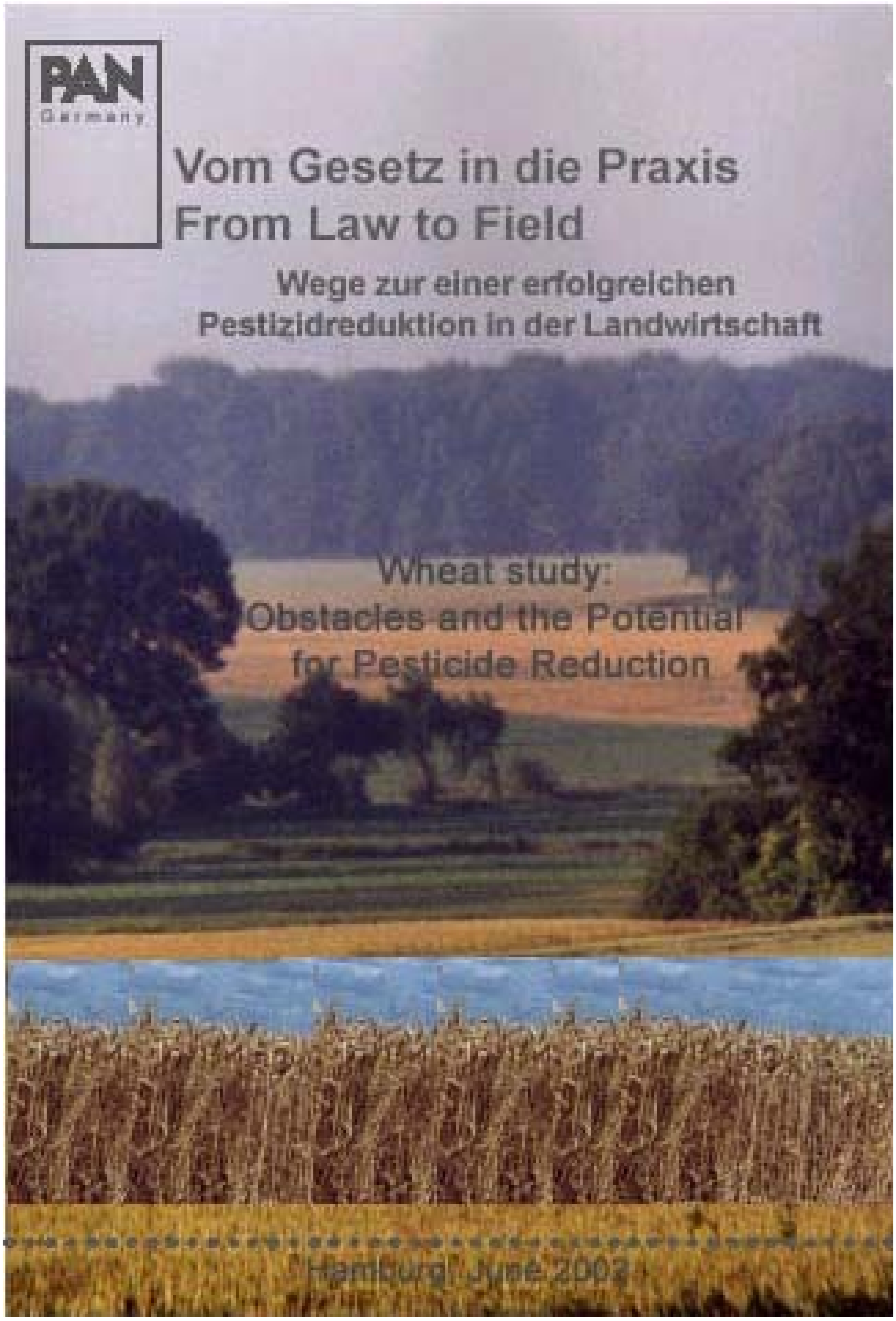
PAN Germany
Vom Gesetz in die Praxis
From Law to Field
Wege zur einer erfolgreichen
Pestizidreduktion in der Landwirtschaft
Wheat study:
Obstacles and the Potential
for Pesticide Reduction
Hamburg, June 2002

Pesticide Action Network (PAN)

Founded in 1982, the Pesticide Action Network is an international coalition of over 400 citizen groups in more than 60 countries working to oppose the misuse of pesticides and to promote sustainable agriculture and ecologically sound pest management.
PAN Germany was established in 1984 as part of this global network and has continually been involved in initiatives to reduce the use of hazardous pesticides and to promote sustainable pest management systems on national, European and global level.

Acknowledgements/ Danksagung

Several individuals contributed their comments, insights and experience to the study "From Law to Field – Pesticide Use Reduction in Agriculture – From Pesticide Residue Analyses to Action". We would like to thank Dr. Wolfgang Bödeker, Dr. Rolf Altenburger (PAN Germany) and Dr. Helmut Santl (GfU) for giving their useful input and for reviewing several drafts of this study. Thanks also to Christine Schmitt (PAN Germany) for reviewing and proofreading. Finally we would like to thank Edyth Watts for the translation of the two case studies "Apple: Obstacles and the Potential for Pesticide Reduction" and "Wheat: Obstacltes and the Potential for Pesticide Reduction".

Viele Menschen vermittelten uns ihre Kommentare, Einsichten und Erfahrungen für diese Studie. Wir danken insbesondere Dr. Wolfgang Bödeker, Dr. Rolf Altenburger (PAN Germany) verschiedener Entwürfe dieser Studie. Danke auch an Christine Schmitt (PAN Germany) für Durchsicht und Korrektur. Abschließend danken wir
Edyth Watts für die Übersetzung der beiden Fallstudien "Äpfel – Hindernisse und Potentiale für eine Pestizid-Reduktion" und "Weizen – Hindernisse und Potentiale für eine Pestizid-Reduktion".

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Funds to this project were made available by the European Commission, Directorate-General XI, Environment, Nuclear Safety and Civil Protection, Reference AD-HOC99/3/246, and the Freudenberg Foundation, Germany. This support is gratefully acknowledged.

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1 Introduction

In Germany, wheat, next to potatoes and sugar beet, is the field crop most intensively treated with pesticides. The average annual frequency of pesticide treatment is 3.36. In comparison potatoes are treated 5.65 times and sugar beet 3.52 times. Next come winter rye (2.08) and maize (1.12). The overall average for field crops is 2.40. In wheat production the main uses are of fungicides and herbicides (WAIBEL AND FLEISCHER 1998).
In this section of the study " From Law to Field: Pesticide Use Reduction in Agriculture – from Residue Analysis to Action" the pest control practice in three methods of wheat production will be compared. Further it will be demonstrated how the obstacles can be overcome and the potential for pesticide use reduction met in these three methods. The objective is to set out simple easily-implemented minimum requirements for good agricultural practice in wheat production.
The following observations are mostly based on wheat production in Germany.

2 Importance of wheat production

Wheat is an important staple food for about 35% of the world's population. With rice, maize and sorghum it is one of the four most widely cultivated cereals. Western Europe, China, USA , India and Canada are the greatest wheat producers. In Western Europe Germany has the largest area under wheat. About 24% of Germany's arable land is used for wheat, that is about 2.7 million hectares, and it is the most important crop in Germany's agricultural output. About 30% is used for bread flour, 70% for fodder.
Wheat prefers rich, deep loamy soil and a good water supply. Typical wheat-growing country is to be found on wide level plains with loamy and marshy soils. Much less will be found on very sandy soils with a poor water supply. The relatively high quality of wheat is the result of highly successful breeding: in contrast to other cereals it fetches the highest prices and has the best profile in the market place (LWK HANNOVER 2000). The constant expansion of wheat production has been at the expense of other cereals. Winter rye, oats and summer barley have been replaced by wheat (DIERCKS,1996). It is particularly noticeable that in typical arable areas the crop rotation is now limited - for example to sugar beet – wheat - wheat. By comparison to the rest of the world, USA, Eastern Europe and Asia, Western European has the highest average production at the rate of over 6000 kg per hectare. In international terms Western Europe also has the highest average intensity of cultivation (e.g. input of fertilisers and pesticides). In 1990, for example, the wheat-growing regions of Western Europe, which represent only 8% of the world's wheat-growing areas, applied almost 70% of the fungicides used world-wide at a cost of US$760 million (VERREET 1995).

3 The main pests in wheat production

The following section introduces the most commonly occurring pests and fungus affecting wheat cultivation, together with weeds and wild grasses. Numerous factors, the site, crop rotation, soil treatment, fertilisation, choice of variety, and not least the weather, decide on the type of pest that occurs in a given area. Pest and fungus attacks can change in nature from year to year.

Table 1: Main pests in wheat production
Fungus
True mildew (Erysiphe graminis) Dry leaf (Septoria tritici) Glume blotch (Septoria nodorum) DTR-leaf spot (Drechslera tritici-repentis) Leag rust (Puccinia recondita) Yellow stripe rust (Puccinia striiformis) Fusarium diseases (Fusarium nivale, microdochium nivale) Stem rust/stem break (Pseudocercosporella herpotrichoides) Take-all/blackleg (Gaeumannomyces graminis) Covered smut (Tilletia caries) Dwarf bunt (Tilletia controversa) Loose smut (Ustilago tritici)
Insect pests
Cereal aphids (Macrosiphon avenae, Metopolophium dirhodum) Leaf beetles (Oulema melanopus, O. lichensis) Saddle gall midge (Haplodiplosis marginata) Gall midge (Contarinia tritici, sitodiplosis mosellana) Wheat bulb fly (delia coarctata) Fritfly (Oscinella frit)
Virus infections
Yellow dwarf virus (BYVD)

Source: OBST AND PAUL (1993)

3.1 Weeds and wild grasses

Weeds and wild grasses compete with cultivated plants for light, water and nutrients. They also make the upkeep and harvesting of the crop more difficult and have a detrimental effect on the quality of the final product. The occurrence of the different weeds and wild grasses depends very much on the region. Intensive farming has led to certain so-called problem weeds becoming well established. Examples are: slender foxtail (alopecurus myosuroides), wind-grass (Apera spica-venti), couch grass (agropyron), cleavers (gallium aparine), camomile (chamomilla), chickweed (stellaria media),and heartsease (arvensis). These weeds are mostly found where there is highly nitrogenous soil due to the use of both organic and mineral fertilisers. The increasing practice of narrowing the sequence in the rotation of crops also favours the reproduction of such weeds as foxtail, cleavers and more recently brome grass (bromus), which are difficult to control with herbicides (PSA HANNOVER 1998). Additionally wind-grass and foxtail have recently built up a resistance to the herbicide Isoproturon which had been widely used for many years. At present use of this herbicide is restricted, at least in Germany, as a result of the conditions it has provoked.

3.2 Fungus pests

The climate and weather conditions in central Europe favour outbreaks of fungus diseases. The different regional climates give rise to very different types of infection, with the attendant economic consequences. There is no area in central Europe which can claim to be free permanently of the risk of fungus infections. Fungicide use in wheat production is therefore a high priority (VERREET 1995).
Wheat is particularly prone to disease and pests due to its long growing period compared to that of other cereals. The importance of certain fungus diseases has been greatly modified by the biological and technical progress of the last four decades. Seed-borne pests such as loose and covered smut have been largely brought under control by the dressing of seed stock and are now much less of a problem. Organic farmers, who are not allowed to use synthetic chemical treatments, may still find that their crops are subject to these diseases. As a leaf pest rust fungus remains a potential threat. It reproduces at a fast rate and is extremely damaging. However It does not appear regularly every year (HEITFUSS,1990). That is also true of yellow stripe rust, which often appears to confine itself to certain areas. The temperatures and humidity that it needs are more often found in the cooler coastal regions or higher land (OBST AND PAUL,1993). More widespread are the following: true mildew, septoria leaf and ear spot, and types of fusarium rot. There is a growing problem with DTR leaf spot, stem break and blackleg, since these diseases profit from the increasingly cereal-rich rotation schemes and the popular plough-free soil management. Each year may bring a new disease. It is still extremely difficult if not totally impossible to make a reliable forecast.

3.3 Insect and aphid pests

Aphids are the most common pests to attack wheat. They only appear en masse in certain years. In extreme cases their sap consumption can cause losses of between 10% and 20% of the crop (OBST AND PAUL,1993). They can also carry the barley yellow dwarf virus (BYDV) across to the wheat, causing yet greater losses. In 1989 there was a very serious attack resulting in tremendous crop loss.
The wheat bulb fly does not occur over a wide area, but causes great damage in some regions, especially where sowing has been late following a sugar beet crop. Gall midges, saddle gall midges and fritflies are all restricted to certain regions, but occur mostly in typical wheat-growing country (DENNERT AND FISCHBECK, 1999).

4 Different methods in wheat production

In principle there are three different systems of wheat production: organic, conventional and integrated. The conventional system can be described as legally regulated agriculture by which is meant that it fulfils the requirements contained in the body of law and various agricultural guidelines. It is regulated by the legal system. In this study the term conventional agriculture will be used as this is the most commonly understood at present.
Integrated agriculture goes beyond conventional legal requirements in the demands it makes on growers. It proposes an agricultural system which has as its objective a further development and improvement of present conventional or generally accepted practices in the raising and protection of plants (ML 1996). The main topic in this

study is pesticide reduction in wheat farming, so in the following section the concept of integrated pest control will be explored.
Pest control is part of the overall concept of integrated agriculture and as such one of its vital elements. The definition of the system will follow.

4.1 Integrated pest control in wheat production

The concept of integrated pest control (IPS) goes back to the 1950s. At that time the first critical reactions were being voiced against the use of pesticides increasing without enough attention being paid to the biological implications. At that period the relationship user/consumer/environmental protection was not in the foreground (FREIER et al.,1995). During the last four decades the concept of integrated pest control has become commonplace all over the world. The German Pest Control Act firmly endorsed the concept. It did not make integrated methods legally binding, but recommended that they be taken into account. FREIER et al. (1995) point out that at the time there was no reliable information on the extent to which integrated pest control was consistently applied in the cultivation of wheat. WAIBEL and FLEISCHER (1998) report that a representative poll taken in North-Rhine – Westphalia showed that only 8% of farms were being run on integrated lines. FREIER and BURTH (1999) are of the opinion that in reality arable farming lags a long way behind the model of integrated practice. Figures show that apple producers have converted to integrated methods on a much greater scale than wheat farmers. Some universities and institutes run model farms and research areas where integrated methods are systematically used but at present there is no evidence that integrated pest control makes more than a very limited contribution to wheat production (FREIER et al., 1995).

4.2 Objectives

Integrated pest control aims to produce healthy plants and high quality crops. First all the established methods of field and horticultural pest control have to be exhausted, in order to reduce the application of chemical pesticides. The three essential features of integrated pest control in this context are:

1 Complex procedures to take account of long-term effects
2 Inclusion of organic requirements and treatments
3 Targeted and sparing use of chemical pesticides

Integrated pest control aims to provide comprehensive treatment in line with both economy and ecology (AID 1997).

4.2.1 Definition

Integrated pest control is defined in §2 Paragraph 1 No. 2 Pesticide Act (PflSchG) "a combination of procedures, by which chemical pesticides are limited to essential use in view of the biological, bio-technical and horticultural implications as well as those of culture techniques and cultivation" (BMELF 1999).
At international level the FAO formulation of integrated pest control is as follows: "Integrated pest control is a system of various economic, ecological and toxicological procedures designed keep pest damage below the economic injury level primarily by the use of established natural controls and regulation techniques" (FREIER et al. 1995).
An important element in the above definition is the principle of the economic injury level. The intensity of infestation, the level of damage and the cost of control must all be taken into account. There is a reciprocal relationship between the damage done by disease, pests and weeds at a tolerable level which can be discounted economically and damage so serious that it is essential to turn to chemical treatments if the economic losses threaten to be too great (DIERCKS 1996).

4.2.2 Documentation

A basic principle of integrated pest control is that it requires documentation. For example reports must be made on the stage of growth, the type and objective of the treatment applied and an evaluation of its effectiveness; in the case of chemical treatments the quantity applied, the type of treatment and the weather conditions at the time. Fruit producers already provide these.

4.2.3 Monitoring

There is no monitoring of the records kept on integrated wheat production, whereas there is in fruit farming.

4.3 Conventional wheat production

By conventional agriculture is understood the current system of farming. It is a regulated system guided by legislation. Important regulations on farming procedures are set out in the Pesticide Act or the Fertiliser Order (STEINMANN and GEROWITT 2000).

4.3.1 Objectives

Conventional farming or regulated agriculture has as its main objective the maintenance of the standards set out in the regulations. Within this framework there is no reason to aim at a reduction in pesticide use, except on economic grounds.

4.3.2 Definition

There is no special definition of conventional agriculture. In this study it will be taken to mean a system of farming which is carried out in accordance with legal requirements such as the Pesticide Act, but recognises no further obligation to restrict the use of pesticides. In the Pesticide Act of 1996 the first mention was made of "good agricultural practice in pest control". The term includes "how" pesticides should be applied in farming: "Pesticides should only be applied in keeping with good agricultural practice. Good agricultural practice in pesticide use means taking into account the principles of integrated pest control" (BMELF 1999). Whereas this could be taken to give official recognition to the principles of integrated pest control the formulation is in a legal sense so weak - "means….taking into account…" – that ignoring it would incur no sanctions (FREIER and BURTH 1999).
There is no precise definition for the conventional system. This study uses conventional to describe practices that conform to legal requirements, such as the Pesticide Act, but do not impose any further limitations on pesticide use. Only in 1998 did the Federal Ministry for Food, Agriculture and Forestry formulate and publish its ground rules for good agricultural practice in the use of pesticides in accordance with the Pesticide Act. There it was made quite clear that good agricultural practice reflected the status quo. The use of pesticides was sanctioned if:

- Their use was scientifically proven safe
- Practical experiment had proved their use appropriate, suitable and necessary
- They were recommended by the advisory services
- They were known to expert users

There was a further prognosis: "In the long term the standard for good agricultural practice in the use of pesticides will alter to a greater or lesser extent to conform to the present day conditions of integrated pesticide use." (BMELF,1998)

Thus "good agricultural practice" only reflects the average, and accordance with the rules signifies no more than conformity to legal requirements. The term "good agricultural practice" might be taken to mean a standard appreciably higher than cultural practice" might be taken to mean a standard appreciably higher than normal, but that is not the case. A more suitable term would be "current agricultural practice".

4.3.3 Documentation

The principles of good agricultural practice in pesticide use recommend the documentation of all measures taken for pest control (BMELF1998). The recommendation is in no way binding. However records of pesticides used, data on varieties and weather conditions etc. should be of primary importance in the system. The farmer often keeps such records for his own use in calculating the economic value of his output. In the age of computers it should be easy. Field card index programmes are already in wide use, making the inputting of data on care, management and evaluation a straightforward exercise.

4.3.4 Monitoring

Yearly monitoring as e.g. in organic farming is not required in conventional farming. There are only such spot checks as to ascertain that regulations concerning the use of pesticides near water courses are adhered to. It is obligatory to make a report every two years to the Technical Control Board (TÜV).

4.4 Organic wheat production

The main idea behind organic production is to remain in harmony with nature. The natural links between the soil, plants, animals and man should be respected as an uninterrupted cycle (AGÖL 2000). High outlay should be avoided to save on energy and raw materials while producing healthy, safe and biologically nutritious foods (SÖL 2001). In Germany there are two different movements in organic farming. The oldest is Bo-dynamic agriculture (Demurer) founded by Dr. Rudolf Steiner in 1924. Both scientific knowledge and spiritual insights are involved. Cosmic influences are taken into account and use is made of preparations containing beneficial herbs and crystals.

The second method is biological agriculture (e.g. Bioland, Naturland…) which was developed in the 1950s by Hans Müller. Hans Müller had worked with bio-dynamic agriculture since the 1930s and his biological agriculture system evolved from it, leaving out the special dynamic influences (AGÖL 2000). At present 1.95% of agricultural concerns, or 2.64% of cultivated land, run on organic lines (Stand 05.06.2001) (SÖL 2001).

4.4.1 Objectives

The main objectives of organic farming are:

- Maintaining the earth's natural fertility
- Observing the natural cycle
- Growing and processing wholesome foods in the manner least destructive to the natural world
- Protection of the natural elements of water, air and soil
- Appropriate animal husbandry
- Active protection of nature and all species
- Economy in the use of energy and raw materials
- Secure employment for farm-workers
- Refusal to employ genetic engineering in either production or processing
- Co-operation in solving the problems of world hunger, including refusal to import fodder crops from the Third World, where their cultivation prevents the growing of staple foods (SÖL 2001).

4.4.2 Definition

Organic agriculture in Germany and throughout the E.U. is defined by Regulation 2092/91 issued in 1991. Minimum standards for organic production were defined and requirements for the inspection of farming methods and processing outlined. From 1998 onwards there has been an umbrella group of nine associations of organic farmers known as AGÖL; ANOG; Bioland, Demeter, Naturland, Biokreis Ostbayern, Biopark, Eco Vin, Ökosiegel and Gäa (AID 1996). In fact the groups Bioland and Demeter left AGÖL in 2001 (SÖL 2001).

4.4.3 Documentation

It is obligatory to provide exact information on the type and quantity of materials used on the farm and details of their application. Full and precise documentation is a condition of being recognised (AGÖL 2000).

4.4.4 Monitoring

Once a year every organic farm is visited by an independent inspectorate recognised by the state and its adherence to organic guidelines checked. In this organic farms are radically different from conventional or integrated ones. Organic products are marked for consumers with suitable logos showing the nature of the goods and the organic association. An organic grower is only entitled to use the logo if s/he is a contractual member of the association.

5 Current practice in pest control in the three systems

In this section concrete examples from the three systems described above will be compared in terms of pest control practices and the contribution to a reduction in pesticide use. The first to be considered will be single instances of pesticide use in wheat cultivation resulting from conversion to the integrated system. Further to that conventional wheat production will be considered and a judgement reached on how far elements of integrated pest control have already passed into conventional farming. Finally pest control in organic wheat production will be examined.

5.1 Pest control in integrated wheat production

In the following the most important principles of integrated pest control with special reference to wheat production will be discussed. A few examples will be cited to indicate what can be understood by integrated wheat production and where the potential for pesticide reduction lies.

5.1.1 Appropriate crop rotation

In integrated farms every effort is made to vary the crops in the rotation, as doing so cuts down on the need for pesticides. According to WETZEL (1995) a varied crop rotation is one of the best ways of dealing with pest infestations before they occur. Crop rotation is the timed sequence of crops with certain ones re-appearing regularly on the same land after an interval of some years. In this way soil-borne pests do not multiply as fast as they would if the same crop was repeatedly planted on the same land, where they have ideal circumstances in which to develop. Leafy plants, (sugar beet or winter rape), and summer crops (oats or peas), break the cycle of stem diseases, such as stem break and blackleg, and leaf infections like DTR in wheat. A varied crop rotation regime can also control the spread of problem grasses such as foxtail and wind-grass (AID 1997). No definite programme for rotation can be prescribed as individual farms differ greatly in their organisation and labour force, not to mention site, climate and soil composition.

There are certain principles to observe in the cultivation of wheat with regard to pest control. There should, for example, be no crop rotation where wheat follows wheat. The proportion of cereals in the rotation should not be more than 67% (FREIER and BURTH 1999). Also an interim crop should be included. An interim crop is normally a quick growing plant that can be sown in between two major crops. It could be mustard, fodder radish or phacelia. The advantages of interim crops are: they conserve nutrients, control weeds, break up the soil and improve the tilth and soil life, preventing erosion and adding to the humus content (AID 1997).

5.1.2 Use of resistant varieties

Cultivation of resistant varieties is an important part of the pest control strategies of integrated farming methods. It leads to a reduction in the use of fungicides and works against fungicides building up resistance in the fungus pest. Within the selection of wheat varieties there is a marked difference in tolerance of fungus disease. The Federal Advisory Service has published a "Descriptive List of Varieties" and graded them from 1 – 9 on susceptibility to disease. Grade 1 denotes fully resistant, grade 9 the highest susceptibility (AID). Resistant varieties do not necessarily remain resistant. In the course of a few years the process of natural selection or modification in the pest can overcome the resistance and the variety will become susceptible once again. The process is even more rapid when rotation is very limited, the intensity of cultivation is great and the same variety appears frequently on the same site and in the same region (BMELF1998). The level of resistance in the different varieties must be checked from year to year and care taken to plant from a wide selection. There are also great differences in the height of the plants and the storage quality of the grain. The use of nitrogenous fertiliser has the greatest influence on the quantity of growth regulators required but the choice of variety comes a close second. When healthy and resistance-lodging varieties are sown the use of fungicides and growth regulators is considerably reduced. Thus choice of appropriate varieties is an important aspect of the attempt to reduce pesticide use.

5.1.3 Appropriate soil management

One main problem for farmers is whether to prepare the soil (before planting) by ploughing (turning over the soil) or without ploughing (harrowing but not turning over). The exemplary system would be to plough thereby removing quickly and easily all the weeds, wild grasses and fallen grain from the previous season (ML 1996). Ploughing can deter the occurrence of fungus diseases, as the fungus spores (e.g. DTR, Septoria dry leaf and the fusaria strains) tend to remain on the stubble ,which ploughing removes from the surface (OBST and PAUL 1993). On the other hand ploughing is costly in terms of time and can lead to soil clodding or erosion. Potatoes for example benefit from land which has not been ploughed. The problem of potatoes growing up through the wheat is lessened by the effect of frost on those tubers which remain on the surface. Another advantage of not ploughing is that erosion is prevented since the wheat stubble is left in place (ML 1996). These two examples show that both ploughing and not ploughing can be justified in terms of pesticide reduction. The integrated approach accepts that in this matter compromise must be reached by the farmers according to conditions in a given locality.

5.1.4 Mechanical weed control

The best tool for controlling weeds mechanically is the harrow. Depending on the condition of the soil and the state of the weather, the size of the weeds and the frequency of planting, the success of eradication can be between 30% and 70% (AID 1997). However in fields where weeds are growing strongly, for example after heavy applications of nitrogenous fertiliser, the effectiveness of ploughing is more doubtful.

Fields with moderate weed cover can be satisfactorily cleared by harrowing, thus making a considerable saving on herbicides.

5.1.5 Crop management

Sowing dates have a deciding influence of the use of pesticides. Very early dates, such as September, should be avoided, as there is then a greater growth of weeds, the danger of aphids spreading the dangerous yellow dwarf virus, and the onset, even in the autumn, of leaf diseases such as mildew (AID 1997). Clearly there are areas where only early sowing is possible (e.g. the marshy coastal areas), as later the soil becomes difficult to work due to the heavy precipitation and low evaporation rate. The quantity of seed is also dependent on the date of sowing. To much leads to close rows and a corresponding alteration in the micro-climate. The result is serious attacks of leaf fungus. The danger to laid grain is increased. The problems of sowing too thickly can made worse by the application of too much nitrogenous fertiliser. Fertiliser should only be applied in keeping with the needs of wheat as a crop, care for the soil, the nature of the previous crop and other conditions affecting the site of the fields in question. Too much nitrogen leads to attacks of mildew and aphid infestations (BBA 2001 a). All these factors – the sowing date, the quantity of seed and the amount of nitrogen have implications for the reduction of pesticide use.

5.1.6 Pesticide use and the principle of economic injury level

In principle integrated pesticide use is only allowed when the economic injury level of certain weeds, diseases and pests has been overstepped. The use of pesticides is reduced, beneficial organisms less affected and the danger of resistance building minimised (PSA HANNOVER 1998). Wheat production has several well established damage levels, the result of years of research projects and experiments (AID 1997). The farmer has to know what the actual situation is in his own fields with regard to pest attacks or weed invasions. S/he must carry out regular inspections to find out if the injury level has been reached. There is for example a frame, “The Göttinger Zähl- und Schätzrahmen” which can be used to help assess the level of weed cover. It is a metal frame measuring $0.1m^2$ and its use can make estimation much easier (PSA HANNOVER 1998). Further support can be had from the official forecasting service of the pesticide departments. They provide information on the current pest attacks in a specific region. The forecasting service does not relieve the farmer of the responsibility for inspection, but rather aims to encourage him to carry it out. Computer support should also be available to add to forecasts. Computer programmes have already been developed to a high degree and it is, for example, possible to forecast the course of an attack, the level of damage and the necessary precautions to take in the short or long term. In Germany programmes already in service are PRO-PLANT for wheat production and the wheat version of BAYERN for fungus pests (AID 1997). They have already proved their worth particularly in the advisory and forecasting services. In the integrated pest control system surveillance, estimation and information-gathering are of central importance in deciding the level of pesticides to be applied in keeping with the principle of the economic injury level. Farmers are encouraged to weigh up the possibility of applying less pesticide, applying it to only part of the fields or using selective preparations that do not harm beneficial organisms (WETZEL 1995).

5.1.7 Encouragement of natural predators

An important pillar in integrated cultivation is the exploitation and encouragement of natural predators. These are creatures which aid in the decimation of pests. The structure of the relationship between pests and their enemies is complicated and many-sided and it is difficult to evaluate the contribution of natural predators. At present research is going on to determine to what extent pesticide levels have to be altered in treating cereal aphids if numbers of natural predators are present. The question remains open, but in the meantime the predators should be encouraged as follows: in integrated fields only selective pesticides should be used, and no broadly effective treatments that would kill useful creatures. Hedges and verges should be left as a habitat and food supply. Even leaving a strip of unweeded land in the wheat field can help the hoverfly (which preys on aphids in cereals) to take hold. Similarly fields which are less intensively worked can house species of ground beetles, another predator (AID 1997).

5.2 Pest control in conventional wheat production

In the following section the current practice in conventional wheat production will be briefly described and obstacles to pesticide reduction pointed out. Only a general overview can be given since wheat is grown in different circumstances on individual farms and in the many regions; these together with the exigencies of sites and weather conditions, make for great variations in practice.

5.2.1 Appropriate crop rotation

The development of arable farming in recent decades has been marked by increasingly intensive methods of production. Technical progress and the economic and agri-political atmosphere have led to much simpler rotation schemes being put into practice. Now the major crops are those which promise the highest economic return and labour is seen in terms of outlay i.e. it has to be as fully mechanised as possible. Concentration on a few crops in the rotation system has led to the onset of diseases and pest infestations. Intensive use is then made of fertilisers and pesticides in an effort to compensate for the damage caused as a result of the diminished rotation schemes (METZ and GARMHAUSEN 2000).

There are very different schemes for rotation in different regions. In arable country, where for the most part farms do not stock cattle, the most common rotation is sugar beet – wheat – barley with a growing tendency towards sugar beet – wheat - wheat. Farms which have no sugar quota and consequently cannot grow sugar beet usually replace it with winter rape. Summer cereals or legumes such as field beans are minor crops.

The rotation is different in regions where there is mixed farming. They are usually areas where the land does not naturally produce such high yields. In these areas farmers often grow the greater part of their fodder themselves. The rotation schemes, besides wheat, can include such crops as winter barley, triticale, field beans, peas or forage maize. On these mostly sandy soils potatoes also are an important crop. Even in fodder-growing country there are extreme practices such as planting forage maize as the sole crop.

In the main it is true to say that the cereal content of rotations has increased and that there are more cases where the same crop follows on i.e. wheat follows wheat. According to METZ and GARMHAUSEN (2000) about 30% of farmland in Germany has adopted the practice. The effect of planting a high percentage of cereals and restricting the choice of crops to a few types is that they are too close to each other, both in time and space. Pests and diseases have less distance to travel and their survival rate and opportunities to reproduce are correspondingly higher. The consequence is yet higher applications of pesticide (WAIBEL & FLEISCHER 1998). By comparison with integrated production where the requirement is to use as varied a rotation as possible the current practice in conventional production leaves much to be desired.

5.2.2 Use of resistant varieties

Today the farmers' main criterion in choosing a variety is the potential yield. Resistance to disease is a secondary consideration. In agricultural circles the belief is often expressed that resistant varieties are genetically restricted to producing lower yields than the more susceptible ones. In this area, however, there has been enormous progress in the development of resistance. Especially in the case of mildew many varieties are no longer so susceptible but the narrow rotation schemes have brought *Septoria tritici* and DTR to the fore. Research carried out by PSA HANNOVER (1998-2000) indicated that many of the more healthy varieties had been treated with fungicides unnecessarily, as they were either less susceptible to disease or able to resist threatened infection. Between 1985 and 1987 the genetic proportion of the total yield (with no use of fungicides) was about 85%. The remaining 15% had been treated with fungicides. Between 1999 and 2000 the genetic proportion had risen to 93% (RAUPERT 2001). The fact that many varieties may not be susceptible is not in practice accepted by farmers as a criterion when applying fungicides. In spite of the success of the trials, resistance is often viewed as a controversial matter and many farmers feel they cannot rely on the genetic resistance of a given variety. In other words the application of fungicides is not automatically reduced by the selection of a resistant variety.

5.2.3 Appropriate soil management

In the face of steadily falling prices during recent years wheat producers have come under increasing economic pressure. More recently the high cost of fuels has added to their worries. That is not all; labour relations have become more difficult as the workload diminishes with greater areas of land turned over to arable cultivation. In practice the trend has been towards less ploughing, which is expensive in terms of time and energy, and in general the second crop is being planted without turning the soil. The plough has been abandoned in favour of plough-less techniques. Also stubble is more frequently left untreated on the fields after the grain has been harvested. The trend is basically negative as far as pesticide reduction is concerned since the increasingly high proportion of cereals in crop rotation encourages the spread of weeds and fungus diseases such as DTR, stem-break and blackleg.

5.2.4 Mechanical weed control

At present herbicides are the only form of weed control in the conventional system. Mechanical weed control is almost completely out of favour. The main reason is, as suggested above, that the success of the technique is not certain. Not only that but most farms have their own spraying equipment, so that investing in additional machinery such as a harrow is not worth while. On the whole herbicides work out cheaper and the final argument is that mechanical control takes up more time as the fields are taken out of use and a single treatment is often insufficient and has to be repeated. There is yet another aspect to consider: the high proportion of cereals in the much narrower rotation and the large amounts of nitrogenous fertiliser applied in conventional farms have led to a proportionate increase in the problems of wild grasses such as foxtail, wind-grass, brome grass and couch grass. They cannot then be removed satisfactorily by mechanical means.

5.2.5 Pesticide use and the principle of the economic injury level

In modern conventional farming the economic injury level is only partly observed. This can be briefly explained by taking the example of weed control. In conventional farming the use of the Göttinger frame, described above, has not come into use. From the point of view of the farmer too much time would be lost. It is also thought that in the long term problem seed would build up in the soil and there would eventually have to be a return to using herbicides. Additionally there is the problem of timing which does not fit in with the principle of the economic injury level. Some herbicides used in wheat fields are often applied in the autumn. Others are most effective if they are sprayed at the stage when the weeds are just germinating, or as the first shoots show above ground. In that case the use of the frame would not be appropriate. The advantage of spraying in early autumn is that less herbicide is needed and the growth of the wheat is less affected. What acceptance there is in practice of the economic injury level principle is due to the increasing economic pressures and above all to the low labour capacity of the farms. Every effort is made to combine different treatments in order to save labour. In many ways it is a matter of common sense and often leads to prophylactic measures. For example the last fungicide spray on the wheat heading is often combined with an insecticide against aphids. There may at that point be no sign of infestation and the economic injury level may not have been reached. The cost of preparations is also decisive. Insecticides that spare useful organisms are mostly more expensive than the more common ones, and the cheaper option is usually chosen. The above examples should not be taken to show that all farmers act in this way, but in general the thinking on the part of both the producers and their advisors is “safety first”.

5.3 Pest control in organic wheat production

In the organic system the following are banned: mineral nitrogenous fertilisers, synthetic chemical treatments, storage and after-ripening preparations, hormones, growth promoters and genetically modified organisms (SÖL 2001). The aim is to cultivate plants in such favourable conditions - (site, choice of variety, soil maintenance, crop rotation and fertilisation) that serious attacks by pests will be prevented from the start (AID 1996). In some ways the measures are similar to pest control in integrated farms.

5.3.1 Weed control

Organic wheat growers are forbidden the use of herbicides and all weed control is mechanical, using harrows or mechanical hoes. Preference is for long-stemmed, where possible wide-leaved varieties which provide more shade, an extra factor in the suppression of weeds. Wheat is sown as late as possible, at the earliest in late autumn (from the end of October to December) when the conditions for germination are worst for wind-grass and foxtail (HOFFMANN et al. 1985). The generally more varied crop rotation, which includes root crops but also a greater proportion of summer cereals and legumes, together with the ban on mineral-based nitrogenous fertilisers, almost eliminates problems with weeds and wild grasses such as cleavers, chickweed, wind-grass and foxtail (ÖKORING 1997).

5.3.2 Control of insect and fungus pests

A varied crop rotation scheme strengthens the plants’ resistance to disease and pests. Further protection can be provided by encouraging natural predators e.g. by leaving hedges and verges and installing nesting boxes, a balance can be struck between pests and their natural enemies (AGÖL 2000). The ban on mineral-based nitrogenous fertiliser makes it much more difficult for fungus pests, particularly mildew, to get established. When attacks do occur they are much less serious than in conventional wheat production. The lower nitrogen level leads to less density of stand and disease spreads less easily. The plants dry out more quickly and do not provide the damp micro-climate fungus has to have if it is to spread throughout the crop. In the choice of wheat variety resistance is an important factor. The varieties must be resistant to fungus, particularly septoria, yellow and brown rust, and fusarium attacks on wheat in ear. Seed stock should be inspected and checked for germination in order to eliminate any batches badly contaminated with seed-borne pests such as covered smut, septoria or occasional spores of fusarium (ÖKORING 1997). None of the above measures should be carried out in isolation. They are only effective against serious pest attacks if they are all taken together.

For direct pesticide treatment certain biological controls are allowed in the organic system as are a number of growth-promoting agents. The latter do not affect pests but strengthen plants and therefore their resistance (BBA 2001b). However, of the pesticides authorised for organic agriculture, none are at present available for use in the cultivation of wheat. The reason lies with the so called “Indikationszulassung” which came into force on1st July 2001. Pesticides can only be authorised for use in stated areas with prior notification (BBA 2001c). For example, normally aphids can be controlled in organic farms with neem, but neem-based treatments have not been authorised for use in wheat. It must be said that even before the advent of the *Indication Permit* the use of pesticides with wheat in organic farms was never very widespread. Control of aphids on wheat was not a major concern as, due to the above measures, aphids never seriously infested the crop. From the economic point of view spraying would rarely be worthwhile, since the cost of pesticides is high and the level of infestation very low. Plant growth-promoting agents are not subject to the *Indication Permit* but in practice are rarely used, as their effectiveness is not proven and they are often expensive. Since there are very many on the market they have not been listed in this study.
To summarise: at present the use of pesticides in organic wheat production is minimal. The biggest contribution to the E.U.’s 5^{th} Environmental Action Programme for pesticide reduction is by the organic system. The output of wheat by organic methods is less than by the conventional system, since no mineral-based nitrogenous fertilisers or synthetic chemical substances are allowed. While the organic crop can be on average 50% -60% less than the conventional one, there is compensation in the fact that the prices are higher. The current price per 100 kg for organic wheat is DM50 – DM60, whereas conventionally produced wheat sells at DM24 – DM26 per 100 kg.

6 Comparison of the systems with reference to the potential for pesticide reduction

There follow the results of some current research into the contribution each of the systems can make to pesticide reduction in wheat production. Organic production methods are not included as no pesticides are at present being used. First are the results of the E.U. project “Environmentally Sustainable Agriculture”. It was based on the E.U. regulation 2078/92 calling on agriculture to respect the environment and protect the natural world, and was launched as a joint initiative by the E.U. and Lower Saxony. The two Agricultural Chambers of Lower Saxony and the Research and Study Centre of the University of Göttingen have set up separate agricultural experiments in farming with elements of environmentally friendly ways of managing food production economically. Over 20 farms are involved and the focus of the project is to establish integrated pest control methods more firmly in general agricultural practice. On many farms integrated methods were demonstrated over a wide area and compared with more usual practices. The aim was on the one hand to make integrated methods more acceptable to farmers and on the other to explore the different ways of managing the crop with less additives and finally to evaluate the economic implications.

The findings of the two projects so far will be related to the production of winter wheat with reference to the research of the University of Göttingen and the Agricultural Department of Hannover (LWK HANNOVER 2000).
In the research programme of the Hannover Department of Agriculture (see LWK HANNOVER 2000) 17 experiments on 5 sites were carried out between 1997 and 2000. The number of fields studied was between 55 and 95. Comparison was made between the following variables: the present wheat-growing practice of the farmers

involved (the “good agricultural practice variable”), the farming strategies of the project advisor (the “integrated” variable) and the reduction strategy of the project advisor (the “reduced” variable). Within the “good agricultural practice” variable the farmer was free to do as he wished with regard to pesticides and nitrogenous fertilisers. The “integrated” group had to accept elements of integrated pest control methods such as selecting certain varieties for their resistance potential and stability, and adhering to the economic injury level. In the “reduced” group the use of nitrogen had to be 30% less than integrated use. Growth regulators and insecticides were as far as possible left aside and in general only one application of fungicide was allowed. Herbicides were treated as in the “integrated” option. The research was between systems; the variables are the use of nitrogenous fertiliser and the use of pesticides but the two elements were not studied separately. Other elements such as soil management, choice of variety, density of seed sowing, and basic fertiliser application were not taken into account. In a given farm the same seed was used over all three variables; mostly resistant varieties. No changes were made in the crop rotation in the various farms, in order to determine to what extent integrated pest control methods on their own would contribute to pesticide use reduction in current rotation schemes. In most cases the crop rotation followed the pattern – sugar beet – wheat – barley and rape – wheat – barley. It is clear from Table 2 that overall the application of pesticides showed a tendency to be more frequent in “good agricultural practice” than in the “integrated”. The very strict conditions in the “reduced” variable resulted in only half the usual amount being applied.

Table 2: Comparison of different wheat production intensities with regard to pesticide reduction in the years 1997-2000, based on 17 studies

	Good Agricultural Practice	Integrated	Reduced
Number of pesticide groups applied			
Herbicides	2.5	2.2	2.1
Fungicides	2.4	2.2	1.1
Insecticides	1.1	0.6	0.3
Growth regulators	1.8	1.5	0.5
Number of pesticide applications [a]	4.2	3.8	2.8
Seasonal variation:	2-6	2-5	1-4
Costs of treatments and application (DM/ha)	296	256	178
Level of nitrogen treatment in kg N / ha Number of fertiliser applications Costs of fertiliser and application in DM/ha	195 4.0 236	166 3.1 196	116 2.9 148
Yield in 100 kg/ha	103	100	93
Net profit in DM/ha	1,797	1,782	1,711

[a] Number of treatments (not detailing substances included in preparations)
SOURCE: LWK HANNOVER (2000)

The difference in yield between the “good agricultural practice” and the “integrated” was very small, merely 300 kg/ha. The much reduced application of fertiliser and pesticides in the “reduced” variable did however lead to an appreciable drop in output, around 1000 kg/ha.

The highest intensity of treatments led to the highest output and therefore the best performance on the market but from the economic point of view the figures for net profit, after the deduction of the costs of N-fertiliser, pesticides and the associated

labour expenses, are much more revealing. There the variables “good agricultural practice” and “integrated” show up at almost the same level. The economic gain in the “reduced” variable is clearly much less than either.
Table 3 shows additionally the recommendations based on 5 of the experimental areas by two advisory groups taking part in comparison to the findings in the three variables described above.

Table 3: Comparison of different wheat production intensities with regard to pesticide reduction in the years 1998-2000, based on 5 studies

	Good agricultural practice	Advisory bodies' good agricultural practice	Integrated	Reduced
Average number of chemical pest control treatments				
Herbicides	2.4	2.4	2.2	2.2
Fungicides	2.4	3.4	2.2	1.2
Insecticides	1.0	0.8	0.2	0.0
Number of pesticide aplications	3.8	4.2	3.6	2.6
Seasonal variation	3–4	4-5	3–4	2-3
Cost of treatments and application in DM/ha	283	297	239	183
Level of nitrogenous fertiliser in kg/ha	202	206	172	127
Number of fertiliser applications	3.6	4.00	3.00	3.00
Cost of fertiliser and applications in DM/ha	219	254	183	149
Yield in 100 kg/ha	103	104	101	91
Net profit in DM/ha	1,756	1,712	1,735	1,612

[a] Number of treatments (not detailing substances included in preparations) Source: LWK HANNOVER (2000)

The advisory groups have the highest levels of nitrogen and pesticides, but the extra amounts are shown to offer no advantage in increased yields. In terms of economic outlay the advisory groups come out worse than “good agricultural practice” or “integrated” because of the higher expenditure. The economic loss in the “reduced” variable is very clear. The results show that under present conditions there is the potential to reduce the amounts of pesticides and nitrogen in wheat production on integrated lines without incurring serious economic loss. Extra preventative treatments should therefore be kept to a minimum. The decision to use no treatments at all as in the “reduced” variable has been shown to incur serious losses in both yield and profits and therefore is not a practice to be recommended (LWK HANNOVER 2000).

There follow the results of the Göttingen University project. Krüssel (2000) observes that, unlike the Hannover project, the Göttingen project included crop rotation schemes in the study of its 6 farms. The classic rotation, winter rape – winter wheat – winter barley was modified by the addition of a fourth, summer, crop. In the main the fourth crop was oats though two exceptions were for summer barley and forage maize. Table 4 shows the number of pesticide treatments recorded:

Table 4: Average numbers of chemical pesticides per crop and year (1996-1999). Treatments arranged according to time and pesticide group

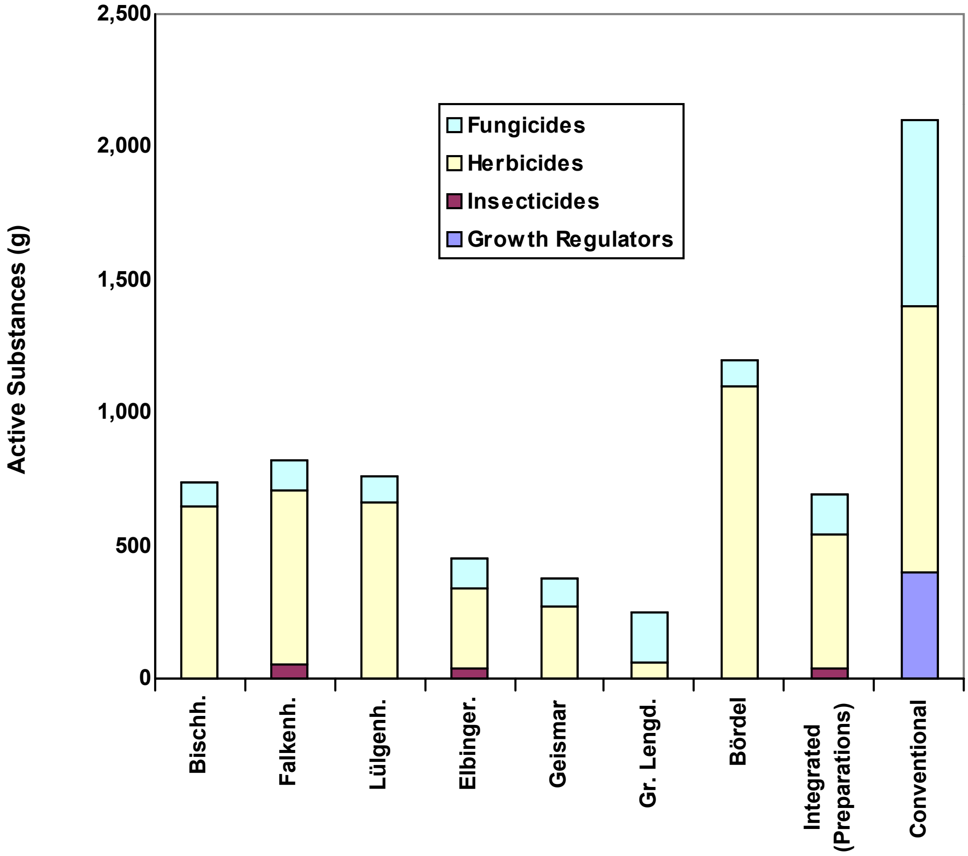
Pesticide Type	Winter Rape	Oats/Maize	Winter Wheat	Winter Barley
Herbicides	1.6	1.2	1.0	1.1
Fungicides	-	-	1.1	1.0
Insecticides	0.6	-	-	-
Molluscicides	0.9	-	-	-
Growth regulators	-	-	-	0.05

Source: KRÜSSEL (2000)

The above table does not indicate how much pesticide is used on the conventionally farmed land in the survey. In comparison with the figures in the Hannover study it would seem that the reduction in pesticide use in wheat farming is greater in the Göttinger cases than in the “integrated” variable where there was no alteration in the crop rotation. The indication is that widening the crop rotation scheme can lead to significant reductions without incurring serious economic loss. For a comparison between the quantities of active substances used per hectare in conventional and integrated farms see diagram 1.

For STEINMANN (2000) the intensity of pesticide use is closely linked to the dose rate of active substances per unit of land. It is not appropriate to compare quantities per se as e.g. - different herbicides have very different formulae with extremely varied quantities of active ingredients and yet have the same effectiveness. It is also not to be assumed that the choice of a different preparation with a lower content of active substances for use in the same area will necessarily have a less detrimental effect on the environment.

Diagram 1 shows that on all integrated sites less active substances were in use than on conventional ones.



Source: KRÜSSEL (2000)

Diagram 1: Quantities of active substances applied on integrated farmland compared to conventional farmland

KRÜSSEL (2000) claims that economies in pesticide use could be made by prioritising planting strategies e.g. by widening crop rotation schemes, applying appropriate quantities of nitrogenous fertilisers, allowing better spacing, choosing resistant wheat varieties, and using pesticides only as a method of controlling infestations that are already present. The damage done by weeds rarely reached the economic injury level with the result that herbicides were not used. Other reductions could be achieved by using selective herbicides for problem weeds and treating only the affected areas. Normally a single fungicide application would be enough to control fungus infections if the other strategies were in use - such as selecting resistant varieties, sowing later and applying nitrogenous fertiliser in appropriate quantities. The economic injury level for aphid infestation, 3–5 aphids per ear and flag leaf of wheat, was never reached during the period under examination. There was thus no need to use insecticides. The low level of attack could be attributed to the presence of natural predators such as ladybirds and hoverfly larvae.
Table 5 shows the economic value of integrated production compared to that of conventional methods. The integrated farms used less pesticides and the variable costs of production (price of fertiliser and pesticides) were lower. An interesting point is that less labour time was required in integrated production. Applying fertilisers and pesticides to the fields was more time-consuming. Also the high autumn demand for labour in the fields was modified by the spring sowing of summer crops. Integrated methods do however require more time for pest control on the ground.

Table 5: Comparison of the contribution of crop rotation schemes in conventional and integrated production (1996-1998, 4 sites)		
	Integrated	Difference from normal conventional figure
Output in tonnes/ha		
Winter wheat	67	-15
Winter rape	22	-34
Winter barley	65	-15
Oats	54	-
Market performance in DM/ha (*inc.premiums*)	2,132	-15
Variable outlay in DM/ha		
Fertilisers	124	-38
Pesticides	127	-48
Total of variable outlay (*incl. seed, var. machinery expenses, drying, tax, insurance*)	666	-25
Contribution to funds	1,446	-9
Labour costs per h/ha[a]	5.3	-13

[a] h/ha =per hour per hectare
Source: KRÜSSEL (2000)

Research over several years has shown that conversion to integrated pest control strategies does lead to a reduction in pesticide use without serious economic loss to the farmers. WAIBEL and FLEISCHER (1998) also, as the result of numerous field tests, believe that as an alternative to conventional practices integrated pest control methods deliver comparable economic gain as well as a detectable improvement in the environment.

7 Obstacles to the expansion of the integrated and organic systems

The facts assembled in this study leave one question unanswered – How can we ever achieve the considerable reduction in pesticide use required by the 5th E.U. Environmental Action Programme? The obstacles to reduction must be recognised before potential strategies can be described. There are many ways in which farming systems could be relaxed to allow for greater reductions.

7.1 Obstacles in the organic system

Organic farming is not widespread, occupying only 2% of cultivable land in Germany. The financial incentives offered in the wake of the BSE crisis to encourage farmers to convert to organic methods have not led to a great movement in that direction. At present the demand for organic milk, meat and fodder cereals cannot be met, but even so there is a no real trend towards organic production. The possible explanation lies in farm structures, sites, social pressure and consumer attitudes. There follow a few examples of such obstacles.

7.1.1 Sites and structures

Farmers who do not keep cattle have no reason to adopt the organic system in preference to the conventional one in which they are working. The present system offers a reliable income in the production of sugar beet. Pig farmers would have to make large investments to comply with the strict conditions for organic animal care and in this area too there is little incentive for change.

7.1.2 Emotional reasons

A not inconsiderable role is played by the generation gap, where the younger successor would like to change but the older owner would not. Social pressure may also play a part. Farmers may worry that conversion to the organic system will not meet with the approval of their colleagues. Many associate it with problems such as overgrown weedy fields, poor quality products, low productivity and loss of income, extra labour costs and a rejection of modern farming techniques etc.

7.1.3 Marketing and consumer attitudes

The demand for organic produce has risen in recent times but in some ways farmers think that meeting the demand could be their greatest problem. It is not certain that consumers will be happy in the long term to pay the higher prices that organic foods attract. Many fear that current attitudes are only temporary. Even those farmers who have changed to the organic system worry that there may be a surplus of organic produce if too many farms are converted because of government incentives. The resulting sharp drop in prices would leave them with a major loss of income. Other doubts about the long term behaviour of consumers are voiced by the food-processing industries. The dairies, bakeries and meat processors have not shown much interest in running an organic range. Farmers thus do not have much encouragement from that sector to convert to organic methods.

7.2 Obstacles to integrated pest control

The efforts of research bodies, educational institutions and advisory services in promoting the practice of integrated pest control over the past years has been relatively unsuccessful in terms of converting farms to the integrated system (WAIBEL and FLEISCHER 1998). The reasons are still unclear.

7.2.1 Marketing

The adoption of integrated pest control in integrated fruit production has made good progress because marketing was seen as part of the process. Arable farming has not had that advantage. The reality is a long way behind the principles of integrated pest control. There has been no marketing strategy for integrated wheat that offers an assured price to the growers. They are required to produce wheat in too great quantities and the logistics of planting, drying and storing their product are too demanding. A few cereal producers set up associations in the early 1990s in order to promote the sales of wheat from so-called “controlled” farms. The produce was marketed under so many different names that consumers lost confidence and the associations failed to establish a place for themselves.

7.2.2 Advisory services

Each German state organises its advisory service on pest control in a different manner. Usually it is the Agricultural Chambers or the State Offices that are in charge, though there are private advisory cirlces and professional advisors from the chemical industry, commerce and agricultural associations.

There are also free-lance advisors in the field. As an underlying principle few advisors are prepared to give advice on measures that carry any risk, as on switching to integrated methods. In most cases the main concern is to “play safe”. In case of doubt the tendency is to suggest applying chemical pesticides as an insurance against potential problems rather than wait until the economic injury level has been reached. There are entrenched reasons for the advisory services to align their attitude to the use of pesticides with the views of industry, commerce and the associations, where the first concern is sales of their products. The poor response to the practice of integrated methods may, among other things, be due to the perception that the whole system has to be changed in an expensive and difficult operation. On the whole chemical pesticides are very easy to use on their own and provide the necessary assurance that the yields will be protected. Every pesticide licensed for use in Germany has been tested by the BBA and declared safe when used at the maximum permitted dosage. Official advisors see no reason to limit their use. They are very reluctant to take up integrated methods as there is much less likelihood of their being held responsible for failure if they recommend chemical pesticides rather than moving over to the integrated system. They prefer to give advice that is safe rather than risk losing the confidence of their clients in the future. Miscouncelling that leads to a burden for national economy (e.g. the cost of removing pesticides from drinking water) does not appear in the farmers’ calculations of profit and loss so far.

8 Potential for reduction

The above obstacles to reduction could be overcome and further reductions achieved if the following areas were taken into consideration:

- Production
- Trade
- Consumption

8.1 Potential for reduction at production level

It is relatively easy to pinpoint the distinction between organic and integrated pest control. Synthetic chemical pesticides are not allowed in organic farming, and it is there that the greatest potential for pesticide reduction lies. All other methods occur in both systems. It is much more difficult to pinpoint the difference between conventional and integrated methods. It has to be valid for all situations and all forms of management. The requirements of each system must be concrete and leave the farmer free to make the decisions concerning his business in an informed manner, taking into account the conditions of his site and the intentions of the head of the enterprise (FREIER et al. 1995). The positions taken up in agro-politics, the freedom of enterprise in business, as well as site-specific conditions make it difficult to establish positive criteria.

In Table 6 the minimum requirements are set out for integrated pest control in wheat production. Taken from FREIER et al. (1995), BBA (2001c) and FREIER and BURTH (1999):

Table 6: Minimum requirements for pesticide use in integrated wheat production	
Direct control measures	
Weeds/wild grasses	
Stage for action	Autumn to stage 11 Spring to stage 29
Method	Use of measuring frame in at least 5 locations
Economic injury level	Wind grass - 20 plants/metre^2, foxtail - 30 plants/metre^2, cleavers – 0.1plants/metre^2, other dicotyledonous weeds – 50 plants/metre^2
Ear and leaf disease	
Stage for action	EC 31 - 61
Method	Stalk /3 upper leaves from 5 stalks in 5 locations
Economic injury level	• Mildew:15 infected plants (60%) • Leag rust: 8 infected plants (30%) or first clump • Yellow stripe rust: 8 infected plants (30%) or first clump • Septoria nodorum: 8 infected plants (30%) • Septoria tritici: 8 infected plants (30%) to EC 37; 3 infected plants (10%) from EC 39 • DTR: 2 infected plants (5%)
Target: a maximum of 2 sprayings of fungicide	
Other pests	
Yellow dwarf virus (BYVD) carrier aphids	
Stage for action	Autumn and spring EC 21 - 49
Method	20 stems in 5 locations
Economic injury level	• Autumn: 20 plants with aphids (20%) • Spring: 10 plants with aphids(10%)
Sap sucking aphids	
Stage for action	EC 51 - 69
Method	Ears and flag leaf from 5 stalks in 5 locations
Economic injury level	3 5 aphids/ear and flag leaf
No preventative spraying of insecticides on the lines of fungicide spraying of wheat ears. Only insecticides not harmful to natural predators	
Other requirements	
Documentation	• Of incidence of infection • All measures taken
Other	• Regular use of warning system • Control strip (untreared) in at least one location

Source: Altered from FREIER et al. (1995), BBA (2001c) and FREIER and BURTH (1999)

There are many good reasons for setting out concrete terms for the reduction of pesticide use. The most important is that the undesirable “side effects” of pesticide use can be reduced without the farmer incurring financial loss. The rising production costs of, for example, fuel, fertiliser and pesticides, allied to the ever lower prices to the producer and the withdrawal of EU subsidies leaves the farmer in a position where he must turn to integrated methods of pest control. An additional factor is that the limitations of pesticide use are

becoming increasingly apparent (the current build-up in some weeds and pests to some of the herbicides and fungicides in use).
Agricultural advisors have to alter the situation:

- No further detachment of personnel from the official independent advisory services
- Better opportunities for farmers to be trained, not only in the recognition of pests and disease etc. but also in the practice of integrated pest control.
- Better training opportunities for advisors, and the advisory rings, in the practice of integrated pest control.

Farmers and advisors have to be encouraged to find integrated methods more acceptable and it might be of interest if the research bodies in, for example, the Agricultural Chambers were to set up an experiment with an element of competition. It could be structured in such a way that all those involved in any one region in the advisory services of industry, trade, government and the private advisory circles would be asked to give a practical demonstration of their recommendations on wheat production. The experiments would be given a title - "Which one can produce the highest economic return with the least expenditure on fertiliser and pesticides?" The wheat grown on the experimental plots would of course have to be harvested and assessed for its market value. The participants would be inspired to achieve the highest success rate and the educative impact of the programme would lead farmers and advisors to abandon their "safety first" policies with greater confidence.

8.2 Potential for reduction at marketing level

In the case of fruit production the marketing aspect received considerable attention and the same must be done to promote integrated methods in wheat production. The producers' associations involved in integrated production in the 1990s attempted to market "controlled" produce. As mentioned in Section 7.2.1 their efforts did not meet with much success chiefly because there were so many different descriptions and brand names given to their products. If they had been able to agree on one description, e.g. "produce from controlled integrated farms" the consumer would have known where to look for future purchases. There was also the high cost of inspection. Now as then inspection is one of the greatest hurdles, as customer confidence can only be maintained if all farms in the organic system are regularly subjected to fair and independent inspection. In that connection the claims of conventional farmers for the high quality of their produce must be challenged. For instance the baking industry demands a falling count, and a certain value for sedimentation and crude protein. These characteristics are not directly relevant to pesticide use, more to nitrogenous fertilisers. As shown in an earlier part of this study nitrogen has a bearing on the incidence of pests and therefore of pesticide use. The crude protein content, in particular, demands high applications of nitrogenous fertiliser in addition to the selection of appropriate seed varieties. The target for crude protein content in conventional production is between 12.5% and 14%, which only obtainable in highly nitrogenous soils. Millers, and bakers, require these qualities in flour because in the automated bakery business the loaves must be as uniform as

possible. Bakers working with organic cereals are able to work with much less crude protein. The crude protein content of flour, organically produced without the use of mineral-based nitrogenous fertilisers, is between 10% and 12.5%. Bread rolls can still be baked with this level of crude protein, but are likely to vary much more in size and shape.
Organic production has the highest reduction in pesticide use. It should not be only the small bakeries that offer a choice of breads from organic or conventionally produced flours. The large cross-regional chains should also run some organic lines. The producers' guilds and millers who can deliver safe organic cereals and flour are already in existence. The farmers will have no reason to convert to organic methods unless the food trade and food processors take up organic products as part of their stock in trade. The present incentives to farmers to convert must continue in future, but payments "on the ground" are not enough. Much more support is needed for re-structuring both marketing and the processing industry.

8.3 Potential for reduction at consumer level

Producers, traders and food processors will not continue to offer integrated or organic products if the consumer rejects them on account of the higher price. In shopping for foodstuffs the cost is currently the deciding factor. One of the objections to organic foods is that the price to the consumer is far too high and only affordable by the wealthy. Much more information must be available if the consumer is to accept the need to spend more. By buying organically produced goods the consumer is contributing not only to the conservation of the environment, but also to the more humane treatment of animals, and finally his/her own health. It is not only domestic consumers who should be targeted; the huge kitchens of hospitals, university canteens, restaurants in ministries and major firms should also be drawn into the movement.
It is important to draw the line between integrated and organic produce. The consumer can find the many different names and product descriptions confusng and they should be simplified. A product from an integrated source it should be quite clearly labelled so that the consumer can see that it may have been treated with synthetic chemical pesticides, in contrast to an organic product which has not.

9 Summary and prospects

Wheat is the most extensively cultivated crop in Europe and in comparison to other cereals the most intensively treated with pesticides. There are three systems of cultivation, organic, integrated and conventional. The greatest reduction in pesticide use is in the organic system, which uses no pesticides at all. At present only 2% of German farms are worked organically and few farmers are willing to convert to organic methods. The consumer demand for organic produce increases only slowly due to the high prices required. An increase in organic production can only come about if consumers are better informed. They should know how to identify genuine organic products and where to buy them locally. Additionally there should be an awareness that in buying organic foodstuffs one is not only contributing to the conservation of the environment, but also to more humane treatment of animals and one's own health.

As far as marketing and processing are concerned much more must be done to persuade firms to make organic products part of their stock-list, so that they have a larger share of the market. Farmers will not have any incentive to turn to organic methods unless they are urged to do so by consumers, traders and food processors uniting to create the demand. Fruit producers have already made a noticeable advance towards integrated pesticide use.

The reality lags behind the practice in integrated pest control. For several years now different research projects have confirmed repeatedly that the adoption of integrated principles in agriculture can among other advantages lead to a reduction in pesticide use without financial loss. There has been official commendation of the integrated system since the Pesticide Act of 1986 but scarcely any sign of a change in attitude in German agricultural practices. The explanation lies in the economic climate, failures in marketing and to some extent a lack of conviction on the part of farmers and their advisors that integrated pest control is effective. It seems to many of them that chemical pesticides are easier to apply and carry less risk of economic loss. A major feature of integrated pest control is the expansion of crop rotation but for economic reasons farmers have tended to make rotations more one-sided. The economic risk could be avoided by careful implementation of the simple and straightforward methods of integrated production. They involve preventative measures such as late sowing dates, less use of nitrogenous fertilisers and the selection of resistant varieties of seed. These together with observance of the economic injury level should have wider recognition among famers and their advisors. However success will not be easily achieved without a greater share of the market. Advisors from the chemical industry and the "Landhandel" will continue to promote the use of their products on the land. The official advisory services and private advisory circles are not subject to this kind of "sales pressure" but they are under pressure to succeed in the sense of providing recommendations that lead to visible success for their clients. It is natural for them to want the farmers to continue to consult them, and confidence is best built up by recommending chemical pesticides with a certain outcome rather than preventative non-chemical measures. There would be wider acceptance of integrated pest control among farmers and advisors if there were corresponding outlets in the processing industries and the markets. There would also be a need for much higher levels of inspection, and the logistics, finance and recruitment of personnel required make it unlikely that such a development will occur.

The greatest contribution to pesticide use reduction is in the organic system. For this reason it would be wisest to give it the highest level of incentives and support.

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