SESSION 10

CHANGING WORLD MARKETS – IMPLICATIONS FOR WEED CONTROL

Chairman | Professor G Jellis *Home Grown Cereals Authority, London, UK*

Session Organiser | Mr J H Orson *Morley Research Centre, Wymondham, UK*

Papers | 10-1 to 10-4

Current and future challenges for weed control in the United States

M M Loux
Department of Horticulture and Crop Science, The Ohio State University, Columbus, OH 43210, USA

C Zulauf, R Shao
Department of Agricultural, Environmental, and Development Economics, The Ohio State University, Columbus, OH 43210, USA

ABSTRACT

Changes in domestic farm policy and fluctuating world markets have resulted in a shift in cropping patterns in the United States since enactment of the 1996 Farm Bill. Planted acres of cotton, wheat, and other small grains declined greatly, while oilseed and corn acres increased. These changes are primarily a shift in acres among the major crops planted, but they represent further specialization in some regions and limited diversification in others. Changes in cropping patterns present challenges in weed management. A primary concern in all rotations is the development of herbicide-resistant weed populations. Other concerns are shifts in weed populations, which could occur more quickly with the rapid adoption of herbicide-tolerant crops; and herbicide drift and carryover to sensitive crops. Production systems with specialty crops, such as value-added corn and soybeans, and organic and non-genetically modified crops present additional challenges.

INTRODUCTION

Farmers in the United States (US) have changed their cropping patterns significantly since enactment of the 1996 Farm Bill. These changes have been driven not only by policy changes but also by farmers seeking the most profitable crop rotation. Cropping changes and the introduction of herbicide-tolerant crops have created new opportunities and challenges in weed management. It is the intent of this paper to summarize recent changes in cropping patterns of the major agronomic crops in the US, along with the reasons for these changes, and their impact on weed management.

THE 1996 US FARM BILL AND OTHER POLICY FACTORS

The 1996 Farm Bill significantly changed US agricultural policy by removing the link between income support payments and annual acreage controls (Zulauf *et al.*, 1996). Farmers were given the freedom to plant, or not plant, their land to any crop except fruits and vegetables. A seven year production flexibility contract provided a series of fixed annual 'market transition payments' independent of farm prices and specific crop production. Prior to the current farm bill, farmers were required to set land aside (in most years) in order to be eligible for federal payments. For example, in 1995 US farmers set aside 4.9 million acres in the annual land removal program in order to qualify for farm program subsidies. In 1996, these acres were released for production. Farmers can now shift crops without penalty to what they perceive are the most profitable, and still retain eligibility for the market transition payments. In addition, other forms of subsidy are still in place, including disaster aid and commodity loan programs. The latter pays producers the difference between current market price and a price set by the federal government, thus providing a floor on per unit gross income. Commodity loan rates can significantly affect cropping patterns, as producers will tend to plant more of the crop with the highest commodity loan rate and lowest cost of production when prices are near or below the loan rate.

The Conservation Reserve Program (CRP) also remains in place. CRP pays farmers an annual rental payment over 10 years for taking land out of production to enhance environmental quality. When first enacted in the 1985 Farm Bill, the environmental goal of CRP was to reduce soil erosion. However, over the years its objectives have been broadened to include enhancing cover for wildlife, improving water quality, and improving air quality (Zulauf *et al*, 1996). CRP acreage is expected to total 31.3 million acres as of October 1, 1999 (Osborn, 1995), compared with an enrollment of 35.7 million acres as of October 1, 1995. CRP acres have thus declined by 4.4 million acres.

CHANGES IN CROPPING IN THE US

Overall US acreage planted to the principle crops increased by 3.1%, or 9.8 million acres, from 1995, the last year under the 1990 Farm Bill, to the current year of 1999 (USDA, 1995). This increase can be attributed primarily to the elimination of the annual set aside requirement and to the withdrawal of land from CRP starting in 1996. The acreage of principle crops decreased by 5.0% in the Southeast region, 3.2% in the Northeast region, and 2.3% in the Pacific region. In contrast, acreage increased by 6.1% in the Corn Belt, 4.6% in the Southern Plains, and 3.5% in the Northern Plains. Planted acreage thus shifted from the two coasts to the central areas of the US. During this same period, substantial shifts occurred among crops. Soybean acreage increased by about 12 million acres or 18.7 percent between 1995 and 1999 (Table 1). Sunflower and canola (*Brassica napus*) acres increased by a combined 777,000 acres. Corn (*Zea mais*) acreage expanded by 6.1 million acres, while planted acreage of the other feed grains declined by over a combined 3.0 million acres. In terms of acres, the greatest declines occurred for wheat (6.1 million acres or 9%) and cotton (2.4 million acres or 14.0%).

Changes in cropping patterns within regions of the US between 1995 and 1999 are primarily a shift among the major crops produced, rather than a move into different crops. In some regions this represents further specialization, or intensification. For example, in the Corn Belt, corn and soybeans increased from 40% each of planted acres in 1995 to 41% and 44% in 1999, respectively. In other regions, cropping changes represent limited diversification, due to the inclusion of additional crops in the rotation. In the Northern Plains, wheat acres declined from 37% in 1995 to 31% in 1999, while corn and soybean acres increased 3% and 5% respectively. Overall, cropping changes between 1995 and 1999 do not indicate a move by farmers to make substantial changes in the type of crops they produce. However, an increase in canola acres of 145% indicates some diversification is occurring.

Table 1. Changes in planted acres of major field crops in the US between 1995 and 1999 (USDA, 1995 & 1999).

Crop	Change from 1995 to 1999 (1,000 acres)	Change from 1995 to 1999 (%)	1999 acres (1,000 acres)
Soybeans	11,710	18.7%	74,205
Corn	6,132	8.6%	77,611
Canola	649	145.5%	1,095
Rice	479	15.3%	3,600
Sunflowers	128	3.7%	3,606
Sorghum	-380	-4.0%	9,049
Barley	-1,452	-21.7%	5,237
Oats	-1,567	-25.2%	4,658
Cotton	-2,372	-14.0%	14,559
Wheat	-6,148	-8.9%	62,853

The most important policy change enacted in 1996 was giving farmers the freedom to switch from crops with depressed markets to what they perceived as more profitable crops. Such switching was prohibited under previous policy unless the farmer wanted to give up government subsidies. For example, relative profitability caused many producers in the Northern Plains to switch to corn and oilseed crops from small grains. In Nebraska, there was a shift toward soybeans from continuous corn acres. Likewise, the increase in soybeans in the Corn Belt was due partly to the freedom of no longer having to plant wheat for the program. The large increase in soybean acres was caused in part by the increase in the government loan rate in the 1996 Farm Bill. However, much of the shift to soybeans occurred in 1996-97, before the market price had declined to a level equal to the loan rate. This earlier shift reflects a higher net profit from soybeans relative to other crops at that time.

Agronomic factors have allowed or facilitated some of these changes in cropping. Soybean expansion in the Northern Plains has occurred in part due to the development of varieties adapted to cooler climates. The availability of herbicide-tolerant corn and soybeans have probably not contributed to their increase in the Corn Belt and Northern Plains as much as other factors, since herbicide options were generally adequate for these crops prior to the development of herbicide-tolerant crops. However, one effect of herbicide-tolerant traits has been a decline in herbicide prices and weed control costs, especially in soybeans, and this has contributed to more favorable economics for soybean production compared to some other crops. Development of herbicide-tolerant varieties of more minor crops, such as sunflower, could lead to an increase in their acreage where weed management has been a limiting factor. The acreage of some crops has been limited by the amount of land suitable for their production. Rice acreage has increased in the past several years, but could expand further if not limited in areas by its rather specific production requirements. In addition, some crops may not be adapted to conservation tillage, which is required in sensitive areas to maintain eligibility for federal farm subsidies.

BEYOND THE YEAR 2002 - A RESTRUCTURING OF US AGRICULTURE?

It is almost certain that key characteristics of US agricultural production and producers will change over the next few decades. Currently, producers are under economic pressure due to generally low commodity prices and depressed export markets in some areas of the world. Low commodity prices have been the result of competition from other countries in the export market, and high domestic yields in the US, making producers to some extent victims of their own success. A goal of the 1996 Farm Bill was the creation of a class of producers who could shift production to meet the demands of end users and maintain profitability, thus requiring fewer subsidies. While commodity crop production will continue, specialty crops and value-added traits will have an increasingly important role. The focus in agricultural biotechnology and Genetically Modified Organisms (GMO's) until now has been toward input traits to lower the cost of production and increase productivity, but biotechnology is shifting the focus from "how much is produced" to "what is produced" and "what markets demand". According to one view, some characteristics of US agriculture in the future might include (Shimoda, 1999):

1. A shift from lowering the cost of production to expanding the value creation potential of agriculture and attaining premium economic value for the end user, as plants are utilized to produce many new products.
2. This shift will require a restructuring of the entire production and marketing system and pricing structure. "Agricultural-industrial" complexes and linkages of producers with multiple end users could result. Producers will have to increase both efficiency and quality to be successful.
3. The worldwide role of US agriculture will expand, based on a history of crop production efficiency and success in development and commercialization of biotechnology.
4. A re-defining of the producer's role in the agricultural production system. There is likely to be a shift to specification-based farming where all production practices are specified by the end user. Farmers are likely to have to give up part of their traditional independence, to become in effect "parts suppliers" for many industries.

While this scenario is proposed for farming as a whole, there will continue to be an evolution of niches occupied by small groups of farmers to meet a limited demand. Organic and GMO-free production are examples of these niches. Farmers will also increasingly attempt to capture the profit from the processing and end-use that they cannot capture in commodity crops. Examples include the durum wheat producers in North Dakota who are marketing pasta made from their grain, and the clear-hilum soybean producers in Michigan who purchased a grain elevator to have a larger stake in the marketing of this specialty crop to Japanese end-users.

WEED MANAGEMENT CONCERNS

Weed scientists in the US are most concerned about the following aspects of weed management in changing cropping systems:

- Herbicide resistance and weed population shifts, especially with regard to adoption of herbicide-tolerant crop systems.
- Herbicide drift.
- Herbicide carryover.
- Herbicide tolerance and weed management in specialty crops (e.g. value-enhanced corn).

Herbicide-tolerant crops

Herbicide-tolerant crops, most of which are GMO's, have become an important part of weed control programs in US crop production. The impact has been greatest in soybeans, where an estimated 50% of the soybeans planted in 1999 were glyphosate-tolerant (Roundup Ready). Rapid adoption of glyphosate-tolerant soybeans has occurred because of the broad-spectrum weed control it provides for a reasonable cost, and the perception by producers that it is a simple solution to weed management problems in soybeans (Owen, 1997). Producers with diverse rotations and crops sensitive to herbicide carryover have rapidly adopted glyphosate-tolerant technology to eliminate carryover concerns. It has also been used to manage weeds resistant to another herbicide site of action. Other herbicide-tolerant systems for corn and soybeans have been less widely accepted, but do provide effective tools to manage various weed problems. Acceptance by producers of herbicide-tolerant crops has been limited in areas by continued problems in the export market, a situation that appears to have no immediate remedy.

It is expected that varieties with tolerance to glyphosate, glufosinate, or sulfonylurea herbicides are or will be available for wheat, sugar beet, sunflower, canola, potato, rice, and others (Duke, 1999). Rapid adoption of herbicide-tolerant systems for these crops should occur unless affected by export issues, because the availability of effective herbicides has been more limited than in corn and soybeans. While herbicide tolerance can certainly be of great benefit for these crops, it likely will also enable producers to use the same herbicide or herbicide site of action throughout crop rotations. This has been possible in rotations of corn, soybeans, and wheat for a number of years, and has led to an increased rate of development of herbicide-resistant weed populations. Populations resistant to acetolactate synthase (ALS) inhibiting herbicides are an increasingly important problem in most areas of the US where corn and soybeans have been primary crops, and have been well-documented (Heap, 1999). Increasing the number of crops where ALS-inhibiting herbicides can be used will most likely result in even greater selection pressure and additional resistant populations.

Continuous use of other herbicide-tolerant systems will cause changes in weed populations, although the mechanism of change could vary among herbicides. Glyphosate has been used worldwide in varied crop production systems, and resistant populations have occurred in only one specific situation (Bradshaw *et* al, 1997; Powles *et al*, 1998). This would seem to indicate a low potential for resistance, but shifts to weeds with innate tolerance to glyphosate could occur over time, if these weeds are not controlled with other herbicides or in another crop in the rotation (Duke, 1999). Use of glyphosate-tolerant crops throughout the rotation would cause this to occur more rapidly, and limit the long-term utility of an effective herbicide, especially for producers of crops with fewer herbicide options than corn and soybeans.

Herbicide drift and carryover

Herbicide drift and carryover are a concern in most crop rotations, but become more of a concern when diversity of the rotation increases. In specialized systems with a two-crop rotation, as occurs in much of the Midwestern US, the number of herbicides available tend to allow farmers to make appropriate herbicide choices based on soil factors and rainfall, greatly reducing the risk of carryover. In addition, corn, soybeans, and wheat tend to be more tolerant of herbicide residues in soils than most other crops. In regions where diversification exists, some of the crops now planted, such as canola, sunflower, and potatoes, are more sensitive to herbicide carryover. This forces farmers to avoid the use of persistent herbicides in the previous crop, with the net effect of reducing the number of herbicide options. Use of glyphosate-tolerant or glufosinate-tolerant crops throughout the rotation will avoid carryover problems, due to the lack of soil residual activity of these herbicides. However, intensive use of these systems may increase pressure for shifts in weed populations and/or resistance to occur.

Herbicide drift is an unfortunate consequence of herbicide use, and is possible in all crops where herbicides are used. Concerns about drift have increased with the rapid adoption of glyphosate-tolerant soybeans, due to the broad-spectrum activity of glyphosate and the likelihood that a field adjacent to glyphosate-tolerant soybeans contains a susceptible crop. Specific concerns about drift as cropping systems diversify include:

- The increase in the number of herbicide-tolerant crops available, and increased use of broad-spectrum herbicides such as glyphosate.
- The possibly greater sensitivity to herbicide drift of crops such as sunflower, sugar beet, canola, potatoes *etc.*
- The possibility of drift onto high-value crops, including vegetables, GMO-free crops, and value-enhanced crops.
- The possibility of drift onto a field certified for organic production, causing loss of organic production status.

Value-enhanced corn and soybeans

The value-added and identity-preserved crops currently available to US farmers include primarily Value-Enhanced Corn (VEC) and some specialty types of soybeans. Types of VEC include high oil, white, waxy, hard endosperm/food grade, and high amylose corns (Anon., 1999a). A number of companies are also developing nutritionally dense hybrids, which usually include some combination of higher oil, higher protein, and/or altered amino or fatty acid profiles. The projected combined 1998 acreage of VEC's was 4.5 to 5.1% of the total US harvested corn acreage, an increase from the estimated share for 1996 acreage of 3.3 to 3.9%. High oil corn is the fastest growing VEC in the US, and accounted for the majority of the increase between 1996 and 1998. VEC's were grown across most of the Midwestern US, with some regional specialization in a specific VEC(s) based on previous experience. The majority were produced under contract, although this ranges from about 50 to 100% by VEC. Identity-preserved and value-added soybeans currently available include: large seed, high protein, yellow or clear hilum, small seed, lipoxygenase free, low-saturated fat, reduced linolenic acid, and increased sucrose (Liu, 1999; Wilson, 1999). Currently, only about 1% of soybean seed sold is for specialty soybeans, substantially smaller than for corn. The majority of the specialty soybeans are produced under contract.

Markets are still developing for value-enhanced products, and there are some logistical issues, such as segregated production, to be worked out. Currently, the factor that is most limiting to specialty crop production is the profitability to the producer compared to commodity production. While value-enhanced traits result in a premium to the producer, this may not offset substantially lower yields. Value-enhanced varieties or hybrids can also be more sensitive to stress from cultural and environmental conditions as well as pests, and may require more management than commodity crops. As a result, there has been considerable turnover in the producers growing value-enhanced grains from year to year. At the same time, some producers successful with value-enhanced grains are increasing their acreage.

Due to their current availability, value-enhanced corn and soybeans serve as effective examples of the weed management issues that can arise in specialty crops. Several characteristics can be attributed to VEC, relative to commodity corn, although these do not necessarily hold true for all VEC hybrids. First, they may have less vigorous growth than commodity corn, which results in reduced mid-to late-season suppression of weeds by the crop. Second, they may be more susceptible to herbicide injury than commodity corn. Third, there is little information on VEC sensitivity to herbicides. For example, a number of corn herbicide labels contain statements to the effect that the product is registered for use on a VEC, but the manufacturer does not assume liability for any crop injury that results from use. The label may refer the user to the seed company for more information on VEC sensitivity, and the seed company may not have the needed information. The net result can be a limited selection of herbicides available for use on VEC's, uncertainty about safety to the crop, more restrictive use directions, and trial and error use of herbicides. The combination of these factors can result in generally more weed management problems in certain VEC's relative to commodity corn.

Several other weed management issues have occurred or can be foreseen. First, end users are likely to become very specific about production practices for crops grown under contract. For example, in some areas end users of clear-hilum, large-seeded soybeans grown for tofu have already specified that producers should avoid use of post-emergence herbicides. Second, while herbicide choice for use on commodity grains is generally not an issue, there may be an effect of specific herbicides on the expression of the specialty trait in value-added crops. Research is lacking in this area. Third, there may be concerns with residues, or perceived residues, of certain herbicides in specialty grain, or a desire by the end user to avoid varieties or hybrids that have been genetically modified. On the one hand, the net result of these issues can be a restricted selection of herbicides and weed management tools. Restrictions could intensify selection pressure if they lead to a further decline in rotation of herbicide site of action. Furthermore, introduction of herbicide tolerance into value-added crops, if allowed by end users, could also intensify selection pressure. On the other hand, herbicide programs and cultural practices for value-added crops may not represent a significant departure from the norm and do not make a crop rotation more diverse. Concern exists already over herbicide resistance and species shifts due to lack of crop diversity in the rotation and intensive use of herbicides with the same site of action.

Organically-grown crops

Niche markets have developed across the US for crops grown using organic techniques, i.e. free of synthetic pesticides and fertilizers from inorganic sources. The market for this production is currently small, accounting for less than 1% of the grain and oilseed crops produced (Anon., 1999b). Producers involved in organic production, which may or may not be on a contract basis, can obtain a 20 to 300% premium for their crop. The premium is likely to decline if many additional producers enter this market, unless demand increases greatly. The US does have a small core group of organic producers who are generally low-acreage, diversified producers with established markets. A number of larger producers have tried organic production on a limited basis, and returned to conventional production, but it is likely to be these larger producers who are or will be supplying organic crops for larger markets. A major hindrance is the certification of fields for organic production, which may require up to five years of organic production before crops can be labeled as such.

For major grain and oilseed crops, weed management is usually cited as the single most important factor affecting success in organic production. Organic producers make several preplant tillage passes to stimulate depletion of the soil seedbank and as many post-plant passes as possible with a rotary hoe and cultivator to remove emerging weeds. Weather and soil conditions can hamper mechanical weed control methods, and most producers who attempt organic production cite examples where weeds were not adequately controlled. Flame devices and other alternative weed control methods could be utilized in organic production, but are not panaceas for current weed problems.

Non-GMO crops

Global concerns about GMO crops and their products have led to a limited market in the US for crops grown using GMO-free production systems. This varies by crop, depending upon the approval status for various GMO traits around the globe. A number of food processors, including two major producers of baby food, have indicated an intention to use only products of non-GMO crops. In 1999, US producers in some areas could contract with a processor to supply sulfonylurea-tolerant (STS) soybeans for a premium to fill the GMO-free demand (Anon., 1999c). STS soybeans were developed using non-GMO techniques, and grain can be tested to verify the presence of the STS trait and thus non-GMO status. Except for assuring the segregation of production to ensure no contamination by GMO crops, production of GMO-free crops does not present a major problem for crop producers, especially for major crops with many herbicides available. Producers of lower acreage crops, such as potatoes, looking forward to the availability of herbicide-tolerant varieties that are GMO's, may be forced to limit their use of this technology unless it is approved by the end user. The market for GMO-free crops could increase greatly or remain a niche in US production, depending upon what occurs globally with regard to this issue.

CONCLUSIONS

Changes in domestic farm policy and world markets have caused major changes in cropping patterns in the US during the past four years. As a result of the 1996 Farm Bill, farmers were allowed the freedom to plant whatever crop they deemed most profitable, with no requirement to remove land from production. Farmers have subsequently increased production of corn and oilseeds, with a concomitant decrease in production of wheat, cotton, and other feed grains. Additional adjustments in cropping patterns are likely within the next few years as farmers strive to maintain profitability. Most US farmers are still specializing in several major field crops, but they may have to explore other opportunities to be successful into the next millenium. Farmers now have the option of obtaining a premium above commodity crops for production of identity-preserved and value-added crops, organically-produced crops, and GMO-free crops, but they may lose some of their traditional independence as end users become more specific about production practices and quality. In addition, management of weeds where these niche crops are grown can be difficult due to restrictions on herbicide use.

Farmers currently have more tools for weed management than at any time previously, and additional tools become available annually. Herbicide-tolerant crops are a significant part of this new technology, especially for the more minor agronomic crops where herbicide options have been limited. However, weed populations in the US are developing resistance to herbicides at an increasing rate, and misuse of herbicide tolerant crops and their respective herbicides could add to this problem or result in weed species shifts. For best stewardship of herbicide-tolerant systems, producers should decide where in crop rotations use of herbicide-tolerant crops is most justified, and rotate herbicide site of action over time. As cropping patterns change, and especially when diversification occurs, herbicide drift and carryover become more of a concern. Herbicide drift has the potential to affect high-value crops and interfere with organic production. One possibility to avoid drift problems is further specialization within farms or cropping areas, so those situations most sensitive to drift problems are more isolated. Further specialization, or segregation of crops, could be recommended for producers of GMO-free crops as well, in order to avoid contamination with GMO crops. Lack of global acceptance of GMO crops with pest or herbicide resistance could result in a significant opportunity for US producers to produce GMO-free crops at a premium. It is also possible that refusal of these crops around the world could end their use in the US due to the expense of segregation from non-GMO crops.

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The development of cropping systems in Eastern Europe - implications for weed control

S P Ward
Bidwells, Trumpington Road, Cambridge, CB2 2LD, UK

ABSTRACT

Changes to crop area in the Eastern European Countries are examined with particular regard to changes since the collapse of Communism. The possible impact of accession to the European Union is also considered. A number of drivers for crop area change in Eastern Europe are discussed. The changes to date have been small for the major commodity crops. Trends pre-break up of the Soviet Union have largely continued and are expected to persist in the medium term. Weed control is a secondary influence on crop system changes and no major change in the balance of weed species is anticipated. However, the expected increased area in production and improved levels of weed control is likely to increase herbicide usage. The gradual move towards non-cereal crops will change the balance of products used.

CROP AREA CHANGES

Eastern Europe includes Bulgaria, Hungary, Macedonia, Czech Republic, Poland, Slovenia, Slovakia, and Yugoslavia. This covers a range of climatic areas and consequently the major crops tend to be those that can tolerate the widest conditions.

Figure 1 shows the major Eastern European cereal areas and Figure 2 the major oilseed and protein crops. Major has been defined as cereal crops with an area of more than 2 million ha and combinable broad-leaved crops of more than 0.5 million ha in 1961, 1997 or on average. Potatoes, sugar beet and pumpkins/squashes/gourds would also have fulfilled these area conditions.

Crop area change trends pre 1989/90 have tended to continue and the only notable exception is the decline in the soybean area and an increase in sunflower area. However the aggregated data is for a range of countries all operating under differing economic constraints, support arrangements and crop self-sufficiencies and the average may mask changes in individual countries. Yields and consequently total production have fallen markedly since 1989.

DRIVERS FOR CROP AREA CHANGE

In the market economy post-1989 it is reasonable to assume that crop areas change in response to changes in crop profitability, or expected changes in profitability, within economic and environmental constraints. Many of the variables are related.

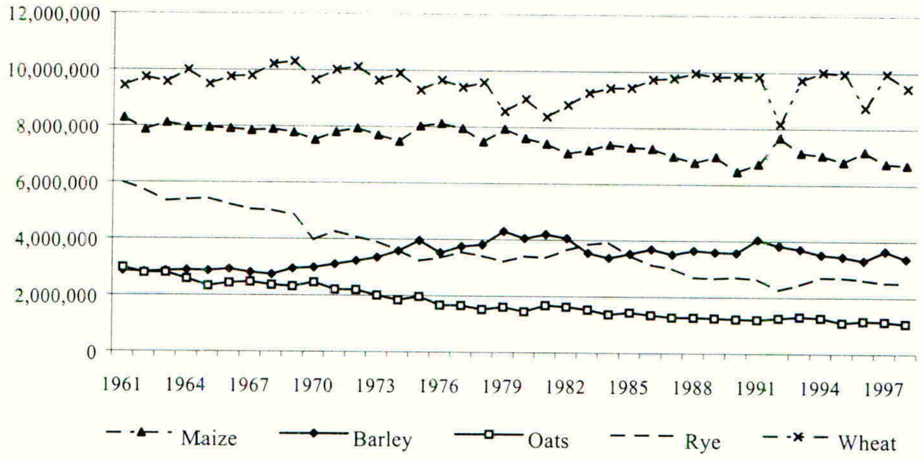

Figure 1. Eastern European cereal areas (ha; FAO, 1999).

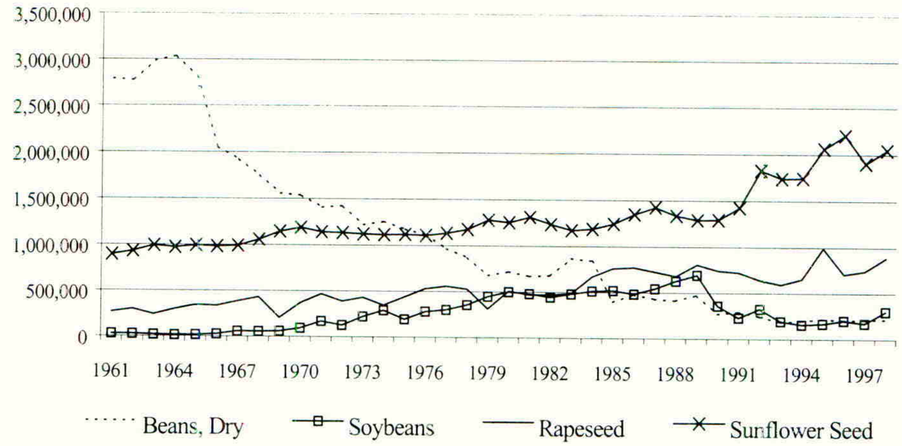

Figure 2. Eastern Europe protein and oilseed areas (ha; FAO, 1999).

Changes in relative crop price

Prices for commodity crops largely depend on their physical components (e.g. energy, protein and energy density) modified by specific characteristics such as bulk density or appropriate to niche markets. Niche markets tend to be price elastic and maintain minimum crop volumes. Thus despite a strong price relationship between cereals prices (Table 1), wheat has increased in area at the expense of rye and oats (Figure 1). Similarly the area of soybeans has fallen while the area of sunflowers has increased (Figure 2).

Within Eastern Europe local demand and access to export markets is an important influence on price. In addition wheat, when compared to rye and oats, would be favoured because of lower transport costs due to higher specific weights. Exchange rate changes can distort the relative profitability of crops particularly where output price depends on imports or exports and a large proportion of inputs are priced locally. Exchange rate changes affect the relative profitability of high output and input crops more rapidly than low input and output crops.

Table 1. Correlation coefficients between prices for several US commodities and Canadian rapeseed from 1976 to 1995, taken as an approximation to open market prices.

	Wheat	Barley	Maize	Soybean	Sunflower	Peas
Barley	0.809102	1				
Maize	0.671519	0.828952	1			
Soybean	NS	0.566488	0.634885	1		
Sunflower	NS	0.648377	0.732604	0.768035	1	
Peas	NS	NS	NS	NS	NS	1
Rape	NS	NS	0.471342	0.612079	0.609521	NS

NS = not significant

Changes in relative crop yield

The yield of wheat in Eastern Europe increased by 0.0870 t/ha/annum for the period 1961 to 1989 (r^2=0.9192, d.f.28) while oats and rye increased similarly at 0.0382 t/ha/annum (r^2=0.8134) and 0.0396 t/ha/annum (r^2=0.7614) respectively from an almost identical base yield. Over this period the area of wheat remained constant but the area of oats and rye declined at an average rate of 87,942 ha/annum and 47,996 ha/annum respectively. However, yield increases resulted in only small reductions in rye and oat production while wheat production increased to fulfil additional demand for cereals.

Within a single country an increase in yield alone is not sufficient to increase area if competitors in other countries are increasing yield to a greater extent. In addition, there are incidences when a higher yield reduces the crop area. This will occur where the market is already fulfilled. Crop area is most likely to reduce where the market is local (as a consequence of perishability or transport cost), is governed by quota or there is no direct substitution for other crops.

In more Central European countries, oilseed and protein crops are relatively more competitive than wheat, than in the UK and there are indications that this difference is becoming larger. This is illustrated by comparison of oilseed rape yield as a percentage of the wheat yield for the period 1961 to 1997 (Table 2).

Table 2. Comparison of oilseed rape yields relative to wheat, 1961-1997 (FAO, 1999).

	Eastern Europe	UK
Oilseed rape yield as a % of wheat yield	64.3%	49.2%
Standard Deviation	0.0159	0.0155
Kurtosis	0.2314	-0.4460
Skewness	0.8600	0.5909

Changes in relative input prices

A percentage change in price of any input is less significant than the same percentage change in output price. Thus a change in input price exerts a relatively small influence on the commodity crop area. It can however be important for specialist crops.

Eastern Europe has a number of competitive advantages. For example in Hungary land may be bought for the equivalent of £300/ha and labour costs are approximate one fifth of UK levels. These advantages for combinable crops are relatively small compared to the penalties of lower yields, more volatile yields and less support. However, the advantages are more significant for unsupported or labour intensive crops.

Technical advances lowering relative costs

Advances in crop protection or husbandry can change the relative profitability of crops (and crop area) but tend to operate over a long time period. The introduction of herbicide tolerant crops is a possible exception and could, together with the other factors discussed, lead to a rapid change in area.

Gross domestic product (GDP) and population

Increasing population and wealth generally increase food consumption, albeit at a lower rate. The population in Eastern Europe has fallen by approximately 1% from 1989 to 1997 while the agricultural population has declined 24% in the same period. In addition, since 1989 the GDP in Eastern Europe has generally fallen. In Hungary, for example, cereal consumption fell from 148 kg/head in 1989 to 117 kg/head in 1996. While there is not a direct relationship in this instance (Table 3), changes in GDP are frequently quoted as a reason for changes in world food demand.

Limited access to capital

This is an important influence with substantial impact on Eastern European crop areas. All the Eastern European countries receive less agricultural support than in the European Union (EU). Exposure to world prices and extreme price volatility has produced a cash shortage for many countries. This has been so severe that not only has capital investment been reduced but also in investment with an expected payback of a single crop cycle. This is illustrated by fertiliser expenditure (Table 4). Changes in relative crop areas cannot explain the downward trend, however total area cropped changed significantly with Hungary for example showing an increase in fallow (Table 5).

Longer-term investment in machinery or buildings necessary to handle more crop or different crops has not usually been possible without outside investment.

Table 3. Hungarian GDP (European Commission DG VI, 1998).

	1990	1991	1992	1993	1994	1995	1996	1997
GDP (% change in real terms)	-3.3	-11.9	-4.3	-2.3	2.9	1.5	1.3	4.4

Table 4. Fertiliser consumption as a percentage of 1980 use (FAO, 1999).

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
E. Europe	105	96	67	35	34	32	33	34	38	37
EU 12	105	103	94	89	80	81	84	83	86	84

Table 5. Fallow land as percent of arable area in Hungary (European Commission DG VI, 1998).

	1989	1994	1995	1996
Percent of arable land fallow	0.0	5.0	4.1	4.6

Perception of risk

A grower will tend to balance risk for the overall farm business and, even without husbandry or technical limitations, is unlikely to commit the total acreage to the same crop.

Commitment will vary with volatility of the particular crop and degree of risk the business can with stand.

Expertise

New crops require a period of learning and individual growers tend to build up expertise over a period of time. My experience is at odds with other observers in that I have found that basic agronomy was often good in Hungary and East Germany. The bigger problems appeared to be motivation, reliability of delivery, shortage of cash, over manning and clarity of objectives.

Interaction with other crops

A large number of interactions exist including competition for labour and machinery at harvest and drilling, competition for fertiliser, production of volunteer weeds that may be difficult to control in specific crops, increase in weed problems and multi-host diseases such as *Sclerotinia*.

Climate

Climate determines cropping range and crop reliability. As may be expected oilseed rape generally dominates the oilseed area in the more northern countries such as Poland giving way to sunflowers in Hungary.

Seasonal factors

Seasonal influences can severely change crop areas distorting managed change derived from economic factors. The more continental and consequently more extreme climate of Eastern Europe exerts a significant influence on relative crop areas.

Figure 1 illustrates the impact of annual weather variation on crop area. The area of maize changes inversely to the area of wheat. This is statistical significant with a 99% confidence limit for the years since 1980. The implication is that cold or wet winters prevented planting, or damaged, the winter wheat crop forcing spring planting of maize.

This is supported by my experience of East Germany in 1995/96 when severe cold destroyed vast tracts of rapeseed, barley and wheat while rye was relatively unscathed. The weather was similar in Poland and in that year oilseed rape area was halved compared with the previous year and the remaining yield per unit area was approximately 75% of the long term average (FAO, 1999). Wet autumns in Hungary, such as 1998, have had a similar effect.

Crop protection and weed control

There is little quality information available on the impact of crop protection on the changes in Eastern European cropping. Pesticide use appears to have mirrored fertiliser use with, for example, Poland showing a fall in the use of active ingredient from 1.4 kg/ha in 1989 to a low of 0.36 kg/ha in 1991, before returning to 0.63 kg/ha in 1997 (FAO, 1999). As use has risen, the tendency has been to increase the area to which pesticide has been applied rather than the intensity of use.

Personal experience of East Germany and Hungary suggests that weed levels are often high. Common couch (*Elymus repens*) infestations are common and appear to have been badly controlled prior to 1989. Anecdotal evidence states that glyphosate was not available until around 1996 in Hungary. Wild-oats (*Avena fatua*) are common throughout these countries.

Lower yield potential and more erratic prices are likely to maintain lower fungicide inputs than in Western Europe. For instance, pesticide use in Hungary in 1995 was 15,393 tonnes of which herbicides comprised 48% of and fungicides 26.8% (Anon., 1996). As demand for crops increase raising prices and herbicides such as glyphosate cost less, the point at which marginal cost equals marginal return changes, increasing herbicide use as farmers will keep crops cleaner and also return land to production.

INFLUENCE OF THE EUROPEAN UNION

Poland, Hungary, the Czech Republic, Estonia and Slovenia are likely to begin entry to the European Union from 2003. There has already been some harmonisation. For example, Hungary has introduced measures to assist harmonisation such as value-added tax (VAT), low rates of area aid and limited opportunity to export to the EU. It is a condition of entry that land must be freely tradable and this is likely to lead to introduction of more capital.

Details of entry conditions are still unclear but it is unlikely that EU rates of area aid will be paid (Timms, 1999). It is also likely that the next World Trade Organisation (WTO) round, due to finish in 2003, will aim to restrict existing production distorting subsidies and will prevent extension of these subsidies into new areas. Several of the Eastern European countries have already introduced support and in common with the EU are already constrained by the export limitations imposed by the last General Agreement on Tariffs and Trade (GATT) round.

However, if the revised intervention system successfully allows price support during periods of low world price and a recouping of the subsidy when world prices rise, it would be difficult not to extend the system into the Eastern European countries either directly or *via* allowing exports into the current EU.

The impact of accession will be country specific as demonstrated by a study on Hungary (Table 6). This is based on a combination of financial recovery, removing the capital constraints and increasing demand and extension of the pre-1989 trends. The oilseeds growth is assisted by increased crushing capacity. Hungary already has an intervention system for wheat and maize operating on maximum yields of 2.4 t/ha and 3.2 t/ha respectively and maintaining prices at 60% of pre-Agenda 2000 EU levels. Sugar is supported at 54% EU levels and oilseeds are largely unsupported although there is some import controls. Under "The Association Agreement" between Hungary (and the other Central European countries) and the EU, there is a mutual agreement on tariff and quota concessions.

Table 6. Land Use Projections ('000 ha; European Commission DG VI, 1998).

	1996	2000	2003
Cereals	2,772	2,820	2,850
Oilseeds	577	590	601
Sugar beet	99	104	96
Other	1,265	1,196	1,163

CONCLUSIONS

Crop area is likely to increase through removal of fallow. There are no indications that there has been a different trend in the major crop areas since the fall of the Communism. The increase in sunflower and rapeseed seen to date at the expense of dry beans (*Vicia faba*) is likely to continue. In the longer-term the relative competitiveness of oilseeds will allow further substitution for a proportion of the cereal area. Seasonal factors will continue to exert a large impact on cropping.

Weed control is a secondary influence on crop system changes and no major change in the balance of weed species is expected. However, the expected increased area in production and improved levels of weed control is likely to increase herbicide usage. The gradual move towards non-cereal crops will change the balance of products used. Herbicides rather than fungicides are likely to see the biggest increase in market.

The introduction and acceptance of herbicide tolerant crops is likely to be particularly valuable in Eastern Europe where the main crop protection input is herbicide, availability of capital is limited and competitive advantage is increasingly in favour of non-cereal crops.

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Changes in support systems and the effect on arable crop production in the EU

K Timms
Head of Agricultural Crops and Commodities Directorate, Ministry of Agriculture, Fisheries and Food, Nobel House, 17 Smith Square, London, SW1P 3JR, UK

ABSTRACT

This papers outlines the policy changes in the European Union (EU) arable sector resulting from Agenda 2000 and indicates the results of analysis carried out by MAFF into the effects of those changes, and their long term sustainability. It examines the implications for the sector of further political and economic pressures on the Common Agricultural Policy (CAP), in particular from further EU enlargement and the next World Trade Organisation (WTO) round. Changing consumer concerns in relation to arable crops, notably the debate over GM technology and the growth of organic farming are also considered. It also looks ahead to the likely policy context for the sector by 2006.

THE IMMEDIATE FUTURE: POLICY CHANGE POST-AGENDA 2000

Agenda 2000 set out to be a set of radical policy prescriptions, designed to equip the EU for further enlargement and to put it in a strong position to confront a new round of WTO negotiations. The Commission's radical vision for the arable sector embraced deep price cuts (-20%), a uniform rate of arable aid compensation at less than 100% of the price cuts and 0% set aside.

The radical vision came adrift on the twin obstacles of politics and finance. Politics because the emerging shape of reform for the arable sector, which was tantalisingly close to the Commission's proposals as it emerged from the Agriculture Council of Ministers in March this year, proved a step too far for their political masters. Finance because in the end the wish to place tight budgetary limits on CAP spending proved greater than the desire to reform the policy fundamentally.

The outcome of the Berlin Heads of Government meeting in March was such that:

- cereals intervention prices were cut by 15% (instead of 20%), and in two stages, starting on 1 July 2000;
- set aside reintroduced for 6 years (2000-2006) at 10% default rate;
- uniform arable area compensation payment to be phased in by 2002, with a higher rate for protein crops. Oilseed and linseed payments therefore set to decline over period 2000-2002, though never lower than the cereals rate;
- payment period to be deferred for one month (hence November - end January from year 2000).

Because of uncertainty as to the long-term durability of this set of reforms, Heads of Government agreed on two further steps. The first was to review in year 2002 the case for a further 5% cut in cereals intervention price. The second was to call for a report in 2002 of how successfully (or otherwise) the Commission is managing the agricultural budget within the very tight constraints laid down in Berlin.

These reviews may change nothing. They could be the occasion for further steps in the reform process if market circumstances prove adverse.

AGENDA 2000: ECONOMIC IMPACT AND LONG TERM SUSTAINABILITY

There are two main aspects to analysis the economic impact of arable sector changes. The first is the impact on products generally and on market balance within arable sector and the second is the impact on consumers and taxpayers.

Producer impact

The UK Ministry of Agriculture, Fisheries and Food (MAFF) estimates (Table 1) show that losses to UK farmers resulting from the totality of Agenda 2000 reforms, but before any restructuring as a result of the changes, will amount to some £150 million per year in aggregate compared to incomes they would have earned in the absence of reform. Arable producers, being compensated at less than 100% of the support price "loss", will bear the brunt of these changes, with livestock producers (though not dairy) being relative beneficiaries as a result of high levels of compensation.

Table 1. Change in producer returns 2008 - post Agenda 2000 (a).

	Supported arable crops (b)	Beef	Milk	Other commodities	Total
EU15 (euro million)	-1,770	1,070	-1,540	400	-1,830
UK (euro million)	-270	200	-160	0	-230
UK (£ million)	-180	130	-110	0	-150

(a) The change is measured against the expected level of producer returns in the absence of reform. Totals may not add due to rounding.
(b) Consists of cereals, oilseeds and proteins.

The likely impact of the arable sector changes on EU market balance depends on whether Agenda 2000 as delivered goes far enough to prevent a recurrent build up of intervention stocks over the period 2000-2006. The answer to this depends critically on forecasts of trends in world market prices. But given the effect of existing WTO limits which constrain the volume of subsidised exports from the EU to world markets, coupled with uncertainty as to whether a 15% intervention price cut is enough to allow large scale exports without subsidy, the future begins to look very uncertain. Table 2 shows MAFF estimates of the likely intervention stock build up in wheat and in coarse grains on the basis of current forecasts of world market price movements over the period to 2006. This demonstrates the likely unsustainability of the Berlin agreement without further price cuts, or equivalent measures, during the period and hence the importance of the price and budget review clauses scheduled for 2002.

Table 2. Projected EU15 cereal intervention stocks under Agenda 2000 (million tonnes).

	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07
Wheat	3	7	12	16	20	25	31	40	50	61
Coarse grains	11	13	26	15	11	8	6	6	7	9
Total	13	20	27	31	30	33	38	46	57	71

For EU arable producers, the most significant impact on their cropping decisions which was promised in the Agenda 2000 reforms, a 0% rate of set aside, failed to materialise. They face the prospect of a 10% set aside rate, which can be varied up or down, for the foreseeable future. This outcome is a direct corollary of the decision not to cut prices by more than 15%, and to phase that cut across two years. As a result, we in MAFF do not foresee a significant change in cropping patterns over the period, but with reductions in arable support prices we do expect a small reduction in nitrogen and pesticide usage as producers adjust to lower overall returns.

Consumers and taxpayers

Consumers fared better than producers from the Agenda 2000 deal, limited though the extent of the reform turned out to be. Once fully implemented, the benefits to UK consumers of support price reductions across the three sectors will amount to some £1 billion per year. Table 3 shows the profile of these savings over the period to 2008. The bulk of the consumer gains derive from the milk and beef sectors, with some 25% only deriving from cereals reform, which started from a lower absolute support price level than for other commodities, given the 1992 reform process.

Because the Agenda 2000 deal does not provide for any long-term degressivity of compensation payments to producers, despite increasing those payments to part-compensate for price cuts, the overall cost of the CAP will rise by some 2.5 billion euros by 2008 in comparison with the status quo. Table 4 shows the trend of budgetary expenditure for that period. The bulk of the extra expenditure will arise in the livestock sectors, notably milk where the effect of cutting prices even modestly is to trigger significant costs by way of compensation.

Table 3. Impact of Agenda 2000: consumer savings, 2001 to 2008.

	2001	2002	2003	2004	2005	2006	2007	2008
EU15 (euro billion)	2.5	4.9	6.1	6.1	6.1	7.4	8.7	10.0
UK (euro billion)	0.4	0.7	0.9	0.9	0.9	1.1	1.3	1.5
UK (£ billion)	0.2	0.5	0.6	0.6	0.6	0.7	0.8	1.0

Table 4. Projected CAP expenditure under Agenda 2000 (euro billion).

2001	2002	2003	2004	2005	2006
43.0	44.4	45.4	45.3	45.3	45.8

FURTHER POLITICAL AND ECONOMIC PRESSURES

The main issues are how far does Agenda 2000 equip the EU for further enlargement, notably to the east, and for the WTO round due to begin in January 2000?

EU enlargement

The forecasts referred to in this paper are based throughout on fifteen current members of the EU. It is unlikely that the Agenda 2000 outcome could be extended as a set of policy prescriptions to the applicant countries of Eastern Europe (CEs) without:

- very heavy EU budgetary cost, not provided for in the future financing agreement (Table 5);
- acute political differences about the applicability of direct payments to CE producers;
- placing complex bureaucratic requirements upon them, subsequently to be dismantled;
- creating economic distortions to CE economies by raising market price support for their producers and hence increasing consumer costs.

The implications of this is that further CAP reform will be needed before the CE economies - and the EU budget - can cope with full integration into the EU. Also, if there is a political will to bring about early EU enlargement without early further reform, then the CE countries may have to face part-exclusion from the main CAP framework for some time to come.

WTO

The WTO round starting in Seattle in November this year represents a further challenge to the Agenda 2000 CAP reform outcome. The main areas of negotiation are bound to be:

- pressure on the EU to reduce or eliminate reliance on export subsidisation. This is possible only if EU prices are at or near world market price levels, or if the EU is prepared to meet the high budgetary costs of significant intervention purchasing. Neither is the case at present;
- pressure to open up EU markets to greater direct access for third country producers. With high internal support levels, the EU is ill-placed to cope with the market destabilising effects of increased import penetration. The consequence would have to be either further internal price cuts, or tighter production controls (e g set aside);
- pressure on the EU to end its reliance on the so-called blue box measures i.e. the brigading of EU direct compensation payments into a special category exempt from the discipline of support level reductions. In view of the greater dependence of the EU on such payments as a result of Agenda 2000, losing the protection of blue box status would be a serious blow to a key element of EU agricultural policy.

By the end of 2003, the "peace clause" which protects the CAP from external challenge in the WTO comes to an end. It is reasonable to expect some movement on the part of the EU to meet concerns of WTO partners before then.

Table 5. Estimate of budgetary cost of CE5 enlargement against Berlin Agreement provision, 2002-2010 (euro billion) (a).

	2002	2003	2004	2005	2006	2007	2008	2009	2010
MAFF estimate (b)	2.2	7.3	8.0	8.7	9.5	9.9	10.3	10.6	10.9
Current provision (c)	1.7	2.2	2.7	3.3	3.9				

(a) The CE5 consists of Poland, Hungary, the Czech Republic, Estonia and Slovenia.
(b) MAFF estimates include the extension of CAP direct payments to the CE's.
(c) Expenditure provision as agreed at the Berlin Summit, 1999. The Commission has made no proposals to extend direct payments to the CE's in the next financial perspective.

CHANGING CONSUMER CONCERNS

Alongside changing political and economic conditions affecting the nature and extent of support given to European farming come changes arising from consumer concerns and preferences. These can be characterised as:

- a significantly heightened awareness amongst European consumers of issues concerning the safety, reliability and quality of foodstuffs;

- hence a keen interest in transparency and openness in relation to origin of food and methods of production. This translates into demands for traceability via labelling and similar assurance schemes;
- a growing consumer preference for foods which are organically produced. Retail sales of organic products are growing at around 40% per annum. The area of organically managed land or land in conversion has increased from around 30,000 ha in 1995 to nearly 250,000 ha in 1999 (Soil Association; personal communication).

Consumer reactions to the development of GM crops have been the most recent, and most high profile, example of demand-driven effects on the agricultural market. In conditions of plenty, it is difficult to convince consumers that they (as distinct from producers) stand to gain from technological developments that they do not understand. For that reason, it is essential that EU governments proceed with the greatest possible care in permitting the testing of GM crops in farm conditions. This is in order to give assurances to consumers as to the confidence to be placed in the regulatory framework.

This approach ensures that the EU farming industry will not be denied the possibilities of lower pesticide and herbicide usage, if these can be reliably achieved without damage, and preferably with benefit, to the natural environment. This approach also avoids provoking confrontation with other WTO trading partners over access to EU markets for genetically modified crops. The interests of neither side, nor of biotechnology generally, would be furthered by such a situation.

CONCLUSION: EU ARABLE POLICY IN 2006?

It is assumed that across the EU the trend to increased yields will continue and that market prices will follow support prices downwards. However high and rising sales into intervention are unlikely to be avoided, especially with existing and future WTO export subsidy limitations.

EU enlargement will pose a major challenge to the agricultural status quo as defined by Agenda 2000. Political, budgetary and market factors clash head on in this area, and something will have to give. Meanwhile UK Government policy makers will continue to seek most economically rational outcome for the CAP, encouraging EU agriculture to become competitive so as to take a growing share of international markets. A component of that drive for efficiency and sustainability will be to encourage farmers to minimise use of pesticides thus aligning economic rationality with environmental responsibility.

Changes in consumer demands and preferences may not have a major effect at the macro level, though could create niche opportunities for specialist producers. However, consumers demand reassurance about the robustness of regulatory processes for handling technological development. Without that reassurance, opportunities to maximise the benefits of biotechnology in Europe will be lost.

Implications of Agenda 2000 on weed control in Northern Europe

J H Orson
Morley Research Centre, Morley, Wymondham, Norfolk, NR18 9DB, UK

ABSTRACT

Agenda 2000 further exposes European crop production to global markets. It is surmised that wheat is currently the only commodity crop that can be grown competitively in Northern Europe. This is particularly true for the heavier soils, where production is often limited to commodity crops. The ability to increase the area of wheat and/or to reduce its unit cost of production on these soils is severely limited by annual grass weeds and take-all, the cereal root disease. The continued development of herbicide resistance in annual grass weeds is of particular concern. Hence, Agenda 2000 has increased the need for better annual grass weed control in wheat. New knowledge and technology have the potential to more than offset the possible reduction in biodiversity caused by any increased adoption of winter wheat should the industry fail to increase the choice of crops that can be produced competitively.

BACKGROUND

The previous paper in this conference suggests that cropping systems will be little changed as a result of Agenda 2000 (Timms, 1999). This is the new support system in the EU, which aims to comply more closely with World Trade Organisation (WTO) requirements to increase the exposure of European agriculture to world markets. To help to achieve this objective, area aid support for combinable broad-leaved commodity crops is being reduced to a level similar to that for cereals.

However, it is likely that there may be a financial benefit to adopt systems that rely more heavily on winter wheat production, if the associated agronomic problems can be overcome. Exposure to global commodity markets results in farmers concentrating on those crops that can be produced competitively. There is evidence that wheat can be grown competitively in Northern Europe (Table 1) but it is accepted that North European protein crop production is less competitive than soya bean production in many parts of the world. In addition, vegetable oil production from oilseed rape (*Brassica napus*) is less competitive and has lower functionality than that of oil palm (LMC International, Oxford; personal communication).

Forecasts of world demand for cereals and oils over the next twenty years are heavily influenced by the sensitivity of consumption to income and suggest an increase of around 40% for wheat and of around 75% for vegetable oils. However, it is forecast that rape oil production will increase by only 20% over this period (Anon., 1999): this production could come from the current or an even lower crop area if yield increases are maintained. There is rapid expansion of this crop in the United States (Loux *et al.*, 1999) and it is suggested that there will be expansion in the area of production in Eastern Europe (Ward, 1999). Hence, opportunities for even maintaining the area of production in Northern Europe may be limited.

Also linseed (*Linum usitatissimum*) for oil production, which is mainly spring-sown, clearly becomes uneconomic under Agenda 2000.

Table 1. Wheat production costs - international comparison (Michael Murphy, University of Cambridge; personal communication).

	UK	France	Germany	US	Ireland
Yield - t/ha	8.1	7.4	7.6	2.4	7.8
		All figures below are £/tonne			
Total variable costs	33.6	32.1	33.6	26.0	39.3
Total fixed costs excluding rent/rental value	47.9	58.3	62.7	54.8	44.8
Total costs before rent	81.5	90.4	96.3	80.7	83.9
Rent/rental value	17.3	11.7	13.6	34.1	19.2
Total production costs	98.8	102.2	109.9	114.8	103.1

1. Winter wheat in UK, France, Germany, and Ireland, winter and spring wheat in the US
2. Based on input levels, prices and volumes between 1994-1996 in each country
3. Exchange rate £ per ECU - 0.677353

Medium term forecasts also predict a continuation of low but fluctuating world prices for commodity crops. This is resulting in great pressures to reduce the cost of production of these crops, which in turn is bringing radical changes in the size and management of arable farms.

Clay soils represent around 25% of the arable area of the UK but their extent in Europe has been impossible to estimate, although there are extensive areas in most countries. Winter crops dominate these soils because of unreliable and poor crop establishment in the spring. Currently, winter oilseed rape and, in some parts of Europe, winter or spring field beans (*Vicia faba*) are of importance on clay soils as they are often the sole non-winter wheat crops. They offer the opportunity to control black-grass (*Alopecurus myosuroides*), a weed which shares the same growth cycle as winter crops, with herbicides whose efficacy is not affected by the enhanced metabolism form of herbicide resistance. Herbicide resistance in black-grass has been recorded in many parts of Northern Europe, particularly in the UK: such resistance has been confirmed on at least 750 farms in England (Stephen Moss, IACR Rothamsted; personal communication) and can result in extreme financial penalties.

The additional black-grass control that can often be achieved in these crops plus the break from take-all, a cereal root disease caused by the fungus *Gaeumannomyces graminis*, results in the following crop of winter wheat having a higher yield and enables it to be sown earlier in the autumn. Early sowing reduces the risk of poor soil conditions and facilitates the spread of labour and machinery costs. Hence, whilst as individual crops oilseed rape and field beans may not be able to compete in international markets, their overall contribution to the financial performance of the farm may result in their retention, at least in the short term.

Thus, it is clear that the area of autumn established crops will remain at least at current levels. This means that in the cereal dominated regions of Northern Europe, weed pressures will remain the same or even intensify if herbicide resistance continues to develop.

Technological developments have profoundly influenced arable systems in the past and will continue to do so. Conventional plant breeding or genetic modification may make some crops financially more attractive, either by reducing the cost of production and the ease of management or by increasing functionality. Better pesticides may further reduce the problems associated with the increased adoption of particular crops. The introduction of more effective chemical control of black-grass and/or the effective chemical control of take-all would significantly increase the competitiveness and area of wheat production in Northern Europe and enable farmers, particularly those on clay soils, to respond more effectively to the economic realities imposed by Agenda 2000.

Unlike some of our international competitors, arable production often dominates land use in densely populated parts of Europe and consumers have expressed fears over its impact on the environment. There are concerns over the landscape value and biodiversity of the countryside and also over nitrates and pesticides in water. Medium term forecasts suggest that potentially there will be arable land available not only to cope with the expected increase in organic production with its lower yields but also to devote some land in conventional agriculture to protect water and to provide habitats in order to meet biodiversity targets.

It is clear that consumers, either through product purchase or as voters, will determine the final shape of agriculture in Northern Europe. There will be a further increase in organic production (Timms, 1999) and there is already a differentiation in the commodity market in the United States, the weed control implications of which are discussed by Loux *et al.* (1999). However, commodity crop production is likely to continue to dominate arable land use in Northern Europe in the medium term. This paper describes the likely impact of Agenda 2000 on weed control in the wheat dominated commodity production systems that will be most affected by the changes in support. Also discussed is the role of new technology in weed control in maintaining competitiveness whilst meeting the environmental concerns which will result from a possible reduction in the diversity of cropping due to Agenda 2000.

BASIS OF CURRENT AND FUTURE COMPETITIVENESS OF NORTH EUROPEAN WINTER WHEAT PRODUCTION

Pesticides and chemical fertilisers have, along with plant breeding and improvements in plant nutrition and farm machinery, enabled North European farmers to exploit more fully soils and a climate that sustain high yields of winter wheat. They have also allowed winter wheat to be grown more regularly, in many cases continually, on soil types most suited to its production. Hence, the basis of the competitiveness of wheat produced in Northern Europe is, and will continue to be, the optimisation of inputs to achieve high and sustainable yields, thus spreading the cost of production over a greater output. This is in contrast with countries such as the United States and Canada where typically hot and dry conditions limit yields (Table 1).

Table 1 also demonstrates that the so-called fixed costs are higher than the variable costs of seeds, fertilisers and pesticides. Specialist cereal growers in the UK now consider that they have virtually minimised variable costs and that further reduction in costs will have to come from fixed costs, particularly labour and machinery. This is already resulting in larger farms, the increased use of contractors and/or machinery and labour sharing. It is also leading to the demand for simple management and cropping systems.

THE ROLE AND IMPACT OF NEW TECHNOLOGY

It is evident that on clay soils, where winter wheat dominates cropping, the threat from annual grass weeds and particularly the presence or threat of herbicide resistance in black-grass is preventing approaches, such as earlier drilling and non-plough tillage, that might further reduce fixed costs. Hence, improvements in annual grass weed control, within a sound anti-resistance strategy, are an essential key to the future competitiveness of North European systems that rely solely or heavily on winter wheat production.

Whilst increased knowledge of these weeds may provide improved cultural control measures, there is little doubt that there is the need for better selective herbicides and/or the adoption of herbicide-tolerant crops. This will be so particularly if the production of oilseed rape and field beans continues to be financially unattractive, resulting in the economic need to expand the area of winter wheat on clay soils.

The introduction of herbicide-tolerant rape has been delayed in Europe, due to consumer concerns, and its impact on the environment is being evaluated in the UK. From a technical point of view, this must be seen as a retrograde step. It would introduce new and effective modes of action for grass weed control in winter wheat/oilseed rape rotations.

To increase the efficiency of labour and machinery, approaches also need to be developed whereby the same herbicide mixture can be applied to many fields: the doses will be adjusted by changing spray volume according to parameters such as weed species, population and resistance status. This approach is already possible for fungicides in winter wheat but may require the introduction of more effective herbicides for the control of black-grass. Currently, the control of weeds on many farms often results in having to use specific herbicide mixtures in individual fields. This applies in particular to the control of black-grass, where the status of herbicide resistance (either target site and/or enhanced metabolism mechanisms) and weed population and growth stage can vary from field to field.

An alternative approach is to use a direct injection sprayer in order that herbicide mixtures can be changed with little or no reduction in work rates. These sprayers may be more generally adopted when spatial application of herbicides becomes feasible. However, there still remains the need to reduce the potential number of herbicides required between fields or parts of fields. In time, sensor technology allied to spatial application may enable populations of weeds that will not affect current and future crops to be left unsprayed.

Particular care needs to be taken with resistance management where the same product mixtures are adopted over the whole farm in the same year. Different basic programmes need to be developed both for annual grass and annual broad-leaved weed control in order that these can be rotated on an annual basis. Such approaches will be supported by improved information systems that will enable the better exploitation of simple decision structures.

Chemical control of take-all, in addition to improved grass weed control, may be required to increase further the area of winter wheat, particularly on the light to medium soil types. Seed dressings are being developed for the control of the fungus. Their impact on the flexibility of winter wheat production, both in terms of drilling date and cropping sequences, has yet to be fully evaluated. Initial research suggests that they supplement rather than replace cultural control measures.

WEED CONTROL AND BIODIVERSITY

Herbicides may have had an indirect effect on biodiversity in Northern Europe in two ways:

- farmers have been better able to grow the crops most suited to their land and markets, so reducing the diversity of crops within a given area (Feber *et al.*, 1997).
- effective weed control has reduced in-field biodiversity leading to claims that this has caused the recent falls in the numbers of some bird species (Campbell *et al.*, 1997).

Agenda 2000 provides no opportunity to increase the diversity of cropping; quite the opposite. However, greater knowledge of the impact of modern arable systems on the environment (Firbank, 1999) along with new technology should result in increased biodiversity. For instance, it may be possible to drill herbicide-tolerant sugar beet in strips of cultivated soil, retaining much of the cereal stubble which research has proved is an important food source for farmland birds. This may be impossible with conventional herbicides because they may not provide effective weed control in the remaining stubble.

The agronomic value of herbicide-tolerance has to be judged on a case-by-case basis. However, there are other approaches that can be adopted with these crops to increase the environmental value of land, such as enabling weeds to be controlled at more advanced growth stages, resulting not only in more biodiversity but also in the increased predation of crop pests. In addition, herbicide-tolerance will give farmers the confidence to leave narrow unsprayed strips within the crop knowing that the plants from the resulting shed seed can easily be controlled in future crops. Also, by enabling easy and cheap weed control, farmers will less zealous in their approach to the control of broad-leaved weeds that are an important part of the food chain for birds. Similarly, herbicide-tolerant crops will also increase the confidence of farmers to adopt spatial application (Orson & Oldfield, 1999). Many of the objections to herbicide-tolerant crops are based around their ability to achieve consistently very high levels of weed control, thus reducing biodiversity. The use of selective herbicides also normally results in weed free crops, the impact of which can be partially offset by not controlling the less pernicious weeds close to the crop edge. In the future, the adoption of spatial application will have a significant positive impact on in-field biodiversity.

On many arable farms in the UK, an increased diversity in habitat is now being provided by taxpayers supporting two or six-metre strips on field edges being sown to grass mixtures. The introduction of an option to place set-aside in narrow strips, particularly around the edge of fields, will have a beneficial effect on the provision of habitats for farmland biodiversity and will also help to reduce spray drift contaminating water and the impact of soil erosion.

Recent research suggests that point source contamination can account for a very significant proportion of the pesticide contamination of surface waters in the UK (Andree Carter, ADAS; personal communication). The farmer with little cost can reduce this dramatically.

CONCLUSIONS

Annual grass weeds along with take-all pose a greater threat to the economic sustainability of winter wheat dominated systems on the clay soils in Northern Europe as a result of the support arrangements introduced by Agenda 2000. Further reductions in the unit cost of wheat production are limited by the need to prevent or manage herbicide resistance and by the restrictions that these weeds impose on the methods of primary cultivation and the date of sowing. Therefore, better herbicides and management strategies for the control of annual grass weeds in these systems, including herbicide-tolerant crops, are urgently required. Unless new cropping opportunities arise, the effective control of black-grass and take-all in wheat will result in a significant expansion of this crop, particularly on the heavier soil types.

The environmental damage of modern cropping systems is due to a number of reasons, notably different crop rotations, increased nutrient status and weed free crops, as well as pesticides *per se*. (Feber *et al*., 1997). Hence, herbicide minimisation will have little effect on the environment if current crop rotations and standards of weed control are maintained. Herbicide minimisation will be encouraged by simple decision-making structures. These will be delivered to farmers in new and novel ways and based on a limited number of robust herbicides or herbicide mixtures, in order to minimise total costs, including labour and machinery, and to avoid the development of herbicide resistance. The introduction of an option to place set-aside in narrow strips, particularly around the edge of fields, will provide of habitats for farmland biodiversity and help to protect water from pesticide contamination and the effects of soil erosion. Increased knowledge, improvements in spray application and pesticides, and the sympathetic management of weeds, where herbicide-tolerant crops have a potential major role to play, have the capability to more than offset any reduction in the diversity of crops as a result of Agenda 2000.

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