley in the field will be investigated and discussed in this chapter. The influence of reducing sowing densities on sowing methods and equipment will be considered in Section IV.

There have been few experiments specifically intended to examine the field emergence of cereal seed, but emergence data is often included in work on the relationship of other factors and crop yield. Both sources of data have been considered. In most of the references on emergence data, the laboratory germination levels of the seed lots used are not given; it may not be unreasonable to assume that, unless otherwise stated, the authors used seed lots of an acceptable quality for seed sales. In Scotland, this generally means seed lots with a laboratory germination level greater than 90%.

Barley Demirlicakmak, Kaufmann and Johnson (1963) found little difference in field emergence between small, medium and large seeded Canadian barley cultivars, and noted a range of emergence levels from 76.1 to 79.1% of seeds sown. Kaufmann and McFadden (1960) found little difference in emergence between seed sizes selected from within one barley cultivar; however, inter-row competition was noted to have a significant effect on emergence levels, which ranged from 32.0 to 83.2% of seed sown.

Experiments by Kubota and Williams (1966) on the effects of roller compaction of the soil on the field emergence of spring barley in England, revealed an emergence range from 28.9 to 73.8%. A wide range of emergences, from 24 to 98%, was also found in a Canadian barley cultivar (Kaufmann, 1968) when sown at different soil depths in various soil types under greenhouse conditions.

In the United States, Sprague and Ferris (1931) found no significant difference in the emergence of one barley cultivar sown at four densities. They reported an emergence range of 79.5 to 82.2%. Willey (1964), in England, found significant differences in the plant establishment of Proctor and Rika barleys between sowing densities in several years. Proctor barley showed an establishment range from 69 to 87% of seeds sown in 1961, and Rika barley, a range from 51.27 to 70.84% in 1962, and from 56.9 to 86.4% in 1964.

A range of emergences in a Canadian cultivar from 77% in early sowings to 92% in late sowings was noted by Chiasson (1972). In his experimental sowings of spring barley, Kirby (1965; 1969) found a range from 89% of seed sown in Proctor barley to 93% in Plumage Archer and Domen barley in 1966, and from 79 to 100% of seed sown at different densities of Maris Puma and Proctor barley in 1969. In an autumn sowing of Maris Puma barley sown at different densities, Kirby (1969) found an emergence range from 49 to 72% of seed sown.

Recently, detailed information on the emergence of farm crops of spring barley has been collected by Richardson (1972), who surveyed thirty four randomly selected farms in Scotland who grew more than ten acres of barley in 1970. From the farmers' estimates of sowing densities and his own emergence counts, Richardson calculated a range of emergences from 40 to 100% of seed sown in crops which covered a range of seed lots, sites, and sowing dates for several barley cultivars. A fifth of the crops had a field emergence of less than 60%, and 17.6% of the crops had an emergence of more than 80% of seed sown. Laboratory germinations were determined for twenty eight of the seed lots used by the growers and all had a germination level greater than 80%; and twenty three of the lots had a level greater than 90%. Of the latter crops, the emergence range remained from 40 to 100% of seeds sown. Thus a recent survey in Scotland has shown a considerable variation in emergence in the field in barley seed lots that exhibited a small range of laboratory germinations.

Wheat and oats Reports on field emergence in wheat and oats, the other cereals commonly grown in Britain, have been few. Willey (1964) noted that Koga II wheat, in England, showed some variation in emergence depending on the sowing density; this ranged from 72 to 82.84% in 1962, from 74.1 to 89.9% in 1963, and from 65.05 to 82.81% in 1964.

Low levels of emergence (from 28 to 38% of seeds sown) have been recorded in Scotland (O.S.T.S.S., 1955) on six seed lots of an oat cultivar with a laboratory germination range of 94 to 98%. However, a further six lots of an oat cultivar tested (O.S.T.S.S., 1959) with a laboratory germination range from 93 to 98%, showed a wider range of emergence levels, from 57 to 84% of seed sown in the field.

Over four experimental seasons in England, Bedford, Flood and MacKay (1972) found a wide range of emergences in seed lots of cultivars of spring wheat; as low as 6.7% for one seed lot in 1968. However, the comparisons were made of seed lots showing a wide variation in laboratory germination; for instance, eight seed lots of Opal wheat with a germination range of 59 to 92% in 1966 showed a field emergence range from 35.0 to 41.5% of seeds sown. A significant positive correlation between emergence and germination levels were found for each year's experiment.

In Scotland, Richardson (1972) surveyed thirty five wheat crops in 1970, and calculated a range of emergence levels from 50 to 96% of seed sown, covering a range of seed lots, sites and sowing dates for several wheat cultivars. The laboratory germination of eight of the crops surveyed was determined, and was found to be in excess of 90% for all of them. The emergence of the same eight crops ranged from 50 to 96% of seeds sown.

Low emergence in barley, wheat and oats is not a consistent feature in the work reviewed, but emergence levels of less than 60% of seeds sown have been recorded under varying conditions, even when laboratory results indicate a germination level of greater than 90%. Some of this variability in emergence may be attributable to variability in the condition of the seed lots, as well as to factors in the sowing techniques. Nevertheless, laboratory germination did not appear to be a consistent guide to emergence in the field.

The aim of the experimental work in this chapter was to compare the emergence levels of commercially available seed lots in Scotland under the same sowing conditions, and to examine the value of the laboratory germination test as an indicator of field emergence. The chapter presents the results of two experiments undertaken at the experimental gardens, in the University of Stirling, in 1970 and 1972.

7.2 Materials and methods

Seed Samples of thirty seed lots (fifteen of Golden Promise and fifteen of Ymer)of spring barley were obtained from a seed merchant (Harley & Son, Ltd., Milnathort, Kinross-shire) in 1970. All the seed lots were to be used for commercial crops and had been dried and cleaned by the merchant, and most of the seed lots had been dressed with a fungicide (eleven with mergannic, nine with cotol, three with panogen). The seed lots were either B.C.S.S. graded seed, or from S.B.C.S. field inspected crops (Chapter 3 : 3.8), and none of the lots had a laboratory germination level of less than 93% (Appendix D).

Samples of seed for the 1972 emergence experiment were obtained by post from the respondents to the 1971 barley growers' survey (Chapter 4). Seventy six growers were asked for samples of the seed they intended to sow in 1972, both material they had grown themselves and any seed they had bought; thirty seven growers returned seventy eight seed lot samples. Only thirty five of the seed samples arrived in time for inclusion in the field experiment. The seed lots sent in were of twelve cultivars of all grades of seed (Chapter 3) and of ungraded own-grown seed (Table 7.1). The laboratory germination levels of the seed lots were determined by the O.S.T.S.S., and were found to range from 88 to 99% (Appendix D). The mean weight of five replicates of 100 seeds was determined for each seed lot used (Appendix D).

Table 7.1 Cultivars and seed grades of seed lots used in the 1972 emergence experiment

Cultivar	Seed grade* B/C	MS	FA	Comm	O	Total
	Number					
Golden Promise	1	1	3	2	8	15
Ymer	-	-	2	3	2	7
Zephyr	1	1	-	1	3	6
Midas	1	2	-	1	2	6
Clermont	-	-	-	-	2	2
Imber	-	-	2	-	-	2
Sultan	-	-	-	2	-	2
Berac	-	1	-	-	-	1
Crusader	-	-	-	-	1	1
Julia	-	1	-	-	-	1
Pallas	-	-	-	1	-	1
Vada	-	-	-	1	-	1
Total	3	6	7	11	18	45

* Annotations:
B/C Basic and Certified seed
MS Multiplication stock seed
FA Field approved seed
Comm Commercial bought seed
O Ungraded own-grown seed

Field experiments In both experimental years seed lots were sown in rows randomized within each of four replicate blocks. In 1970, the seeds were sown by hand at a depth of 1.5 in (3.81 cm.) in rows 4 yd (3.66 m) long and 0.33 yd (15.24 cm.) apart. Seed lots of Golden Promise were sown at a density of 282 seeds per row, and the Ymer lots at a density of 246 seeds per row; both densities were equivalent to sowing at 1.5 cwt per acre (188.31 kg per ha). Seeds were sown from 11-12th May, 1970, on a good tilth previously treated with 10:10:10, N:P:K. No bird or rodent damage was noticed during the course of the experiment. The emerged seedlings were counted from 25-28th May, 1970, when preliminary counts had shown that the number of emerged seedlings had reached a constant level.

In the 1972 experiment, seeds were sown by hand at a depth of 1.5 in (3.81 cm) at a density of 100 seeds per 5 ft (1.53 m) row, on 31st March, 1972, into a good tilth. The plots were covered by netting to prevent bird damage. Seedling counts were made on 1st May, 1972, after preliminary counts had shown that the emergence levels were constant.

7.3 Results

Field emergence

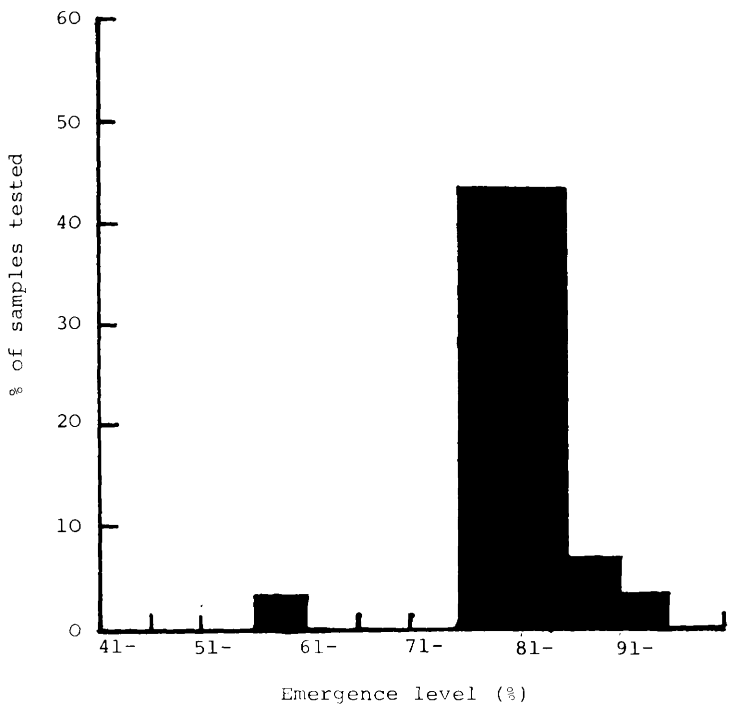
Details of the emergence levels obtained in each experiment are given in Appendix D, and the frequency of the different levels of emergence is shown in Figures 7.1a and 7.1b. All but one seed lot sown in 1970 had an emergence level greater than 75% (Figure 7.1a). Most of the seed lots emerged within the range from 76 to 85% of seeds sown. Only one seed lot achieved an emergence level of greater than 90% of seeds sown.

A wider range of emergence levels was found in the 1972 experiment (Figure 7.1b). The total emergence range was from 46.25 to 84.0% of seeds sown. However, two thirds of the seed lots fell between a range from 70 to 85% of seeds sown. Of the other seed lots, 8.9% fell below an emergence level of 60%, and one seed lot had a level of below 50% of seeds sown.

Analysis of variance on emergence percentages (after angular transformation) revealed a significant difference in emergence between seed lots in both years (Appendix D).

The mean emergence level for each cultivar used in the 1972 experiment is presented in Table 7.2. Of the four main

(a)



(b)

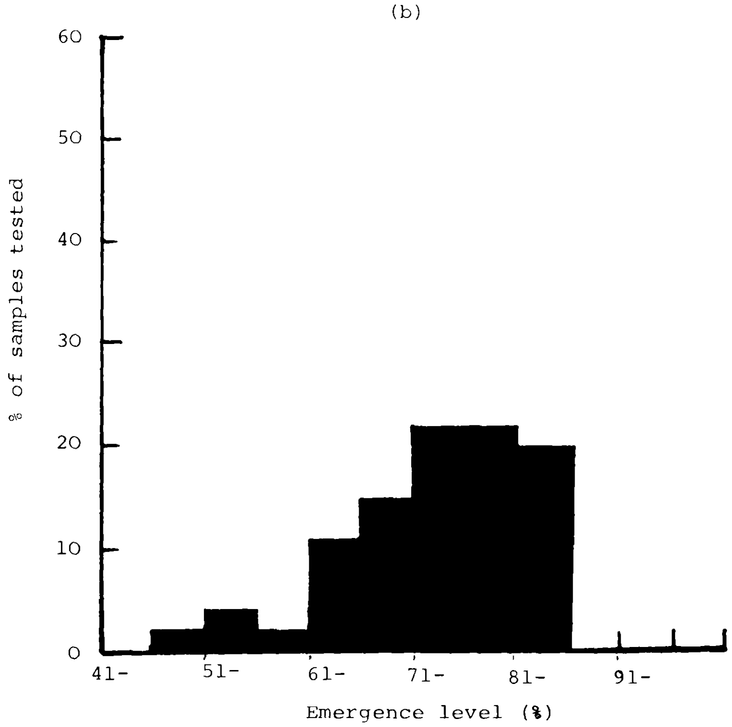


Fig. 7.1 Distribution of emergence levels in experiments undertaken in 1970(a) and 1972 (b).

cultivars, Ymer and Zephyr had significantly lower ($p<0.05$) average emergence levels than Midas and Golden Promise (Appendix D), and Ymer had a significantly lower emergence level than Zephyr. The other cultivars presented insufficient data for similar analyses.

Table 7.2 Mean emergence levels of the cultivars used in the 1972 emergence experiment

Cultivar	No. of samples	Mean Emergence Level %
Midas	6	78.67 a *
Golden Promise	15	77.22 a
Zephyr	6	69.75 b
Ymer	7	63.05 c
Julia	1	79.25
Imber	2	74.50
Berac	1	72.25
Vada	1	72.00
Clermont	2	66.63
Pallas	1	66.50
Crusader	1	65.50
Sultan	2	56.80

* Any two means with the same letter are not significantly different ($p<0.05$) as measured by Duncan's multiple range test on the angularly transformed data. (Appendix D).

There was no significant difference between the mean emergence levels of the four grades of seed sown in 1972 (Table 7.3; Appendix D), except for the Field Approved seed lots whose mean emergence level was significantly lower ($p<0.05$) than that of ungraded own-grown seed and the Basic/Certified/Multiplication Stock seed, but not commercial seed.

Table 7.3 Mean emergence level and emergence range for each of four seed grades sown in the 1972 emergence experiment

Seed grade	Emergence range %	Mean emergence level %
Ungraded, own-grown	61.3-83.5	74.22 a *
Basic/Certified/Multiplication Stock	58.3-83.5	73.13 a
Commercial	53.0-84.0	71.30 a b
Field approved	46.3-82.0	67.49 a b

* Any means with the same letter are not significantly different ($p < 0.05$) as measured by Duncan's multiple range test on the angularly transformed data. (Appendix D).

Field emergence in relation to laboratory germination

Only one seed lot in the 1970 experiment attained a mean emergence level close to its laboratory germination of over 92% (Appendix D). Figure 7.2a shows the linear regression of emergence level against laboratory germination, which was not significant.

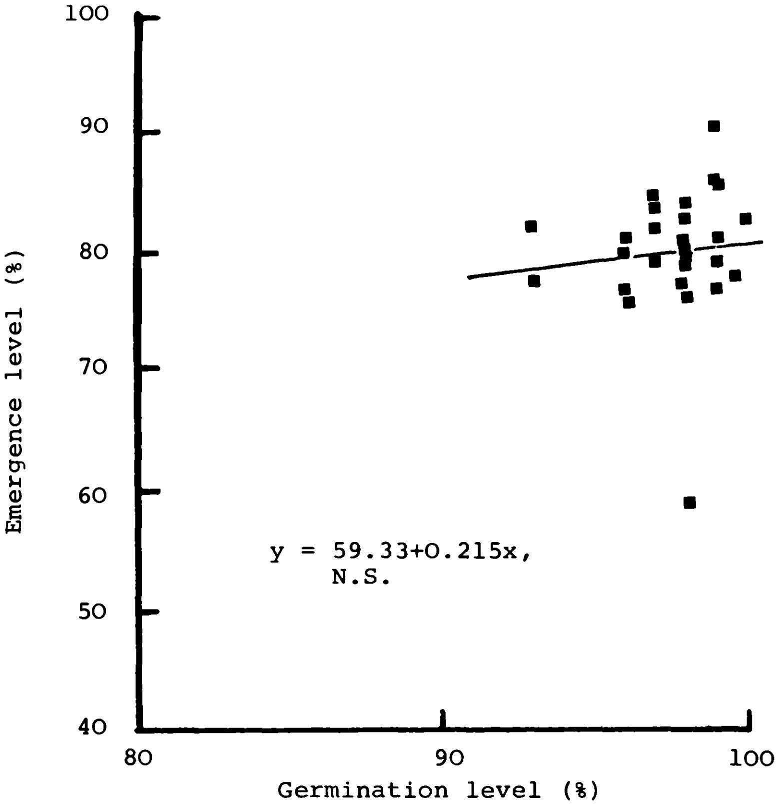
However, Figure 72b shows that the linear regression between the emergence and germination of the seed lots in the 1972 experiment was highly significant ($p < 0.001$), low emergences being a feature of seed lots with low laboratory germinations. When two seed lots with germination levels of less than 90% (Appendix D) were excluded, the regression became non-significant.

Seed weight

Samples of the Golden Promise seed lots used in the 1970 experiment averaged 4.45 g per 100 seeds, and samples of the Ymer lots averaged 5.04 g per 100 seeds.

Details of the 100 seed weights of each seed lot are presented in Appendix D. Table 7.4 gives the average 100 seed

(a)



(b)

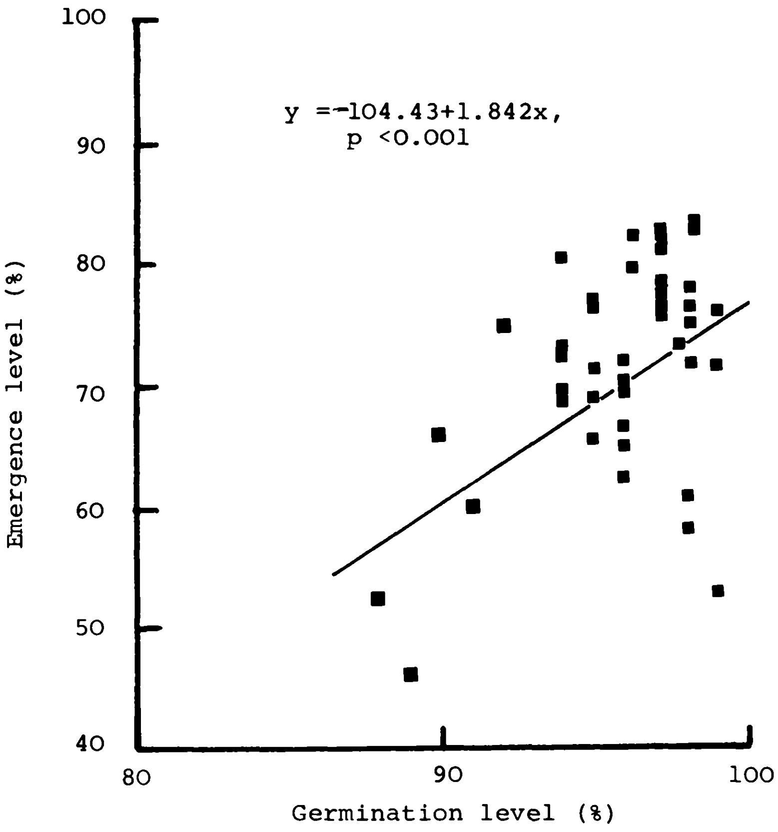


Fig.7. 2 Relationship between the germination levels and emergence levels from experiments undertaken in 1970(a) and 1972(b).

weight of each cultivar used in the 1972 experiment. Of the four most popular cultivars, the average seed weights of Ymer and Zephyr were significantly higher ($p < 0.05$) than those of Golden Promise and Midas (Appendix 10). There was not sufficient data to undertake similar analyses on the other cultivars used.

Table 7.4 Mean 100 seed weights for cultivars used in the 1972 emergence experiments

Cultivar	No. of seed lots	Mean 100 seed weight g.
Ymer	6	4.25 a *
Zephyr	6	4.25 a
Golden Promise	15	3.70 b
Midas	6	3.57 b
Imber	2	4.62
Crusader	1	4.27
Sultan	2	4.23
Berac	1	4.12
Julia	1	3.89
Clermont	2	3.74
Vada	1	3.21

* Any means with the same letter are not significantly different ($p < 0.05$) as measured by Duncan's multiple range test (Appendix 10).

There was a significant negative regression ($p < 0.05$) between 100 seed weights and emergence levels (Figure 7.3; Appendix 10). This suggests that the seed lots containing the smaller seeds emerged better than the seed lots with larger seeds, which follows the relative performances of the cultivars, Those cultivars with the larger seed emerging less well (Table 7.2).

7.4 Discussion

The range of emergence found in the experiments in 1970 (59.0 to 90.5%) and in 1972 (42.25 to 84.0%) was not as great as that noticed by Richardson (1972), in 1970, for farm sown crops. This is understandable since several of the hazards of

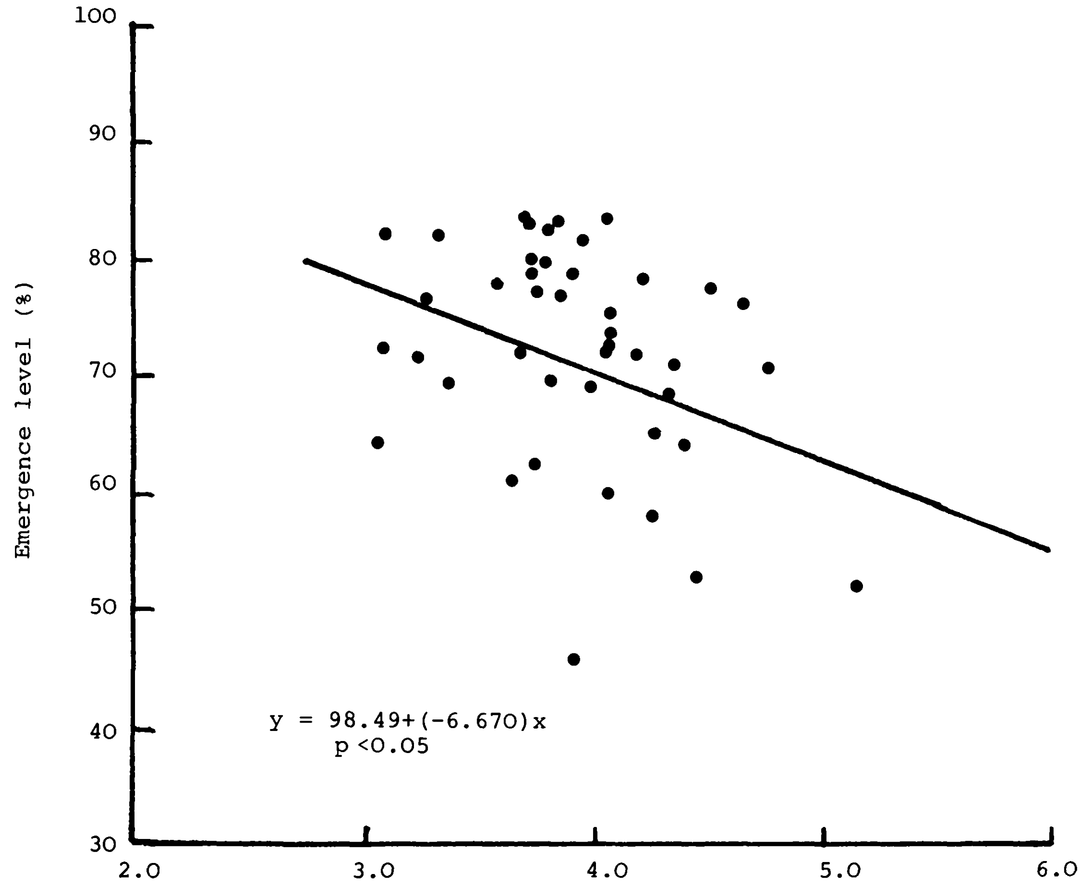


Fig. 7.3. Relationship between emergence levels and 100 seed weight.

sowing under normal crop conditions were eliminated. The seeds were sown by hand, and not with a drill, and attempts to exclude birds and rodents were made.

Nevertheless, the emergence range of seed lots in the 1972 experiment was noticeably wider than those used in the 1970 experiment. This may be attributable to the weather following each sowing. The 1970 sowing was undertaken in May, and was followed by seven days when the mean daily maximum and minimum temperatures were 14.6^{o}C and 5.4^{o}C respectively, and the total rainfall was 31 mm. In 1971, the seeds were sown in March, and the sowing was followed by seven days in which lower temperatures prevailed (mean daily maximum: 11.5^{o}C, and minimum: 3.8^{o}C) and rainfall was heavy (318 mm). Gadd (1932), quoted by Essenburg and Schoorel (1962), noted that the field emergence of spring cereals was 20% lower than the germination level when the weather and soil conditions were good, and 30% lower when they were poor. Bedford, Flood and MacKay (1972) noted differences in spring wheat emergence levels under different sowing conditions.

The 1972 sowing at Stirling was conducted during the sowing season of the surrounding croplands, but the 1970 experiment was undertaken several weeks after commercial sowing had been completed. The 1972 sowing would thus be a better representation of the commercially expected conditions for seed sowing and plant emergence.

There was a significant difference between the mean emergence levels of some of the cultivars used in the 1972 experiment. Midas and Golden Promise had higher emergence levels than the other major cultivars, Zephyr and Ymer. Richardson's (1972) data suggests that Ymer emerges less well than Golden Promise. Significant differences in emergence levels between barley cultivars have also been noticed by Kaufmann (1968) in Canada, and by Kirby (1967) in England.

There appeared to be little difference between the graded and ungraded seed in their emergence ability. However, within the graded seed lots, Field Approved material emerged significantly less well than other seed material. It is interesting to note that of the four seed lots sown in 1972 with an average emergence level of below 60%, three were of B.C.S.S. graded seed lots (Table 7.5). Thus, the production of quality seed, with respect to purity, cleanliness of seed lots and high laboratory germination (greater than 90%), appears to make no noticeable improvement in the ability of seeds to emerge in the field.

Table 7.5 <u>Sources of the lowest emerging seed lots in the 1972 emergence experiment</u>

Seed lot ref. no.	Germination level %	Emergence level %	Seed source
31 Zb	98	59.4	Basic/Certified
70 S	88	53.0	Commercial
54 Y	99	52.5	Field approved
74 Y	89	46.25	Field approved

Bedford, Flood and MacKay (1972) noted highly significant correlations between emergence levels and laboratory germination in spring wheat over a wide range of germination levels. In the 1972 experiment, the inclusion of two seed lots with germinations of less than 90% produced a significant positive regression which stresses the merits of using seed with a laboratory germination in excess of 90%. But there was no significant relationship between field emergence and laboratory germination in 1970 and 1972 when only the seed lots with a laboratory germination in excess of 90% were included. Nevertheless, a wide range of emergence levels was found in both years (59.0 to 90.5% in 1970, and 52.5 to 84.0% in 1972) in seed lots with a greater than 90% laboratory germination. Similarly, Richardson (1972) found there was no correlation between emergence and laboratory germination in spring barley when germinations were greater than 90%, but the emergence levels ranged from 40 to 100% of seed sown.

In contrast to the findings of Demirlicakmak, Kaufmann and Johnson (1963) in Canadian barley, the emergence levels of seed lots in the 1972 emergence experiment were greater for the seed lots with lighter seed than for those with heavier seed. Of the four most popular cultivars (Table 7.1), the two that had the heaviest seed, Zephyr and Ymer, had the poorest emergence levels (Table 7.2). Because of a lack of data on a large number of cultivars, it cannot be assessed whether this is attributable to a difference between cultivars or whether seed size has an effect in itself.

The experimental results obtained in 1970 and 1972 have revealed a range of field emergences which was not related to laboratory germination in seed lots whose laboratory germination was greater than the declarable minimum of 90%. This confirms other results on cereal seed lots with germination levels in excess of 90%. It is, therefore, suggested that the laboratory germination test is useful in discarding very low emerging seed lots. However, a wide range of emergence levels have been exhibited in seed lots with germinations of over 90%. Thus the laboratory germination test does not appear to be a completely consistent guide to field emergence. There is a case for further research into finding an indicator of the field emergence potential of viable seeds, similar to that available for pea seed testing (Matthews and Bradnock, 1968), before a rigorous control of barley plant densities in the field can be achieved.

Section IV

This section includes an economic analysis of some of the data presented in Section III. The first chapter lists the current costs and returns for growing different crops of spring barley in lowland and upland Scotland. In addition, some estimates of future costs and returns will be presented. A second chapter contains a method of economic analysis, which is then used on data available from the Scottish field trials included in Section III, and from the economic data given in the previous chapter. The analysis is also used on a wide range of seed costs and grain prices, including possible future costs and prices. Suggestions as to the economic optimum sowing densities for spring barley under changing cost and return situations are also included.

Chapter 8

COSTS AND RETURNS FOR BARLEY GROWING IN SCOTLAND

8.1 Introduction

This chapter reviews the most recent data available on the costs and returns of barley growing in Scotland, and presents some forecasts of future trends.

Averaged costs and returns data are published by the three agricultural colleges in Scotland: the East of Scotland College of Agriculture (E.S.C.A.), the North of Scotland College of Agriculture (N.S.C.A.) and the West of Scotland Agricultural College (W.S.A.C.) Each college collects accounting data from a sample of farms within a defined area. The area is similar to that in which they perform a farmers' advisory service similar to the Agricultural Development and Advisory Service (A.D.A.S.) in England and Wales. The most recent figures available from the colleges, those for the season of 1968 and 1969, have been summarized by an E.S.C.A. report, edited by Anderson (1972). Anderson (1972), further, looked at future developments in barley growing in Scotland, and estimated some costs and returns for barley growing in 1977.

8.2 Costs and returns for barley growing in Scotland in 1968/9

Anderson (1972) summarized data from 150 Scottish farms growing barley during 1968 and 1969. He separated the sampled farms into upland and lowland, the twenty five upland farms being on the periphery of the main arable areas, but on higher and poorer land. The lowland farm crops were divided further into crops grown for feed, malting and seed (Table 8.1). Table 8.1 gives the mean variable costs, direct fixed costs and returns per acre; however, Anderson (1972) did not include indirect fixed costs in his analysis. Examples of indirect

Table 8.1 Variable costs, indirect costs and returns per acre; means combined for 337 barley crops in 1968 and 1969.

	Lowland farms-crops grown mainly for:			Upland, all crops:
	FEED	MALTING	SEED	
Average yields: grain: cwt:	30.5	34.5	35.7	28.7
straw: cwt:	20.7	20.0	24.1	21.9
Average price/ton: grain: £:	20.8	22.0	25.4	21.2
OUTPUT:	£	£	£	£
grain	31.7	38.1	45.5	30.5
deficiency payments	5.1	4.6	5.4	5.3
straw	4.9	4.2	5.3	5.4
TOTAL	41.7	46.9	56.2	41.2
VARIABLE COSTS:				
seed	2.9	2.9	3.3	2.6
fertilizer	3.8	3.9	4.2	3.3
casual labour	.2	.3	.4	.1
contract	1.1	.9	.8	1.1
sundry	.7	.8	.7	.8
TOTAL	8.7	8.8	9.4	7.9
GROSS MARGIN:	33.0	38.1	46.8	33.3
DIRECT FIXED COSTS:				
Depreciation charges for specialized equipment:				
sowing	.3	.3	.3	.3
harvesting	2.8	2.6	2.8	2.8
drying and storage	1.2	1.4	1.7	1.1
TOTAL	4.3	4.3	4.8	4.2
Regular labour	2.7	2.4	2.2	2.7
Tractor work	1.4	1.2	1.4	1.3
TOTAL DIRECT COSTS	8.4	7.9	8.4	8.2
NET MARGIN:	24.6	30.2	34.4	25.1

Source: Anderson, 1972, pp. 27, 33.

fixed costs are available from a W.S.A.C. 1968 survey (MacPherson, 1970) of feed and seed crops, and from a N.S.C.A. survey of fifty two farms in 1968 (Sutherland and Steele, 1970). Estimated net margins including these estimated indirect fixed costs are presented in Table 8.2.

The mean seed costs per acre, the seed costs as a percentage of the variable and total costs, and the average price per ton of grain for each category of crop, are summarized in Table 8.3.

The mean seed cost figures may disguise a very wide range of seed costs dependent on the grade of seed used (Chapter 4: 4.7). From the growers' survey in 1971 (Chapter 4), the seed costs ranged from an estimated £1.08p for own grown seed to £6.60p per cwt for Basic Seed; at a sowing density of 1.5 cwt per acre, the equivalent seed cost per acre would range from £1.54p to £9.90p.

8.3 Predicted future costs and returns for barley growing in Scotland

The relatively high cereal prices obtained in the E.E.C. and the increase in production costs will markedly affect the gross margins of barley growing. Anderson (1972) predicts (Table 8.4) a 79% increase in the gross margin by 1977, over the 1968/9 figures (Table 8.1), for feed crops with a 95% increase in the price of grain per ton, and a 72% rise in the cost of seed. However, he predicts no change in the seed cost as a proportion of the total variable costs.

Larger increases in the cost of seed have been suggested in some recent predictions. For example, Wickers (1971) suggests that current work on hybrid cereals may increase the

Table 8.2 Mean indirect fixed costs per acre for West and North of Scotland farms in 1968

West of Scotland

	5 seed farms	32 feed farms
	£	£
Indirect fixed costs:		
rent	5.0	4.1
Share of general farm expenses	4.2	6.7
Other fuel, or power	0.6	0.3
TOTAL (F)	9.8	11.1
NET MARGIN (Table 8.1) - F.	24.6	13.5

Source: MacPherson (1970) data

North of Scotland

	All farms (52)
	£
Indirect fixed costs:	
rent	4.9
overheads	3.9
TOTAL (G)	8.8

NET MARGINS (Table 8.1) - G.	Feed crops	Malting crops	Seed crops	Upland crops
	£	£	£	£
	15.8	21.4	25.6	16.3

Source: Sutherland and Steele (1970) data

Table 8.3 Mean seed costs, seed costs as a percentage of the variable and total costs*, and grain prices for Scotland in 1968 and 1969 combined

Crop	Seed cost £/acre	Seed cost % of V.C.	Seed cost % of T.C.	Grain price £/ton
Feed	2.9	33.3	17.0	20.8
Malting	2.9	33.0	17.4	22.0
Seed	3.3	35.2	18.5	25.4
Upland	2.6	32.9	16.2	21.2

* Total costs = variable costs + direct fixed costs

Annotations: V.C. = variable costs
T.C. = total costs

Table 8.4 **Estimated costs and returns per acre for feed barley growing in Scotland in 1977**

	cwt
Average yield	34
	£
Average grain price per ton . .	41
	£
OUTPUT	
Grain	70
Straw	5
TOTAL	75
VARIABLE COSTS	
Seed	5
Fertilizer	8
Sundry	3
TOTAL	16
GROSS MARGIN	59

Source: Anderson (1972) p. 43.

cost of seed by between three and five times if they come on to the market. He further notes that the cost of seed of standard cultivars is also likely to increase markedly.

The E.E.C. regulations as regards seed sales (Chapter 3: 3.9) may result in many growers using their own grain for seed, which may affect the cost of seed purchases from seed merchants depending on a smaller trade. This may result in substantial increases in the cost of seed (Harley, 1970; Keppy, 1971; personal communications). The implications of marked increases in seed cost will be discussed further in a later chapter.

Chapter 9

AN ECONOMIC EVALUATION OF THE PHYSICAL OPTIMA FOR BARLEY GROWING IN SCOTLAND

9.1 Introduction

An analysis will be presented in this chapter to show whether the average sowing density currently used in commercial crops in Scotland, that is, circa 1.5 cwt per acre (188.31 kg per ha), is the economic optimum sowing density, or whether there is an economic argument for a reduction in sowing densities. The analysis is developed in three stages: firstly, using present seed costs and grain prices in Scotland, secondly, for predicted future costs and prices, and, thirdly, for a wide range of costs and prices.

9.2 Method

Three sowing densities below that of 1.5 cwt per acre (188.31 kg per ha) will be considered for this analysis: 0.75, 1.0 and 1.25 cwt per acre (94.16, 125.54 and 156.93 kg per ha). The three lower densities have been agronomically compared with 1.5 cwt per acre (188.31 kg per ha) in Chapter 6: 6.4. If a choice has to be made between 1.5 cwt per acre (188.31 kg per ha) and one of the lower densities, then this becomes a selection of alternatives, which has to be based, firstly, on physical differences and, secondly, on economic differences.

The decision process that will be used to estimate the physical difference between the densities is presented in Fig. 9.1, and is based on the agronomic differences calculated in Chapter 6: 6.4. The range of results from the agronomic trials have been averaged into mean gain, no gain or loss and mean loss, and are presented as such in the decision process (Figure 9.1).

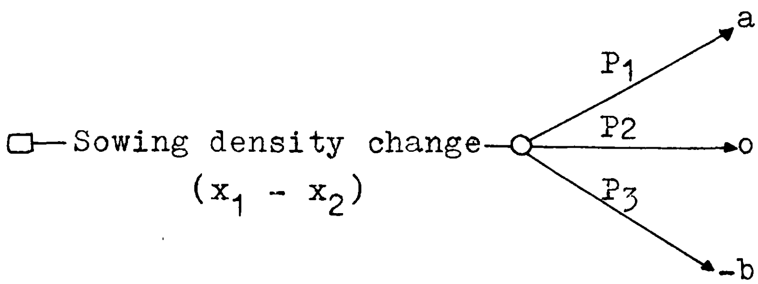


Fig. 9.1 The decision process for the physical choice of sowing density alternatives.

Annotations: x_1 = higher sowing density, cwt per acre
x_2 = lower sowing density, cwt per acre
P_1 = probability of attaining an increased yield from the lower sowing density
P_2 = probability of attaining no difference in yield between the sowing densities
P_3 = probability of obtaining a decrease in yield from the lower sowing density
a = mean yield increase, cwt per acre
o = no increase/decrease in yield
-b = mean yield decrease, cwt per acre

The physical choice, which is an agronomic comparison, is therefore:

Expected yield benefit of using the lower density:

$$P_1.a + P_2.o - P_3.b$$

The economic decision must further involve the cost benefit of a sowing density reduction, and the economic yield changes. The decision formula therefore becomes:

$$E.M.V. = +(x_1 - x_2)s + P_1.a.g + P_2.o.g - P_3.b.g$$

where: E.M.V. = Expected monetary value, £ per acre
s = cost of seed per cwt.
g = price of grain per cwt.

For the purpose of this analysis, three assumptions will be made. Firstly, that the relationship between sowing density and yield for seed of any cost remains the same; this has been suggested in the results of the growers' survey (Chapter 4: 4.8). Secondly, that the reduction in sowing density does not have any effect on the other variable costs involved. Finally, that no new equipment is necessary from the change in sowing densities.

Thus, solving for the E.M.V. formula, a mean economic gain or loss can be calculated for a change from a higher to a lower sowing density. Using the formula, comparisons have been made between the reviewed sowing densities using seed cost and grain price data for lowland feed, malting and seed crops, and for all upland crops in Scotland in 1968/9, and on predicted costs and returns for 1977 feed crops (Chapter 8), also, the formula has been used for a wide range of possible present and future costs and prices.

9.3 Results

Table 9.1 presents data calculated from the E.S.C.A. (1972) report and used in the E.M.V. calculations. The agronomic data for the formula is presented in Chapter 6, Table 6.14.

The results of solving the formula for each crop type, and density comparison are presented in Table 9.2. It is noticeable that gains are possible for all the crops by a reduction in sowing density to both 1.25 and 0.75 cwt per acre (156.93 and 94.16 kg per ha), but not by a reduction to 1.0 cwt per acre.

There are three reasons for this. Firstly, 1.25 cwt per acre (156.93 kg per ha) generally outyielded 1.5 cwt per acre (188.31 kg per ha) in the Scottish field trial comparisons (Table 6.14), and this, including some seed cost savings, would naturally give rise to a higher E.M.V.; secondly, the reduction in yield when sowing at 1.0 cwt per acre (125.54 kg per ha) was not compensated for by the reduction in sowing cost; and thirdly, the reduction in sowing cost overcompensated for the reduction in yield at 0.75 cwt per acre (94.14 kg

Table 9.1 Mean seed costs and grain prices for five crop types

Type of Crop	Mean Seed Cost £ per cwt	Mean Grain Price £ per cwt
Lowland feed crops	1.90	1.04
Lowland malting crops	1.90	1.10
Lowland seed crops	2.36	1.27
Upland crops	1.76	1.06
Predicted 1977 Scottish feed crops	3.33	2.05

Source: E.S.C.A. (1972) data

Table 9.2 E.M.V. calculations for five crop types

	Higher density	Comparison	E.M.V. £ per acre
(a) Lowland feed crops			
	1.5 cwt per acre	1.25 cwt per acre	+ 0.699
	1.5 " " "	1.00 " " "	- 0.474
	1.5 " " "	0.75 " " "	+ 0.164
(b) Lowland malting crops			
	1.5 cwt per acre	1.25 cwt per acre	+ 0.764
	1.5 " " "	1.00 " " "	+ 0.557
	1.5 " " "	0.75 " " "	+ 0.278
(c) Lowland seed crops			
	1.5 cwt per acre	1.25 cwt per acre	+ 0.764
	1.5 " " "	1.00 " " "	- 0.557
	1.5 " " "	0.75 " " "	+ 0.278
(d) Upland crops			
	1.5 cwt per acre	1.25 cwt per acre	+ 0.719
	1.5 " " "	1.00 " " "	- 0.572
	1.5 " " "	0.75 " " "	+ 0.214
(e) Predicted 1977 feed crops			
	1.5 cwt per acre	1.25 cwt per acre	+ 1.369
	1.5 " " "	1.00 " " "	- 1.138
	1.5 " " "	0.75 " " "	+ 0.359

per ha). These figures suggest that, given present costs and returns, 1.25 cwt per acre (156.93 kg per ha) is probably the economic optimum sowing density for Scotland.

However, the figures represent a mean of many crops. Some growers are at present sowing much more expensive seed (Chapter 4, Table 4.16), and Figure 9.2 shows the effect of a reduction in sowing density from 1.5 cwt per acre on the expected monetary values for a whole range of seed costs and grain prices, extrapolating beyond the present costs and prices of barley growing to possible future market conditions.

Figure 9.2 shows that 1.25 cwt per acre (156.93 kg per ha) is economically superior to 1.5 cwt per acre (188.31 kg per acre) under all seed cost and grain price conditions. At the higher seed costs, however, it may be beneficial to reduce the sowing density to 0.75 cwt per acre (94.16 kg per ha), as the saving in seed cost becomes greater. One cwt per acre (125.54 kg per ha) is only superior in cost saving to 1.25 cwt per acre (1.56.93 kg per ha) when the seed cost becomes very high, but the grain price remains very low. However, Figure 9.2 shows that if it is worthwhile to reduce the sowing density to 1.0 cwt per acre (125.54 kg per ha) then it is always worth reducing it further, to 0.75 cwt per acre (94.16 kg per ha).

Appendix C presents the whole range of E.M.V. comparisons available from the Scottish agronomic trial data.

9.4 The economic optimum sowing density

It has been suggested (Chapter 6: 6.4) that 1.25 cwt per acre (156.93 kg per ha) is most frequently the physical optimum sowing density when included in field trials. The results of the economic analysis suggest that, for crops grown at present

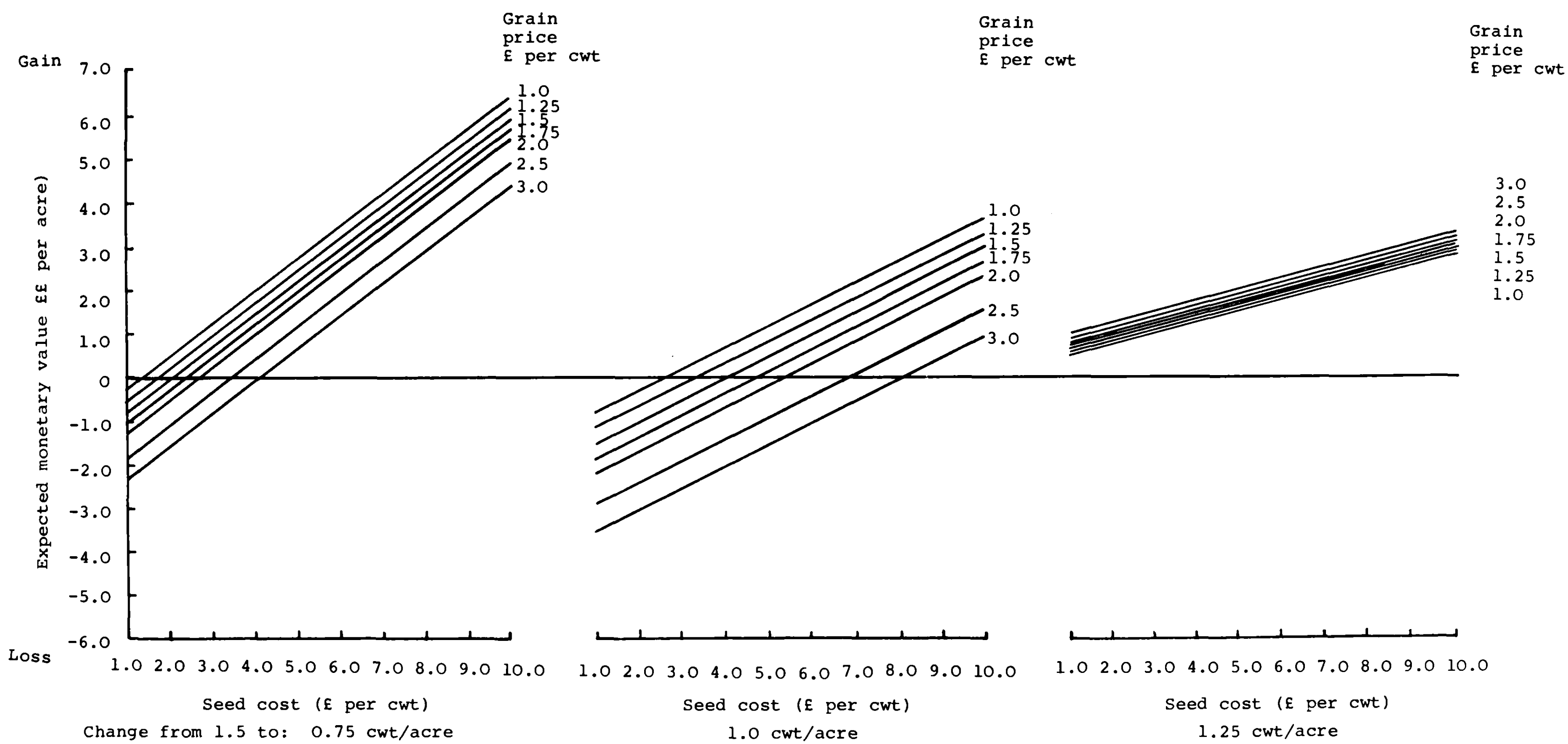


Fig. 9.2 Effects of changing the sowing density of spring barley from 1.5 cwt per acre to 0.75 > 1.0 and 1.25 cwt per acre on the expected monetary value (E.M.V.) for a range of seed costs and grain prices.

mean seed costs and grain prices, 1.25 cwt per acre (156.93 kg per ha) is also the economic optimum sowing density.

However, some graded seed may cost a great deal more than the suggested mean costs (Chapter 4, Table 4.16). A crop covered by the grower's (1971) survey (Chapter 4) involved a seed cost of £6.60 per cwt for Basic Seed and a grain price of £1.30 per cwt. In this case, the cost benefit of sowing at 0.75 cwt per acre (94.16 kg per ha) rather than 1.5 cwt per acre (188.31 kg per ha) would be over £3.00 per acre (Figure 9.2), and £2.20 for a sowing of 1.25 cwt per acre (156.93 kg per ha).

Section V

This section includes the economic and technical implications of the changes in current sowing densities suggested in Sections III and IV. The values of such changes, now, and in the future are considered.

Chapter 10

POSSIBLE IMPLICATIONS OF A REDUCTION IN SOWING DENSITIES IN BARLEY GROWING

10.1 Economic implications

A case has been made in support of the suggestion that there is room for a reduction in commercial sowing densities of spring barley in Scotland. At current seed costs and grain prices, a reduction of the normal sowing density of circa 1.5 cwt per acre (188.31 kg per ha) to 1.25 cwt per acre (156.93 kg per ha) would result in increased profit margins. Further, a reduction to 0.75 cwt per acre (94.16 kg per ha) may result in greater savings in the more expensive seed crops (Basic and certified grades).

Projections have also been made into the future concerning savings in the event of increases in the cost of seed and price of grain. There are two reasons why an especially rapid increase in seed costs is likely. The first in the influence of E.E.C. entry and the consequent changing seed grain sales policies (Chapter 3: 3.9), and, secondly, new plant breeding procedures.

The E.E.C. regulations concerned make it illegal to sell seed at a lower grade than that termed Certified in Great Britain; that is, no more than two generations removed from the mother seed, and subject to strict quality control regulations.

An effect of these regulations will be a greater usage of own (farm) grown seed. An editorial in Arable Farmer (1972) noted that the use of own grown seed in Britain could increase from 174,000 tons at present to 250,000 tons per year as a direct result of the new regulations. There is a danger inherent in this practice that growers may continue to use own grown seed for too many successive generations, resulting in a deterioration of the general quality of seed used in the country. There may be a case for measures to be undertaken ensuring that farmers do not sow too many successive generations of a seed lot.

Another effect of the regulations is that, smaller growers, who have been shown in a survey of growers in Scotland to have poorer seed drying and storage facilities (Chapter 4: 4.3), will have to buy high quality seed, or lower the quality of their own seed in poor storage conditions, whereas the larger growers with better storage facilities are better able to use their own seed.

For those growers who continue to buy seed from merchants the increase in cost may be considerable as the merchants attempt to recover lost sales profit, and, also, because of the higher quality of the only seed available.

The second factor influencing seed costs will be the breeding of new barley cultivars. Barley breeding costs are increasing generally for the standard cultivars. Research is also being undertaken on hybrid cultivars, which may prove very expensive to produce. Wickens (1971) suggests hybrid wheat seed may show an increased cost of three to five times the present costs for standard cultivars. This possibility of new cultivars in the future costing considerably more than in the past may mean that lower sowing densities may be considered more seriously as a farm management decision in the future.

Entry to the E.E.C. will also lead to increases in the marked price for barley grain (H.M.S.O., 1970b). The target price for barley in Germany in the Spring, 1972, was £2.10p per cwt (Stewart, 1972), as compared with the British guaranteed price for barley grain in the cereal year 1970/1 of £1.40p per cwt. Thus increased returns will compensate to some extent for increased costs, although not for farmers retaining their grain for feed.

10.2 Technical implications

Sowing methods

A suggestion that a reduction in sowing densities for spring barley might be possible has been made on the basis of the results of an experiment on the sowing density/grain yield relationship, at Stirling, and of a review of Scottish experimental field trial results.

The experiment, undertaken in 1971 at Stirling, showed that, providing the sowing is not too late, sufficient yield compensation may occur at very low plant densities to provide yields as good as those from much higher densities, such as are currently used in commercial sowing.

The Scottish field trials generally showed that higher yields were obtained from higher sowing densities up to 1.25 cwt per acre (156.93 kg per ha), but, within experiments with sufficient comparisons, the yield generally declined beyond that density. Reductions in sowing densities below those in current use seldom resulted in a very great reduction in yield, although, below 0.75 cwt per acre (94.16 kg per ha) there was a reduction in yield which made the use of lower densities an uneconomic proposition at present costs and returns. However, the Stirling experiment suggested that, given the right conditions, densities of below 0.75 cwt per acre (94.16 kg per ha) may be able to yield as well as higher densities.

A technical implication of reducing sowing densities is the effect on the sowing methods and equipment. The Scottish field trials were undertaken using standard barley sowing procedures - a gravity feed of seed into a furrow. Sowing densities as low as 0.75 cwt per acre resulted in small decreases in yield, but below that density, that is 0.5 cwt per acre (62.77 kg per ha), there was a noticeable drop in yield. In the Stirling experiment, there was probably a better distribution of seeds in the furrows, particularly at the lower plant densities, and under those circumstances, 0.25 cwt per acre (31.39 kg per ha) equivalent density produced as good a yield as any higher density. Richardson (1972, personal communication) has suggested that present sowing machinery can be regulated to sow seed below 0.75 cwt per acre (94.16 kg per ha), but suggests that the distribution of the seed at low densities becomes more important. Kirby (1969) noted that a greater amount of seed clumping occurred at low densities than at high densities.

Therefore, for sowing densities down to 0.75 cwt per acre current sowing machinery would not need to be changed. However, at lower densities the precision drilling of seed may be required to achieve the necessary compensation. Furthermore, Patterson (1972 - personal communication) considered that the optimum distribution of plants would be a triangulation. Precision drilling would be needed to achieve this.

Two problems of economic importance arise, however, if precision drilling is to be considered. Firstly, precision drilling equipment can cost twice as much as present machinery, and, secondly, the precision drilling of seed has to be done at a slower speed than cereal growers generally use at present (Wickens, 1971). This would add to labour costs and may cause difficulties in the timing of the sowing. Further development would also be required to convert present precision drilling machinery to enable the precise placement of seeds such as wheat and barley.

Therefore, further research is required into the economic possibilities of sowing at densities below 0.75 cwt per acre. The analysis in this thesis suggests that, at the present, this would be an uneconomic proposition.

Seed quality

One factor that becomes of increasing importance with decreasing sowing densities is the emergence level of the seed. The emergence experiments undertaken at Stirling suggested that a wide range of emergence levels was possible from seed of over 90% germination levels in the laboratory.

Low emergence in low density crops may result in plant populations below the level at which they can compensate. It may be that more discerning test methods that will allow for the detection and elimination of seed lots of low emergence potential will be needed before very low plant densities can be considered.

10.3 General significance

Davies (1972), the Chief Agricultural Officer of the A.D.A.S., suggested that, in the future, expansion and profitability in agriculture '... will continue to be achieved by paying close attention to scientific, technical - including husbandry - and economic detail, and there is undoubtedly room for savings for individual producers of the more important crops ..... The two most obvious ways of improving productivity are by reducing costs and by increasing output. Farmers will benefit directly where cost savings can be achieved..... Therefore the first priority should be to concentrate ..... on opportunities for cost saving'. He suggested certain factors he considered worth looking at, which included the time of sowing, sowing density and seed spacing. This thesis has examined possible cost savings that may result from a closer examination of the yield/density relationship in spring barley.

In industry, technical development has gone hand in hand with the development of ways of evaluating finance (Thomas, 1964). In the economic situation at the time of writing, decreased profits in industry in general has resulted in a more detailed analysis of cost savings. The control of costs in agriculture has not reached the same level of sophistication.

Although concentrating on the specific problem of sowing densities in spring barley, this study suggests that a similar attitude to costs in farming as is prevalent in industry, may prove of benefit.

It can be argued that the possible cost savings suggested in this thesis are relatively small when compared with returns; but, if a large grower growing over 500 acres of barley is considered, then the sowings suggested may amount to as much as a labourer's annual wage. For many growers, however, the savings may not be dramatic enough to be considered worthwhile.

Nevertheless, if the approach used in this study is applied to a number of similar situations where cost reductions may be possible, then the accumulation of cost savings may result in a significant effect on the farmer's profit margin.

In conclusion, this study presents a possible approach to the study of economically important biological phenomena. It is insufficient to present innovations in agriculture without looking at the biological, technical and economic implications. Furthermore, many practices in common usage over a long period of time should occasionally be reviewed, since both the technical and economic circumstances change.

Appendix A

I. Survey methodology:

(a) Survey A

(b) Survey B

II. Chi-square (χ^2) values and significances:

(a) Cultivars grown by five growers or more in each of three acreage groups of grows (Table 4.5).

(b) Use of merchants (M) seed, own seed (O) and merchants' seed only (Only M) between three acreage groups (Table 4.8).

(c) Use of storage facilities and grain drying between three acreage groups (Table 4.9).

(d) Choice of B.C.S.S. graded seed and commercial seed within three acreage groups (Table 4.10).

III. Analysis of variance of growers survey (1971)

(a) Analysis of variance and standard error, 1970 data, of the number of cultivars grown in three acreage groups. (Table 4.6).

(b) Analysis of variance and standard error, 1971 data, of the number of cultivars grown in three acreage groups (Table 4.6).

(c) Analysis of variance and standard error of difference in sowing densities for the four main cultivars in Survey B (Table 4.13), in 1971.

I. <u>Survey methodology</u>

(a) Survey A.

The list of 100 farmers contacted for survey A were obtained from an O.S.T.S.S., East Craigs, list of growers who had co-operated with the O.S.T.S.S. on certain seed testing procedures. No further selection was involved.

In both surveys A and B, the questionnaire was restricted to a single sheet. Boyd (1960) suggested that this aids the stimulus of the grower to fill the questionnaire.

Further, in both surveys, the questionnaires were sent by post with a letter of introduction, and stamped and addressed envelopes were included to facilitate their quick return.

(b) Survey B

The growers sent a questionnaire in 1971 were selected from county files held by the Economics Department, D.A.F.S. A number of growers, proportionate to the acreage of barley in each county, were picked out at random from the files. The survey was more interested in the barley growing practices and methods of the growers than in the characteristics of the acreage surveyed; therefore, this method of selection was used. As described in Chapter 4: 4.1, the method aimed to provide larger samples of growers with larger acreages of barley than would be obtained from a purely random selection.

The survey B questionnaire was sent to 200 growers. Copies of both questionnaires are enclosed in the end flap of the thesis.

II. Chi-square (χ^2) values and significances

(a) χ^2 values and significances for the cultivars grown by five growers[+] or more in each of three acreage groups of growers[++] (Table 4.5).

YEAR	CULTIVAR	χ^2	SIGNIFICANCE
1969	Ymer	2.3111	N.S.
1970	Ymer	2.0667	N.S.
1970	Golden Promise	7.1833	$p < 0.05$
1971	Ymer	0.6198	N.S.
1971	Golden Promise	4.1692	N.S.

\+ For a ^{2} test, the expected value in any class should not be less than 5 (Woolf, 1968, p.235).

++ The 100-299 and 300 plus acreage groups were combined in this analysis.

+++ N.S. denotes not significant
p denotes probability

(b) χ^2 values and significances for the use of merchants' (M) seed, own seed (O) and merchant seed only (Only M) between acreage groups (Table 4.8).

Seed source	χ^2	Significance
M	1.3714	N.S.
O	6.7692	$p<0.05$
Only M	2.8125	N.S.

(c) χ^2 values and significances for the use of storage facilities and grain drying (Table 4.9) between acreage groups (0-49, 50-99 and 100 + acres).

Characteristic	χ^2	Significance
Storage bins used	6.4329	$p < 0.05$
Some sort of drier used	2.9412	N.S.
Growers not drying grain	5.5556	N.S.

(d) χ^2 analysis of the choice of B.C.S.S. graded seed and commercial seed within three acreage groups (0-49, 50-99 and 100 + acres) (Table 4.10).

Seed choice	χ^2	Significance
B.C.S.S graded	6.9795	$p < 0.05$
Commercial	7.0116	$p < 0.05$

III. Analyses of variance and standard errors

(a) Analysis of variance and standard error, 1970 data, of the number of cultivars grown in three acreage groups (Table 4.6).

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance ratio	Significance
Total	72	61.7	0.857	1.403	$p<0.05$
Between acreage groups	2	18.85	9.425	15.420	$p<0.001$
Error	70	42.8	0.611		

Standard error: 0.092

(b) Analysis of variance and standard error, 1971 data, of the number of cultivars grown in three acreage groups (Table 4.6)

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance ratio	Significance
Total	85	95.4	1.118	2.558	$p<0.05$
Between acreage groups	2	59.1	29.550	67.620	$p<0.001$
Error	83	36.3	0.437		

Standard error: 0.071

(c) Analysis of variance and standard error of difference in sowing densities for the four main cultivars in survey B (Table 4.13), in 1971.

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance ratio	Significance
Total	108	5.21	0.048	1.655	$p<0.05$
Between the cultivars	3	19.82	6.610	227.931	$p<0.001$
Error	105	3.045	0.029		

Standard error: 0.0162

Appendix B

Analyses of variance for the 1971 sowing density/grain yield experiment:

(i) Grain yield per m^2

(ii) Ears per plant

(iii) Ears per m^2

(iv) Grains per ear

(v) 1000 grain weight

(vi) Number of grains per m^2

<u>Analyses of variance for the 1971 experiment</u>

(i) Grain yield per m^2

Source of variation	Degrees of Freedom	Sums of squares	Mean Square	Variance ratio	Significance
Total	119	1247,261.5			
Main plots	7	177,847.2			
Cultivar treatments	1	162,597.2	162,597.2	134.6594	$p<0.01$
Replicate blocks	3	11,627.6	3,875.9	3.2100	N.S.
Error 1	3	3,622.4	1,207.5		
Sub-plots	112	1069,413.3			
Treatments	14	771,237.6	55,088.4	38.5180	$p<0.001$
Sowing dates	2	595,183.9	297,592.0	208.0772	$p<0.001$
Density	4	124,228.5	31,057.1	21.7152	$p<0.001$
Sowing date x density	8	51,824.2	6,478.0	4.5295	$p<0.001$
Sowing date x density x cultivar	8	106,997.8	13,374.7	9.3517	$p<0.001$
Cultivar x sowing date	2	51,077.4	25,538.7	17.8567	$p<0.001$
Cultivar x sowing density	4	19,963.0	4,990.7	3.4895	$p<0.05$
Error 2	84	120,138.5	1,430.2		

Standard error: 3.453

(ii) Ears per plant

Source of variation	Degrees of Freedom	Sums of squares	Mean Square	Variance ratio	Significance
Total	119	996.56			
Main plot	7	6.04			
Cultivar treatments	1	0.82	0.82	3.5652	N.S.
Replicate blocks	3	3.53	1.18	5.1304	N.S.
Error 1	3	0.69	0.23		
Sub-plots	112	991.52			
Treatments	14	935.67	66.83	131.2967	$p<0.001$
Sowing date	2	2.80	1.40	2.7505	N.S.
Density	4	929.15	232.29	456.3654	$p<0.001$
Sowing date x density	8	3.72	0.47	0.9136	N.S.
Sowing date x density x cultivar	8	9.72	1.22	2.3870	$p<0.05$
Cultivar x sowing date	2	2.32	1.16	2.2790	N.S.
Cultivar x sowing density	4	2.36	0.59	1.1591	N.S.
Error 2	84	42.75	0.509		

Standard error: 0.0648

(iii)Ears per m^2

Source of variation	Degrees of Freedom	Sums of squares	Mean Square	Variance ratio	Significance
Total	119	1,529;258.9			
Main plots	7	98;932.8			
Cultivar treatments	1	39;020.4	39,020.4	4.6958	N.S.
Replicate blocks	3	34,983.6	11,661.2	1.4033	N.S.
Error 1	3	24,928.8	8,309.6		
Sub-plots	112	1,450,326.1			
Treatments	14	63;448.4	63,448.4	13.3835	p<0.001
Sowing date	2	11;664.1	11;664.1	2.4604	N.S.
Density	4	204;089.1	204;089.1	43.0495	p<0.001
Sowing date x density	8	6,074.1	6,074.1	1.2812	N.S.
Sowing date x density x cultivar	8	14,906.3	14;906.3	3.1442	p<0.01
Sowing date x cultivar	2	44;570.8	22,285.4	4.7008	p<0.05
Sowing density x cultivar	4	865,727.9	2,587.8	0.5459	N.S.
Error 2	84	398,227.5	4,740.8		

Standard error: 6.29

(iv) Grains per ear

Source of variation	Degrees of Freedom	Sums of squares	Mean Square	Variance ratio	Significance
Total	119	1,186.29			
Main plots	7	198.41			
Cultivar treatments	1	133.78	133.78	24.8200	p<0.05
Replicate blocks	3	48.46	16.15	2.9963	N.S.
Error 1	3	16.17	5.39		
Sub-plots	112	987.88			
Treatments	14	785.91	56.14	29.0429	p<0.001
Sowing date	2	172.82	86.41	44.7025	p<0.001
Density	4	485.52	121.38	62.7936	p<0.001
Sowing date x density	8	127.57	15.95	8.2514	p<0.001
Sowing date x density x cultivar	8	25.94	3.24	1.6762	N.S.
Sowing date x cultivar	2	10.67	5.34	2.7625	N.S.
Sowing density x cultivar	4	3.01	0.75	0.3893	N.S.
Error 2	84	162.35	1.933		

Standard error: 0.1269

(v) 1000 - grain weight

Source of variation	Degrees of Freedom	Sums of squares	Mean square	Variance ratio	Significance
Total	119	1,331.01			
Main plots	7	145.39			
Cultivar treatments	1	38.99	38.99	2.8839	N.S.
Replicate blocks	3	65.85	21.95	1.6235	N.S.
Error 1	3	40.55	13.52		
Sub-plots	112	1,186.40			
Treatments	14	987.25	70.52	44.2104	$p<0.001$
Sowing dates	2	559.56	279.78	175.3997	$p<0.001$
Density	4	346.46	86.62	54.3038	$p<0.001$
Sowing date x density	8	81.23	10.15	6.3632	$p<0.001$
Sowing date x density x cultivar	8	48.58	6.07	3.8054	$p<0.01$
Sowing date x cultivar	2	3.25	1.63	1.0187	N.S.
Sowing density x cultivar	4	13.42	3.36	2.1033	N.S.
Error 2	84	133.99	1.595		

Standard error: 0.1153

(vi) Number of grains per m^2

Source of variation	Degrees of Freedom	Sums of squares	Mean square	Variance ratio	Significance
Total	119	610,342,727			
Main plots	7	140,424,987			
Cultivar treatments	1	134,580,154	134,580,154	121.9908	$p<0.01$
Replicate blocks	3	2,535,221	845,074	0.7660	N.S.
Error 1	3	3,309,612	1,103,204		
Sub-plots	112	469,917,740			
Treatments	14	208,913,792	14,922,414	8.1077	$p<0.001$
Sowing date	2	117,010,149	58,505,075	31.7871	$p<0.001$
Density	4	26,196,545	6,549,136	3.5583	$p<0.05$
Sowing date x density	8	65,707,098	8,213,387	4.4625	$p<0.001$
Sowing date x density x cultivar	8	64,156,889	8,019,611	4.3572	$p<0.001$
Sowing date x cultivar	2	33,181,051	16,590,526	9.0140	$p<0.001$
Sowing density x cultivar	4	9,061,510	2,265,378	1.2308	N.S.
Error 2	84	154,604,498	1,840,530		

Standard error: 259.60

Appendix D

Expected monetary values (E.M.V.) (£ per acre) for a range of sowing densities calculated using present seed costs and grain prices, and predicted 1977 feed crop seed costs and grain prices, as shown in Table 9.1. Details of the method of calculation are presented in Chapter 9 : 9.2.

(a) Lowland feed crops, 1968/9, E.M.V. calculations (£ per acre)

Higher density	Lower density 0.5	0.75	1.0	1.25	1.5
2.0	-	+0.991	+0.350	-	+1.042
1.5	-0.461	+0.164	-0.474	+0.699	
1.25	-2.049	-1.244	-0.823		
1.0	-1.276	-0.481			
0.75	-0.804				

(b) Lowland malting crops. 1968/9, E.M.V. calculations (£ per acre)

Higher density	Lower density 0.5	0.75	1.0	1.25	1.5
2.0	-	+0.937	+1.261	-	+1.047
1.5	-0.597	+0.278	-0.557	+0.764	
1.25	-2.249	-1.371	-0.845		
1.0	-1.404	-0.536			
0.75	-0.878				

(c) Lowland seed crops, 1968/9, E.M.V. calculations (£ per acre)

Higher density	Lower density 0.5	0.75	1.0	1.25	1.5
2.0	-	+1.290	+0.468	-	+1.292
1.5	-0.524	+0.445	-0.560	+0.924	
1.25	-2.472	-1.500	-0.934		
1.0	-1.538	+0.012			
0.75	-0.972				

(d) Upland crops, 1968/9, E.M.V. calculations (£ per acre)

Higher density	Lower density 0.5	0.75	1.0	1.25	1.5
2.0	-	+0.815	+0.180	-	+0.974
1.5	-0.644	+0.214	-0.572	+0.719	
1.25	-2.220	-1.357	-0.832		
1.0	-1.388	-0.535			
0.75	-0.864				

(e) Predicted 1977 feed crop, E.M.V. calculations (£ per acre)

Higher density	Lower density 0.5	0.75	1.0	1.25	1.5
2.0	-	+1.484	+0.275	-	+1.851
1.5	-1.325	+0.359	-1.138	+1.369	
1.25	-4.349	-2.656	-1.630		
1.0	-2.717	-1.056			
0.75	-1.692				

Appendix D

I. 1970 emergence experiment, germination and emergence levels.

II. 1972 emergence experiment, germination level, 100 grain weight, and emergence levels.

III. Analyses of variance

(a) 1970 emergence experiment

(b) 1972 emergence experiment

(c) Emergence levels of four cultivars, 1972

(d) Emergence levels of four seed grades, 1972

(e) 100 seed weights of four cultivars, 1972.

I. 1970 emergence experiment, germination levels and emergence levels

Cultivar and ref. no.	Germination level %	Emergence level %
Golden Promise (GP) 96	98.0	84.1
GP 99	98.0	81.0
GP 103	98.0	80.5
GP 152	96.0	77.2
GP 170	97.0	83.9
GP 222	99.0	79.4
GP 226	99.0	80.1
GP 230	98.0	59.0
GP 280	99.0	85.8
GP 284	96.0	75.7
GP 290	99.0	77.1
GP 382	99.0	90.5
GP 410	98.0	80.7
GP 417	98.0	83.2
GP 436	99.8	78.4
Ymer (Y) 153	97.0	84.7
Y 163	93.0	77.5
Y 179	96.0	81.4
Y 181	98.0	80.7
Y 201	97.0	82.2
Y 204	100.0	83.1
Y 248	99.0	81.1
Y 273	98.0	79.0
Y 276	98.0	76.6
Y 301	93.0	82.2
Y 303	97.0	79.5
Y 350	99.0	86.2
Y 413	99.0	80.3
Y 433	99.0	77.9
Y 438	96.0	80.3

II. 1972 emergence experiment, germination level, 100 seed weight and emergence level

Seed lot ref. no.	Germination level %	100 seed weight g	Emergence level %
12 M	94	3.73	80.5
12 Y	97.5	4.12	73.8
12 B	98.7	4.12	72.3
25 Y	97	4.66	76.3
25 S	91	4.05	60.5
27 GP	98	3.87	77.0
28 GP	97	3.32	82.3
28 J	97	3.89	79.3
28 Z	95	4.22	76.8
31 Zo	95	4.35	71.3
31 Zb	98	4.28	58.3
31 GP	92	3.74	75.0
32 GPo	99	3.27	76.8
32 GPc	98	4.12	83.5
32 Y	98	3.65	61.3
37 P	96	-	66.5
37 Y	95	-	66.0
48 M	98	3.83	83.5
48 Z	93	4.39	64.5
48 GP	94	4.07	73.0
53 Z	98	4.06	75.5
54 Cler	96	3.15	64.8
54 Y	99	5.13	52.5
55 Y	94	3.99	69.5
56 M	95	3.34	69.8
57 Crus	90	4.27	65.5
58 V	96	3.21	72.0
60 GP	98	3.08	72.5
61 I	97	4.50	77.5
61 GPa	97	3.95	82.0
61 GPb	96	3.79	80.0
63 M	97	3.08	82.5
63 Cler	94	4.32	68.5
66 GP	96	3.80	70.0
66 I	95	4.74	71.25
66 M	98	3.69	72.3
70 Z	94	4.20	72.3
70 GP	98	3.78	84.0
70 S	88	4.45	53.0
73 GPa	98	3.73	78.8
73 GPb	96	3.81	82.8
73 GPc	97	3.58	78.3
74 M	98	3.72	83.5
74 Y	89	3.93	46.3
74 GP	96	3.74	62.5

Seed lot reference annotations for cultivars:

B = Berac   Cler = Clermont   Crus = Crusader
GP = Golden Promise   I = Imber   J = Julia
M = Midas   S = Sultan   Y = Ymer   Z = Zephyr

III. Analyses of variance

(a) Analysis of variance in the 1970 emergence experiment

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance Ratio	F-test Significance
Total	119	3006.1265			
Due to block replicates	3	105.8605	35.6202	2.2442	N.S.
Due to seed lots	29	1520.1299	52.4183	3.3044	$p < 0.01$
Error	87	1380.1361	15.8636		

(b) Analysis of variance in the 1972 emergence experiment

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance Ratio	F-test Significance
Total	179	7270.4570			
Due to block replicates	3	11.0000	3.6667	0.3294	N.S.
Due to seed lots	44	5790.2558	131.5967	11.8232	$p<0.001$
Error	132	1469.2012	11.1303		

(c) Analysis of variance in the emergence levels in four cultivars sown in 1972.

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance Ratio	F-test Significance
Total	33	1119.6910			
Due to cultivars	3	463.0000	154.3333	7.0505	$p<0.001$
Error	30	656.691	21.8897		

Standard error: 0.802

Standard errors:

(a) 0.432

(b) 0.424

(d) Analysis of variance in the emergence levels of four seed grades sown in 1972

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance Ratio	Significance
Total	44	1420.1500			
Due to seed grade	3	87.2239	29.0746	0.8933	N.S.
Error	41	1333.9261	32.5348		

Standard error: 0.85029

(e) Analysis of variance in the 100 seed weight in seed lots of four cultivars sown in 1972.

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance Ratio	Significance
Total	32	5.919	0.185	1.7453	N.S.
Between the cultivars	3	2.846	0.949	8.9471	$p<0.01$
Error	29	3.073	0.1060		

Standard error: 0.0569

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BARLEY GROWERS QUESTIONNAIRE

These questions apply to Barley growers for either feed or malting, but not for seed.

A. 1. Name ______________________________

2. Address ______________________________

3. Nearest town or village ______________________________

4. Soil type e.g. sandy, loam, or clay ______________________________

B 1. What varieties sown in 1968? __________ __________ __________

2. What varieties sown in 1969? __________ __________ __________

3. What % used for seed on the farm and what % sold off the farm for feed or malting? ______________________________

4. What is your usual crop rotation involving Barley? ______________________________

____

C. 1. Cost of seed per cwt. 1968 __________ 1969 __________

2. Why do you use that/those particular varieties? ______________________________

____

3. How long do you retain seed in storage before sowing? ______________________________

____

4. Was the seed certified? 1968 __________ 1969 __________

5. Seed treatment, e.g. insecticide 1968 ______________________________

1969 ______________________________

D. 1. What numbers of plants were you aiming for, per unit area? ______________________________

____

2. Average seeding rate per acre (e.g. cwt/acre) ______________________________

3. Distance between rows aimed for ______________________________

4. Time of sowing 1968 __________ 1969 __________

5. What would you consider ideal conditions for sowing, e.g. warm/wet ______________________________

____

6. Depth of sowing (on average) ______________________________

7. Type of seed drill used ______________________________

E. 1. Harvesting dates 1968 __________ 1969 __________

2. Harvesting conditions __________ __________

3. Average yield per acre __________ __________

4. Best and worst yields per acre?

1968 __________ __________

1969 __________ __________

F. 1. Moisture content at harvest ______________________________

2. Moisture content after drying ______________________________

3. Drying conditions ______________________________

G. 1. How much do you retain ? ______________________________

2. How much do you sell ? ______________________________

3. Do you sell direct to a farmer or merchant? ______________________________

4. Do you grow any on contract ? ______________________________

5. Prices given per quantity of crop, e.g. average price/cwt.

1968 __________ 1969 __________

BARLEY GROWERS' SURVEY 1971

A. 1. Name ....

2. Address ....

3. Nearest town or village ....

B. 1. Varieties sown in : 1969 ....

1970 ....

2. What varieties will be sown in 1971 ? ....

3. Of the 1970 seed, which varieties were of British Cereal Seed Certification Scheme certified seed ? Please give grade of certification.

Variety	Grade of Certification (e.g. MS,FA, etc.)
....	....
....	....
....	....

4. Of the seed to be sown in 1971, which varieties will be of B.C.S.C.S. certified seed ? Please give grade of certification.

Varieties	Grade of Certification (e.g. FA-field approved, etc.)
....	....
....	....
....	....

5. Where did you obtain your seed ? (a) Direct from merchant .... (b) Another farmer ....

(c) Other ....

6. Why do you use that/those particular varieties ? ....

C. 1. What proportion of the seed you will sow this year (1971) was grown on your own farm in 1970 ? ....

2. How long do you retain seed in your own storage facilities before sowing (e.g. from previous harvest) ? ....
....

3. What kind of storage facilities do you have on your farm (e.g. bins, barn, etc.) ? ....

4. What seed treatment will the 1971 varieties have (e.g. insecticide) ?

Variety	Treatment
....	....
....	....
....	....

D. 1. Cost of seed per cwt:

1970 Variety	1970 Cost	1971 Variety	1971 Cost
....	....	....	....
....	....	....	....
....	....	....	....

2. What acreage of each variety did you grow in 1970, and propose to grow in 1971 ?

1970 Variety	1970 Acreage	1971 Variety	1971 Acreage
....	....	....	....
....	....	....	....
....	....	....	....

3. Average sowing rate per acre (e.g. cwts/acre):

1970 Variety	1970 Sowing Rate	1971 Variety	1971 Sowing Rate
....	....	....	....
....	....	....	....
....	....	....	....

4. Distance between rows aimed for (e.g. 6 inches) ....

5. Sowing dates in 1970 (e.g. 1st week in March) ....

6. What would you consider ideal conditions for sowing ? (e.g. warm, dry) ....

7. Average depth of sowing (e.g. 2 inches) ? ....

E. 1. Harvesting dates in 1970 (e.g. 1st week in September) ? ....

2. Harvesting conditions in 1970 (e.g. warm, dry) ? ....

3. What was the moisture content of the grain at harvest (e.g. 20% R H) ? ....

4. What was the moisture content of the grain after drying ? ....

5. What kind of drying facilities do you use ? ....

F. 1. Average yields per acre in :

1969 Variety	1969 Yield	1970 Variety	1970 Yield
....	....	....	....
....	....	....	....
....	....	....	....

2. What percentage of your 1970 crop was sold ? ....

3. What percentage of your 1970 crop did you retain ?..

4. Prices obtained per quantity of crop in:

1969 Variety	1969 Price Given	1970 Variety	1970 Price Given
....	....	....	....
....	....	....	....
....	....	....	....

THANK YOU