SESSION 9A

FOOD QUALITY, SUPPLY AND STORAGE

Chairman	Mr R G Hilborn *J Sainsbury plc, London, UK*
Session Organiser	Mr M Gibbard *Zeneca Agrochemicals, Haslemere, UK*
Papers	9A-1 to 9A-4

Influence of weeds on United States food quality and supply

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ABSTRACT

Weeds cause a major loss each year in the United States in terms of quality and quantity. The importance of weeds to crop production will continue even with genetically modified crops due to shifts in weed species. Discussion of losses will be devoted to soybean. The yield loss in soybean can be greater than 80% and for highest and most economical yield potential, weeds must be removed by 2 to 3 weeks after crop emergence. To continue a high level of soybean production, the producer must have variable weed control options available. Thus, varied herbicide modes of action and cultural practices must be maintained. To prevent future losses, the Food Quality Protection Act (FQPA) is providing a stringent health-based standard on herbicides.

INTRODUCTION

Weed interference is a silent robber of a producer's yield potential. An outbreak of weeds goes unnoted by the press, yet weeds are a constant restraint on crop yield potential. Emergence of the weed science discipline has allowed producers to obtain much higher yields than previously obtained. Herbicides account for 70 to 75% of the pesticides sold in the United States (Duke 1999). In general, a given crop will have only about 25 species or 0.01% of the total (250,000 species) that cause a major problem. Of these 25 species, only four to five are the major cause of yield loss (Holm *et al.*, 1997). Over time, these species have shifted and will continue to shift in response to changing production practices, herbicide application, and environmental conditions. Currently, United States producers treat 95 to 99% of the nation's cropland every year with synthetic chemical herbicides to control weeds (Gianessi, 1995). The trend will continue for the foreseeable future because (a) herbicides are effective and economical, (b) environmental risks are extremely low, and (c) economical non-chemical weed control alternatives are not available.

As a weed biologist/ecologist and weed management researcher working primarily with soybean, soybean will be used as an example crop to illustrate the importance of safe, environmentally sound, and effective weed control practices to reduce loss of food quality and supply. The information presented will also apply for most crops. Soybean is capable of producing the greatest amount of protein per unit of land of any major plant or animal source (Considine *et al.*, 1982). However, soybean seed naturally contains certain substances, such as trypsin inhibitors, that may act as antinutrients if not properly heated during preparation (Rackis, 1974). Virtually all soybean protein products are heated prior to human and most animal consumption. Soybean yields about 80% protein-rich meal and 18% oil, providing three major markets: meal, oil, and bean (Padgette *et al.*, 1996). The primary use (about 97%) of soybean meal is as a protein supplement for animal feeds and only about 3% of total derived protein is used in human food in terms of United States domestic usage (Horan, 1974). Soybean oil is the major edible oil used in the United States (Mounts, 1988). Thus, loss of soybean yield potential and quality by weeds is extremely important.

IMPORTANCE OF WEED REMOVAL

Uncontrolled weeds cause loss in soybean yield at an estimated rate of 13 to 27% of total production. Over half of the national losses occur in the Corn Belt due to the large quantity of soybean production in that area. Large losses also occur in the southern states where soybean is a major crop. Percentage losses were estimated to be twice as high in the southern areas as in the northern areas (Bridges & Anderson, 1992).

Crop losses are not only in quantity, but also in harvestability, quality, and seedbank buildup for future crops. Weeds have a major influence on the production decisions made by producers. Key weed interference questions are: What weed species and density are present? What crop is present? How long has the weed been competing with the crop? The affects of these factors on crop yields are illustrated in Table 1. Common cocklebur (*Xanthium strumarium*), entireleaf morningglory (*Ipomoea hederaceae* var. *integriuscula*), and johnsongrass (*Sorghum halepense*) are examples of potentially dominant weeds. Each is more competitive in cotton than soybean even at only 1 plant/m of row. At densities evaluated, johnsongrass is not as competitive in soybean as common cocklebur and entireleaf morningglory.

Table 1. Interference of various weed species and densities on percent soybean and cotton yield potential. (Soybean - Baldwin *et al.*, 1987 and cotton - Scott *et al.*, 1999)

Weed species	Soybean 6*	Soybean 12	Soybean 18	Cotton 6	Cotton 12	Cotton 18
	(% yield reduction)					
balloonvine	3	6	9	24	36	44
common cocklebur	30	44	56	37	59	81
entireleaf morningglory	29	39	45	30	45	66
johnsongrass	0	2	6	14	24	32
prickly sida	12	16	20	38	31	58

* weeds per 6 meter of row.

Soybean, a dominant crop, is approximately twice as competitive as cotton to weeds. Once a dominant weed is controlled in a crop like soybean, the secondary weeds such as prickly sida (*Sida spinosa*) may not cause a yield loss, and control is not economically justified. Even though balloonvine (*Cardiospermum halicacabum*) is not competitive in soybean, its seed are the same size and shape as the harvested soybean seed and result in a great loss to the producer by preventing the soybean seed from being sold as either registered or certified seed.

Yield loss information is pertinent for computerized decision-aid weed management programs designed to determine levels of economically damaging weed populations for the United States soybean producer. Computer programs developed in Arkansas (Baldwin *et al.*, 1987), North Carolina State (Wilkerson *et al.*, 1991), and Nebraska (Mortensen *et al.*, 1999) are used approximately 25% of the time by soybean producers. Note that without control, crop yield losses can be greater than 80%. The concepts of economic threshold or economic optimum threshold are utilized to make sound, economical weed management decisions (Oliver, 1998). The key to effective weed control is optimum control within the first 2 to 3 weeks after soybean emergence. The advantage of early common cocklebur control is illustrated in Table 2. Only a 1-week delay in control from 3 to 4 weeks after soybean emergence results in a 7% loss in yield and a $51/ha loss in net return from two common cocklebur/m of row. Failure to control the weeds reduced soybean yield 44% or a loss of $264/ha. Early weed control allows soybean to obtain the competitive advantage and prevents major yield loss and harvesting difficulties at maturity. For difficult-to-control weeds, herbicide-resistant weeds, or for competitive weed species that have not been observed previously in the producer's field, the threshold concept is not valid.

Table 2. Economic feasibility of controlling 12 common cocklebur/6 m of row at various times in the soybean growing season (Barrentine & Oliver, 1977).

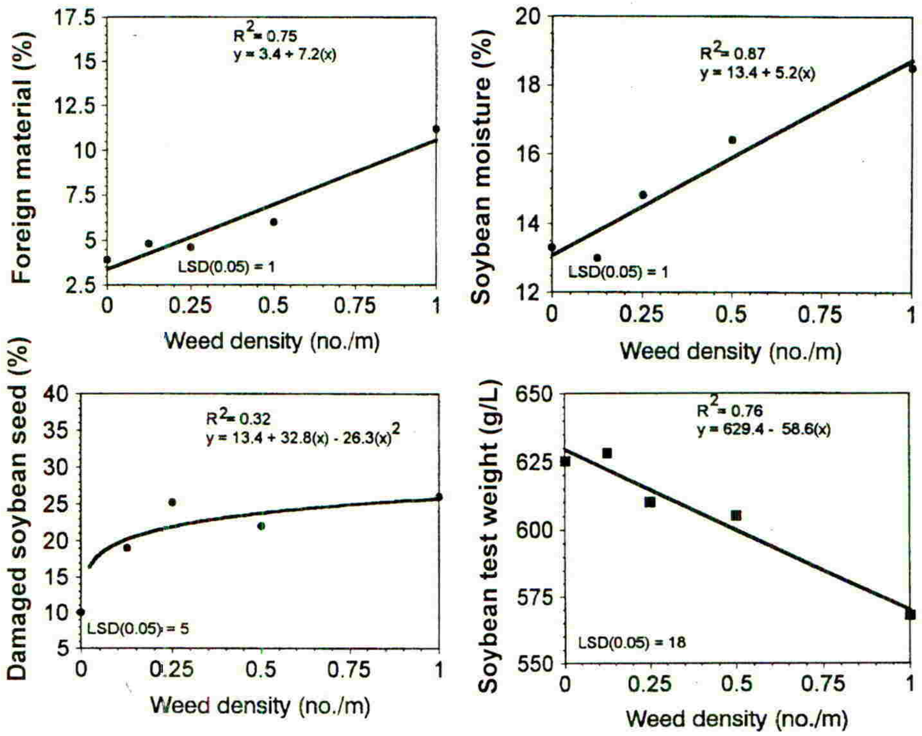
Controlled by (wk)	Yield reduction (%)	Potential yield (kg/ha)	Gross return* ($/ha)	Cost of control** ($/ha)	Net return*** ($/ha)	Loss ($/ha)
0-3	0	2691	692	41	651	0
4	7	2503	643	43	600	51
6	16	2261	581	44	537	114
8	25	2018	519	58	461	190
None	44	1507	387	0	387	264

* Selling price $0.257/kg.
** Herbicide (variable), cost of application ($9.88/ha), and technology fee ($19.10/ha) cost.
*** Only on herbicide investment.

Weeds harbor other crop pests such as insects, nematodes, and plant pathogens that reduce yield and quality. Perennial weeds are better hosts because the pests can overwinter in the underground vegetative reproductive structures. Johnsongrass, a major weed in soybean, can harbor maize dwarf mosaic potyvirus (MDMV) and maize chlorotic dwarf waikavirus (MCDV) in its rhizomes over the winter, and the next growing season insects transmit the virus to corn (Bendixen *et al.*, 1979). Although not a problem in soybean, weed control in kidney bean (*Phaseolus vulgaris*) reduced white mold (*Schlerotinia sclerotiorum*) infection by providing better aeration and less favorable conditions for infection (Burnside *et al.*, 1998).

Competition losses are severe, but reductions in soybean quality due to high seed moisture, foreign material, and damaged and split soybean seed may exceed competition losses and can certainly add to total yield loss (McWhorter & Anderson, 1993). Producers often increase combine cylinder speed when harvesting heavily infested soybean fields to force debris through the machine. Excessive cylinder speeds increase the amount of damaged seed splits and cracked seed coats (Green *et al.*, 1966). Increasing common cocklebur density (Figure 1) led to increases in soybean seed moisture, damaged soybean seed, and foreign material and to decreases in combine speed and soybean test weight (Ellis *et al.*, 1998). Control measures need to be implemented to reduce weed populations to prevent reductions in soybean seed quality. If green common cocklebur plants at 0.5 plants/m or redroot pigweed (*Amaranthus retroflexus*), sicklepod (*Senna obtusifolia*), or hemp sesbania (*Sesbania exaltata*), and ivyleaf morningglory (*Ipomoea hederaceae*) at one or more plants/m or row are present at soybean harvest, a preharvest desiccant may be needed to maintain seed yield and quality (Ellis *et al.*, 1998). Green weeds at harvest also reduced harvesting efficiency.

Figure 1. Effect of common cocklebur density on foreign material, soybean moisture, damaged seed, and test weight (Ellis *et al.*, 1998).



EFFECTIVENESS OF WEED CONTROL PRACTICES

Weed species have a highly heterogeneous genetic makeup or genetic plasticity. Thus, weed species shifts have occurred and will continue to occur in response to production practices, herbicide applications, and other selection pressures. Crop production practices leave safe sites for weeds to germinate, grow, and reproduce, and the tremendous soil seedbank insures continued emergence. Production systems in the United States rely on integration of cultural, mechanical, and chemical weed control practices. Cultural practices include cultivar selection, planting date, row spacing (Weaver *et al.*, 1991), tillage level, and crop rotation (Martin *et al.*, 1991), among others. Producers couple these cultural practices with mechanical and chemical weed management programs in order to manage their weed pressure. In general, herbicide programs involve a soil application followed by one to two postemergence applications. Weeds are still a major problem that must be considered in order to obtain economical crop production. For soybean, many herbicide options are available, and many herbicide programs are effective. Herbicide selection is dependent on weed species, weed size, crop rotation, tillage level, soil texture, row spacing, herbicide price and availability, and producer preference.

Reliance on herbicidal weed control has significantly influenced the quality and quantity of the United States food supply and must be discussed when evaluating the influence of weeds on the food supply and quality. The soybean crop loss would increase 4.9 times without the use of herbicides and monetary loss would increase $3.1 billion. There is an $8 million loss even when herbicides are used (Bridges & Anderson, 1992). The use of herbicides has increased crop production from 30 to 70% and provided high quality produce that would not be possible without herbicides and pesticides in general. The chemical age has resulted in extensive testing of crop commodities to insure that herbicide residues are at levels below harmful effects in the food chain (Council for Agricultural Science and Technology, 1991). Benefits vs risks evaluations highly favor herbicide use. In fact, in random marketplace sampling, over 98% of the commodities tested were well within safe residue levels.

Since 1996, the era of biotechnology has entered the soybean market with glyphosate that can be applied over-the-top of a genetically modified S-enolpyruvylshikimate-3-phosphate synthase (EPSPS) soybean. The herbicide-resistant crop technology has set new standards for herbicide effectiveness and weed control cost. The biotechnology era has also created genetically modified organisms (GMO's) in the food chain. The herbicide-resistant crops such as Roundup Ready soybean have resulted in an extremely unstable chemical industry due to reduced weed control costs and increased savings in time and weed control efficacy. The herbicide and seed markets, generated by herbicide-resistant crops, have become replacement markets; i.e., new sales are generated by replacing a currently used product (Council for Agricultural Science and Technology, 1991). In a replacement market, the most important factor is the competitive advantage provided when regarding success of any new technology, including herbicide-resistant crops. If there is a large perceived competitive advantage, there will be a high level of interest in developing the technology. Conversely, a small perceived competitive advantage will result in low interest. Based on competitive advantage, a definite niche for herbicide-resistant technology in agriculture, including in minor crops, is present. However, herbicide-resistant crops should still be considered just a tool in an effective weed management program.

The economic benefit of herbicidal weed control is very obvious or producers would not be relying on chemical weed control. Because of the small market size and large cost associated with obtaining a government registration for use in minor crops such as vegetables, no herbicides have been developed exclusively for a particular minor crop. If a herbicide becomes registered for a major crop, the inherent tolerance of minor crops to these herbicides is often not adequate. Therefore, low-cost herbicides for weed management in many minor crops are not available, resulting in generally higher weed management costs per acre in minor crops than in agronomic crops (Council for Agricultural Science and Technology, 1991). For example, weed management (with herbicides, cultivation, and hand weeding) in California lettuce (*Lactuca sativa*) fields averaged $257 to $410 per hectare from 1983 to 1987. Clearly, development of herbicide-resistant minor crops could be of significant economic benefit to producers growing these crops.

CURRENT REGULATIONS

Federal regulation of pesticides in the United States has evolved from two pieces of legislation enacted around the turn of the century; the Federal Food and Drugs Acto of 1906 and the Federal Insecticide Act of 1910 (Council for Agricultural Science and Technology, 1991). These early laws were superseded by the Federal Food, Drug and Cosmetic Act (FFDCA) of 1938, which authorized the Food and Drug Administration (FDA) to set tolerances for the amount of pesticide residues allowed in food, and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, which regulates the sale and use of pesticides. The Delaney Clause, which established zero tolerance for food additives found to cause cancer in humans or animals, was enacted in 1958. In 1970, the Environmental Protection Agency (EPA) was created to regulate pesticide use in the United States and prescribe labeling and other regulatory requirements to prevent unreasonable adverse effects on health or environment. The Food Quality Protection Act (FQPA) of 1996 replaced the Delaney Clause and significantly amended FIFRA and FFDCA. Among other changes, FQPA established a stringent health-based standard ("a reasonable certainty of no harm") for pesticide residues in foods to assure protection from unacceptable pesticide exposure; provided heightened health protections for infants and children, based on 'aggregate exposure potential', from pesticide risks; required expedited review of new, safer pesticides; created incentives for the development and maintenance of effective crop protection tools for producers; required reassessment of existing tolerances over a 10-year period; and required periodic reevaluation of pesticide registrations and tolerances to ensure that scientific data supporting pesticide registrations will remain up-to-date in the future.

The use of a herbicide on any crop (including crops made herbicide-resistant by genetic engineering or GMO) requires EPA registration of the herbicide on that crop. Registration requires monitoring cumulative residues of the herbicide and its metabolites and setting acceptable tolerance levels for safe consumption. The setting of residue tolerance levels for each crop and the Acceptable Daily Intake (ADI) level for each herbicide by the EPA provides excellent food safety for the consumer. In addition, approval from state regulatory agencies is required for herbicide use. Requirements for state approval vary among states.

CONSUMER PERCEPTION

In the United States, consumers take plentiful, high quality, and non-weed-contaminated food for granted, and spend only approximately 10% of their disposable income for food (Council for Agricultural Science and Technology, 1992). Yet, weeds cause major production losses in quantity and quality. The consumer does not tolerate a contaminated food supply such as puncturevine (*Tribulus terrestris*) seed in green beans (*Phaseolus vulgaris*) or red rice (*Oryza sativa*) in rice. Producers cannot sell weed-contaminated grain or produce, or if sold, severe dockage in selling price is imposed. Thus, the American consumer does not tolerate grain, vegetable, or fruit that does not look perfect, and consequently, does not purchase such produce.

Consumers have the right to know what they are eating and that it is safe. The United States labeling requires ingredient and nutrient value labeling once the EPA-approved food product is processed. Some concern is being voiced over the labeling of genetically engineered commodities such as soybean, corn, and potato. The 1992 FDA policy on new plant varieties requires that genetically engineered foods meet the same rigorous safety standards required for all other foods. FDA treats substances added to food products through recombinant DNA techniques as food additives if they are significantly different in structure, function, or amount than substances currently found in food. However, if a new food product developed through biotechnology does not contain substances that are significantly different from those already in the diet, the genetically engineered food does not require premarket approval.

Extensive testing confirmed that soybean plants modified for tolerance to glyphosate through the addition of the CP_4 EPSPS gene and the resulting extra soybean protein are not materially different in composition, safety, or any relevant parameter from soybean currently on the market (Padgette *et al.*, 1996). FDA agreed with data presented. Thus, biotechnology is effectively regulated and should be a valuable tool for the producer to utilize in weed management in order to provide the quantity and quality of produce to meet consumer demand. In the future, weeds will continue to be a major problem in agricultural production. The key to effective weed management will be to maintain flexibility in choice of herbicides and crop production programs so that when weed shifts occur, the producer will have viable control options.

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Herbicides and food quality - a misfit?

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ABSTRACT

Herbicides, in common with other crop protection products, have a wide range of benefits in respect of food supply and security, health and economics. In addition, they play an important role in meeting the demands for marketing, processing and nutritional quality. More recently the definition of 'food quality' has been extended to include the subjective criterion of environmental quality. The paper discusses the potential for a misfit between herbicides and all aspects of food quality, but concentrates on the aspect of environmental quality and this fits with herbicide use. It concludes that weed control using herbicides should be able to comfortably pass the test of public acceptability and that it yields a positive environmental balance as a component of Integrated Weed Control. Herbicides and food quality are therefore not a misfit, but herbicides are a unique partner in the production of wholesome and affordable quality food.

INTRODUCTION

The use of crop protection products including herbicide is outside the farming and crop protection industry more readily associated with yield enhancement (or maintenance under pest pressure) than improving crop quality. In Europe, which allegedly suffers from agricultural over-production, these products are therefore often branded as superfluous or outright counter-productive by the media and pressure groups claiming to speak on behalf of the public. This view ignores the role that European agriculture has to play in assuring global food security of a world population not expected to peak until reaching about 8.5 billion people in 2035 (Avery, 1998). It also entirely overlooks the fact that crop protection products play a critical role in enhancing and securing crop and food quality.

Crop and food quality are indeed the main aims of crop protection and the use of crop protection products. This is appropriately expressed in the overall objectives (and definition) of modern, sustainable agriculture: To provide a steady and sufficient supply of high quality, wholesome and safe food and feed at affordable prices produced in an economically viable, environmentally sound and socially acceptable manner. The consumers increasingly demand higher quality, with quality often ill-defined and the term more influenced by subjective rather than objective factors. They expect highest quality food at reasonable prices ('value for money') which has been produced in an environmentally friendly manner (Nieder, 1997). This aspect of method of production is a new criterion in the discussion on food quality and is becoming particularly prevalent and gaining in importance, in well-fed societies.

There is general agreement in professional and policy-making circles in agriculture and horticulture that crop protection products are an integral and essential part of achieving the overall objectives of sustainable agriculture. Over and above food security and supply benefits, crop protection products provide health, environmental and economic benefits. These have been addressed and exemplified elsewhere (Johnen and Urech, 1997). There is official recognition that "the variety of food available for consumption in Europe is manifold and attractive and at the same time safer than ever before" (German Ministry of Health). On the other hand, food can be an emotional subject, in particular when it comes to food and chemicals. This is exemplified by newspaper headlines such as "poison in our food" which do everything but stimulate rational discussion.

DEFINITION OF FOOD QUALITY AND QUALITY NEEDS

Due to the complexity of foodstuffs, the term food quality consists of several material and immaterial components. Generally and traditionally, these are divided into 3 quality categories:

1. "External condition" (marketing quality), which is related to the parameters form, shape, colour, odour, taste, weight, texture and absence of blemishes and diseases.

2. "Utility value" (processing quality), which describes the suitability of crops for specific household uses or industrial processing.

3. "Biological/nutritional value (nutrition physiological quality), which is concerned with the suitability of foodstuffs to satisfy men's needs for nutritious substances. In this context, one differentiates between value-adding substances such as vitamins and carbohydrates and value-lowering ones such as natural toxins.

More recently the term food quality has been extended beyond these intrinsic quality parameters to include more subjective values such as ecological, psychological, political and social values. In this context, the 'ecological value' of an environmentally friendly method of production is important and of particular interest. This means a most preserving agricultural management and production system, which should not burden the environment. Integrated Crop Management (ICM) meets this demand.

Nieder (1997) discusses production quality as follows: "Crop production without directed intervention into natural processes is not possible. These interventions are required to maintain agro-ecosystems. The crop plants need to be protected from competition, diseases and pests. Such measures are necessary to secure harvestability and yields of high quality and, by this means, 'the general basis of life' (Diercks and Heitefuss, 1994, cited in Nieder, 1997). However, opinions about means and intensity of the regulating measures differ greatly in the public discussion. Primarily, the use of mineral fertilisers and crop protection products is questioned. All directed interventions, mechanical, biological or chemical, must ensure that the systems retain the ability of long-term functionality. In our latitudes, there are - except for a few remnants - practically no natural ecosystems any more (such as virgin forest). ....Agricultural areas are ecosystems of anthropogenic origin. They were established by man to primarily secure his basis of life, ie to produce food and raw materials. The term 'production quality' describes [agricultural] management systems, which most preservedly interfere with the natural good soil, water, air and landscape and retain their long-term use. The agricultural production systems must therefore be designed in such a way that the long-term duration of agro-ecosystems is ensured and negative effects on neighbouring ecosystems - for example by means of transfer of substances - are avoided as far as possible."

It is evident that an evaluation of food quality which embraces all objective and subjective aspects would be very difficult, if not impossible. This is compounded by the fact that the priorities concerning food quality differ greatly dependent on the real and perceived needs of the producers, processors, traders and consumers. This has previously been discussed by Johnen and Urech (1997). In short:

- the farmer's needs pertain to marketable quality (and reasonable quantity), ease of harvest and being a reliable supplier;

- the food processing industry requires timely supply of uniform raw produce of consistent quality, free from disease, pests, weeds and other (toxic) contaminants;

- the food trade demands freshness of food combined with adequate shelf-life and best possible appearance.

- the consumer's needs are wholesome, good looking, tasteful and safe food with high nutritional value at affordable prices and all-year-round availability.

HERBICIDES AND IMPROVED FOOD QUALITY

The quality (and quantity) of agricultural produce can vary from year to year because natural influences can fluctuate with more or less intensity. Dependent on the weather conditions the competition of weeds for space, light, water and nutrients can be quite severe leading to less nutritious produce and increased contamination by weed seeds.

Herbicides facilitate a timely and cost-effective weed control, which usually cannot be matched by alternative methods such as hand-weeding or mechanical weed control. They play an important role in meeting the demands for quality of crops and food in all its aspects.

Marketing and processing quality

As already discussed, there is an economic demand for higher quality crops and food and for a reduce seasonality of supply. The food processing industry puts high demand on the quality of raw produce which it uses in food production. The development of canning and frozen food industries has resulted in the need for crops free of any weed. Any weed seeds in a packet or tin of vegetables is totally unacceptable to consumers and would result in the produce being rejected (Lever, 1990). Reliable, uniform high quality is essential to the food processing industry in maintaining economically efficient production. Herbicides ensure that quality-reducing "admixtures" of weed seeds and debris are eliminated. Contamination of cereals with crow garlic, certain vetch sp. and cockle render these useless for milling and bread making purposes, because they unacceptably impair the quality of the final product.

Nutritional quality

It is generally understood that crops must be protected or kept free from undue competition arising from weeds in order to avoid considerable yield and quality losses. The degree of protection is dependent on the sensitivity of the crop to competition as well as the use and destination of the crop (eg processing). Only in healthy crops can their natural, genetically determined potential for yield and quality be realised (Nieder, 1997). For example, nitrogen uptake and protein production in cereal grains are directly related to the state of the health of the plants and the strength of the competition of weeds. The healthier the plant, the higher the protein content (Anon, 1997). The situation is similar with regard to other value-adding substances in crops. The use of herbicides for weed control can prevent quality losses from weed competition. In contrast, alternative methods may not prevent such losses, because possible root and crop damage associated with them can affect the health status of the crop.

Contamination with weed seeds can have harmful health consequences. The seed of a certain vetch sp. at 0.05% produces bitter after taste and above 0.2% the flour produced from such a cereal batch raises toxicological concerns; seeds of cockle contain nitrogen-free glucosides, which can cause severe breathing problems (including cessation).

But what about residues of herbicides and nutritional quality?

The total amount of herbicides applied to a crop (application rate times number of applications) is relatively small, and for the most modern herbicides, very small. Herbicides are usually applied pre-emergence or post-emergence early in the establishment of the crop. This leaves time for degradation and decline of any small residues occurring in the crop. Thus, herbicide residues in food crops at harvest time are generally very low or non-existent. Nevertheless, the question is often raised, whether these residues reduce the intrinsic value of the food. The literature discusses this issue somewhat controversially. In particular proponents of alternative agriculture (crop production without the use of synthetic crop protection products) argue that more presence of residues reduces quality. This argument provides the basis for "absence of residues" often being cited as one, if not the only quality criterion of the alternative agriculture (Woese et al, 1995a).

The arguments against the opinion are more convincing. Firstly, the consumption of food containing traces of herbicide residues does not lead to any harm of the consumer. This will be established as part of the registration or authorisation process by the government regulatory authorities prior to the marketing and use of herbicides (and other crop protection products). This has been described in more detail elsewhere (Johnen and Urech, 1997). In order to protect the consumer from any harm arising from residues in the edible part of a treated crop, maximum residue limits (MRLs) are established for each crop. These ensure that even daily consumption of crops containing residues at this maximum limit for a life-time will not cause adverse effects on human health. In practice, exposure levels of individual consumers to residues in food are much lower than these MRLs. The reasons for this are: Not all the crop or food commodity is treated; the actual practical treatment results in lower residues that the MRL; storage, processing, preparation and cooking reduce the residue. This is confirmed by monitoring studies of residues in food carried out regularly by Governments. These show that residue levels in nearly all cases are below the MRLs and often well below it to not detectable at all (Nieder, 1997; GIFAP, 1992). Thus, concerning consumer safety, quality is not affected.

Secondly, if the use of herbicides in conventional agriculture had any negative effect on the inherent quality of food, then the alternative agriculture, which excludes the use of synthetic herbicides, should produce food of a higher quality. Literature reviews (Nieder, 1997, Woese et al, 1995a and b) comparing the quality of food produced by the two different production systems give no indications of principle qualitative differences between the foods derived from these production systems. The review by Woese et al (1995b) is particularly extensive. It covers a wide range of commodities and animal and crop products.

In addition to studying quality characteristics such as minerals, vitamins, protein content and trace elements, it also covered taste and processing qualities. The review concluded that, contrary to wide-spread opinion, crops and food products derived from alternative (biological) agriculture are not healthier and tastier than those from conventional production. The study found no fundamental differences. The conclusion therefore has to be that the mere presence of crop protection product (including herbicides) residues in food does not negatively influence food quality.

Herbicides and environmental quality

If one accepts a quality definition beyond intrinsic quality and include the 'ecological value' of an environmentally friendly agricultural management system that should pass the measure of public acceptability, does herbicide use pass this test?

It is often claimed, that herbicides unacceptably affect, either directly or indirectly, wildlife, in particular the fauna and flora of the soil and soil surface, and widely contaminate or pollute soil and groundwater. What are the facts?

Prior to marketing of a herbicide or any other crop protection product the potential for direct and reasonably foreseeable indirect effects as well as environmental contamination is explored during product development. This research is evaluated by Government Regulatory Authorities using a process of hazard assessment and risk estimation. Only products passing these examinations and thus expected to pose no undue risk (and showing positive benefit) will be authorised for sale.

Post-registration research involving many herbicides and a multitude of studies of many years confirm that generally there are no undue effects. If there are any direct effects at all, these are far less consequential than those arising from mechanical operations (Graham-Bryce, 1998). Should, against expectation, indirect effects occur, modification in agricultural practice in the use of the herbicide in question will mitigate against or minimise such effects. Whilst absolute numbers of species and individuals may be lower in an anthropenic agro-ecosystem when compared to a "natural ecosystem", this is a consequence of the use of the land and not surprising considering that priority is given to agricultural use and production (Avery, 1998).

In view of this, the assertion that herbicides negatively influence biodiversity is untenable. "Even concerning weeds, not a single species has been eradicated by herbicide use. If anything, the level of infestation may have been reduced to a larger or smaller extent locally and temporarily only. Furthermore, untreated areas at the edges of fields serve as a refuge for weeds" (Anon, 1996).

In addition, these areas and the so-called conservation headlands serve as a refuge and food source for insect and bird species, which more or less rely on weed seeds as the main source of feed. Interestingly, herbicides are used to selectively manage these headlands and control noxious weeds, which otherwise may overpower the less vigorous species and wild flowers needed as a wildlife food source.

The application of herbicides results in some herbicide (in particular soil applied herbicide) reaching soil and, under certain circumstances, water. The risks arising can be minimised and held at an acceptable level by using herbicides in accordance with the principles of Integrated Weed Management (IWE) within the wider system of ICM. This includes the maxim of applying herbicides only when and where needed based on threshold values. This may require a shift from pre-emergence to post-emergence use resulting in less herbicide reaching the soil and water as a consequence of crop interception. This move is greatly facilitated by increased tolerance to herbicides in crop plants as a consequence of using "safeners". Safeners increase choice and influence selection of herbicides and improve both cost-effectiveness and environmental acceptability (North, 1998). Band- and spot-spraying and the developing techniques of 'precision agriculture' further reduce potential environmental contamination. Reduced rates may apply where weed infestation is relatively low or a less than complete weed control is acceptable.

In order to satisfy the growing demand for food of an ever increasing world population and the relative lack of new land area suitable for efficient and sustainable agricultural production, crop production and agricultural output has to be substantially increased, by-and-large, on the land currently in agricultural use (Oerke et al, 1994; Avery, 1995). In other words, agriculture needs to be intensified, unless areas with the richest biodiversity, such as tropical forests, are turned over to agriculture; an agriculture, which would be unsustainable because of the fragility of the tropical forest soil. Herbicides play a vital role in achieving this intensification. Thus they contribute greatly to saving habitats and to maintaining, or even increasing biodiversity, if marginal land can be given back to nature.

Probably one of the most valuable contributions of herbicides to environmental quality and thus their acceptability is their role in achieving "Sustainability through soil protection" (Avery, 1998). Throughout the history of agriculture soil erosion has been by far the biggest problem in respect of farming sustainability. Where herbicide based weed control is operated, soil erosion has been greatly reduced. Combined with increasing yields on existing arable land, soil erosion per ton of food will be increased proportionally to this yield increase.

Herbicides have led to the "invention" of conservation tillage, which has replaced ploughing with discing of crop residues, which creates a multitude of small dams against wind and water erosion. The ultimate in conservation tillage and soil erosion control is no-till farming, where seeds are planted directly through the previous crop residues or cover crop that has been killed by herbicides. In addition to preventing erosion and saving top soil, conservation tillage is beneficial to soil fauna and flora, which can develop without their habitat being regularly destroyed by ploughing and other intensive mechanical cultivation.

In recent years, the development of biologically engineered herbicide resistance has added another tool for weed control that can fit the ecological/environmental quality criterion. Particular advantages are seen, for example, in environmentally benign weed control in row crops like maize and sugar beet with no problem arising from erosion; and targeted postemergence weed control based on the principle of damage thresholds by applying herbicide at the most sensitive growth stage of the weeds using minimum rates. Whilst possible disadvantages of biologically engineered herbicide resistance are discussed controversially, the potential problems, if any exist, are believed to be no greater than those arising from using conventional breeding techniques (Nieder, 1997).

CONCLUSIONS

Herbicides, in common with other crop protection products, have a wide range of benefits covering food supply and security, health and economics. In addition, they play an important role in meeting the demands for marketing, processing and nutritional quality. Concerning nutritional quality, herbicide use contributes to the health of crops and, consequently, the content of their value-adding substances. It protects from potential health consequences that could arise from contamination of crops with weed seeds, whereas the minute residues of herbicides, that may occasionally occur in crops, do not impair the quality and wholesomeness of foodstuffs. Concerning the more recent and rather subjective criterion of ecological or environmental quality, it has been shown, that herbicide use for weed control should be able to comfortably pass the test of public acceptability. Herbicide use as a component of IWC within the wider system of ICM yields a positive environmental balance:

- any possible direct or indirect effects on wildlife in the agro-ecosystem can be managed and are in any case often less disrupting than those from alternative weed control measures;
- local and global biodiversity can at least be maintained and in most cases be enhanced;
- environmental contamination can be held at acceptable levels;
- sustainability through soil protection is achieved by controlling soil erosion and fostering soil wildlife as a consequence of conservation tillage;
- biologically engineered herbicide resistance can provide further tools to foster environmentally friendly farming.

Thus, the question "herbicides and food quality - a misfit?" can be answered clearly. Herbicides and food quality are not a misfit, but herbicides are a unique partner in the production of wholesome and affordable quality food.

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The impact of consumer demands on international vegetable crop production

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ABSTRACT

Vegetable producers operate mainly in a market where free competition has resulted in plentiful supplies with a wide range of choice for the consumer. Consumer trust and confidence in the product is essential to maintain and improve sales. The consumer demands low prices, a wide choice throughout the year, attractively presented clean products which are free from contaminants. In addition, consumers have concerns about pesticide use, pesticide residues, the effect of production on the environment as well as the social aspects of production. Successful producers will be those that can cope with such diverse demands upon them.

INTRODUCTION

The modern consumer in Western Europe has a very wide choice of vegetable products available to them in a whole variety of formats from closely graded raw material right through to ready to use, prepared single products or as components in ready to cook meals. Consumer expectation of quality standards have increased as more sophisticated marketing of products has increased and competitive forces in retailing have lifted the standards demanded from producers. As urbanization has increased the modern consumer has become much more detached from the processes of modern agriculture and thus has little thought or comprehension of the pressures faced by producers of vegetable crops.

The consumer is presented with many strong messages about the need and benefits of increased consumption of fruits and vegetables and yet consumption in the UK remains largely static in overall quantity. It appears that many consumers often may have in their minds a fixed sum of money for their weekly purchase of all foods and are rarely willing to spend much more except for special occasions. There has been a consistent trend in recent years, for expenditure on food to fall as a proportion of disposable income and thus resistance to increased expenditure. In making food purchasing decisions, the consumer may not often take into account the increased value of products which have been partly processed to make them more convenient to use. The trend appears to be for overall food expenditure to remain level while the consumption of added value products increases as well as additional expenditure being made on food that is consumed away from the home in restaurants and take-away food establishments.

CONSUMER DEMAND FOR LOW PRICED FOOD

The problem for vegetable producers who are competing in a market place where the consumer demands low or reasonable food prices is one of maintaining continued consumer interest in their relatively simple products, when there is an abundance of choice of more sophisticated ones. The modern consumer appears not to be willing to spend larger amounts for the more traditional items which, very occasionally, have a higher than usual price because of weather related production problems. An example of this has been the negative consumer reaction to the high prices charged for potatoes in the UK during the autumn and winter of 1998-99 as a result of severe wet weather in North West Europe. This severely hampered harvesting and resulted in a significant proportion of the crop in The Netherlands remaining unharvested. As a result, potato consumption in volumes of the unprocessed tubers, has fallen in the UK and will take some time to recover. With so many alternatives available, the consumer will switch purchases to other items and the old patterns of loyalty to particular products may be disappearing.

The producer's options in such a competitive market place include the strict control of costs in order to remain competitive, producing a limited range of crops to a very high standard with increased production efficiency, or to add value and sophistication to his products by entering into contracts with one or more packers or processors. The vegetable production industry operates in a market environment where supplies very often exceed demand and prices are declining in relation to current production costs. The impact of this is that the less efficient producers are leaving the industry and production is becoming concentrated into fewer businesses. This trend is seen clearly in Northern Europe within those crops where the whole field production process can be fully mechanized so that hand labour and organization no longer remain a limiting factor to the scale of production. An example is the UK carrot industry, producing very large volumes and where production, packing and marketing is now concentrated into no more than fifteen large agri-businesses.

In addition, the reliable production of high yields of quality vegetables becomes very important for the producer to remain profitable. In previous times, some poor seasons could have been sustained financially by years with higher prices and profits. As farm businesses have become larger, with much higher fixed investments in buildings and specialized machinery and with higher borrowings, this tolerance of good and poor years is no longer viable. In areas where production has expanded into regions with less than optimum climates or soils in relation to specific crop requirements, then it is likely that the production in those more marginal areas will now retract and the industry will concentrate in the most favoured areas. The unfortunate consequence of this may be reduction in crop rotation periods with increases in weed, pest and disease pressure in those favoured areas. This does not fit in well with the principles of Integrated Crop Management. The regionalization of production into favoured areas for each crop does often result in production occurring further away from urban end consumers. This will remain an economically viable approach as long as transport costs remain reasonable in relation to the value of the freight carried. In the event of an imposition of an additional energy tax on road fuel within the U.K., the viability of long distance transport of the lowest priced vegetable products may become questionable.

CONSUMER DEMAND FOR A WIDER CHOICE OF PRODUCTS

With increases in overseas travel, food journalism, eating away from the home and an increase in income for a proportion of the population, the demand for non-traditional products has increased.

The vegetable producer now operates in an increasingly dynamic market place where the pace of change has accelerated greatly. Improvements in storage technology, transport, infrastructure and removal of certain trade barriers has allowed the movement of fresh and processed produce to take place over ever increasing distances. In addition, the time period between a shortage in the market place becoming apparent and the void being filled by alternative sources of supply has shortened considerably. Although many production costs have increased, the cost of long distance transport within and into Europe has not increased dramatically in the last few years. This has resulted in the proliferation of supply of 'out of season' products, especially during the winter period in Europe. The last ten year period has also seen a large increase in the volumes of more 'exotic' vegetables grown in tropical and sub tropical locations and exported to Europe by means of air freight, transported either on scheduled passenger services or by cargo aircraft. This increased production of items such as green beans, fine beans, baby corn, mange tout peas and asparagus has been stimulated by consumer demand for more interesting and less familiar products which are easy to use with very short preparation times before cooking. While producers and exporters of such crops face very high transport costs from long distance locations to reach the market, they have the advantage of relatively low labour costs compared with production in Europe. This allows them to produce crops requiring high labour input and those where harvest operations cannot be mechanized. With the forthcoming round of GATT negotiations it can be expected that there will be further removal of barriers to trade, including duty levels, which currently exist and do now have an effect on some areas of international trade in vegetable products.

CONSUMER DEMAND FOR SAFE FOOD

Consumers have to have near complete confidence in the safety of the food for them to continue to make purchases. The continuing problems with actual safety of certain food items in the UK e.g. Listeria in some cheese, BSE(Bovine Spongiform Encephalopy) in cattle, E.coli 0157 in meat products, helps to maintain a heightened level of concern about food safety among the public. Such a concern produces both rational and irrational fears about the effects of minor food contaminants, some of which are very hard to prevent completely with crops grown in an outdoor, soil based production system.

Microbiological Safety

This component of food safety represents an area where problems can occur if the potential hazards are not controlled properly. While vegetable products do not generally provide a good substrate for the growth of human pathogenic bacteria, certain production processes can allow for contamination to occur which can be passed onto consumers if preventative action has not been taken. The public perception of low risk associated with vegetable products does place a further responsibility on the producer or packer. When root and other vegetables were presented in a dirty form (with soil not fully washed off), it was quite clear that those products required washing before they could be peeled or further prepared for use. With the use of enhanced presentation by prepacking, the consumer receives a visibly clean product which a proportion of consumers may assume has already been washed (despite clear advice on the label). The risks are greater for salad products and those vegetables which may be eaten raw. In recent years the industry has moved rapidly into the production of lightly processed fresh vegetables which are sold as ready to use or ready to cook. With these prepared products the customer has the expectation that such products will always be microbiologically safe and the standards required for the processing facilities and procedures for such products are now very high. The main routes for potential raw material contamination include the inappropriate use of animal manures, irrigation water, activities of birds and rodents and via the food handlers involved in harvest and packing or processing operations. The consumer's demands are interpreted and implemented by food retailers and food service companies in the form of detailed raw material specifications, compulsory use of Hazard Analysis (HACCP) techniques and Codes of Practice. The use of animal manures and treated human sewage in relation to fruit and vegetable production, has recently been regulated in the U.K. by the development of The ADAS Matrix (1999), which will be incorporated into buyer's raw material specifications.

Weed and Foreign Body Contamination

Consumer expectations are for products free of foreign bodies and extraneous matter, although with basic vegetables sold in loose format there may be some understanding of the occasional light presence of soil in some products which had not been washed by the producer. Producers, importers and produce packers have a responsibility under the UK Food Safety Act (1990) to provide safe food and therefore must have a sufficiently robust control system in place to minimize the risk of foreign bodies occurring in their products.

Ensuring complete freedom from extraneous matter that has its origin in the production of raw material in the field can present considerable challenges to the grower and processor. This includes weed seeds, weed seed heads, weed fruits (berries), small snails and slugs, insect bodies - both pest and beneficial species and the larvae and adults of predators and parasitoids attracted into the crop by them. The control of weeds by herbicides has been an very important feature in the production of vegetable crops for processing, which includes fully mechanized harvesting where the whole crop including any weeds present are taken into the machine (e.g. green peas, green beans and spinach). The development of more specific pre and post emergence, contact herbicides has allowed these crops to be grown on a large scale without mechanical or hand weed control. There is a continuing need for the development of herbicides for control of difficult weed species. When weed control has partly failed, the grower may have to use hand labour to remove the problem weed species or in severe cases, parts of the crop have to be abandoned and by passed during harvest. Some weed species are attractive to insects which can then spread into the crop (e.g. *Aphis fabae* and *Brevicoryne brassicae*) while the insects living on weeds can also attract predators into the crop which can themselves, become potential contaminants in the harvested crop. For those crops grown for harvest by hand selection, the potential problem is not so severe but growers must achieve a high level of weed control not only as weeds are direct competitors with the crop but because of the risk of seeds falling from tall growing seedheads (e.g. Chenopodium album) into the crop. The crop leaves then continue to grow and entrap the seeds. A proportion of such trapped seeds can then remain within the product even after the cutting, trimming and prepacking operations and hence produce a risk to consumers. The use of selective post emergence herbicides has been an important tool for growers in reducing this potential problem.

In addition to the contaminants which derive directly from the field the producer has to be vigilant to reduce the potential sources of other foreign bodies including metals (from farm machinery) and pieces of plastic (e.g. from litter dropped by the public and from produce packaging).

CONSUMER DEMAND FOR FOOD PRODUCED WITH MINIMUM PESTICIDE INPUT

A significant proportion of consumers appear to be concerned about the use of pesticides in modern agriculture and have a view that they may be over used in order to guarantee yields and quality. It is true that a proportion of pesticide inputs are employed to guarantee the quality of the final product, but this can be justified when consumer expectations of product quality are now extremely high. In addition, there is a linked perception that some or any pesticide residue in food may be, in some way, harmful to human health. Such perceptions are enforced by regular food safety scare stories in newspapers and other media. One result of negative publicity about pesticides is the rising demand for organically produced food. It is essential for the producer to have a completely responsible attitude to the use of pesticides and to minimize their use wherever possible, not only for economic reasons but in order to maintain the trust of consumers in so far as that exists. While certain countries have gone so far as to introduce mandatory reduction in pesticide use, most have a policy of persuasion and encouragement of producers to adopt minimum pesticide use - as little as possible but as much as necessary. In the UK, producers are now able to register with the 'Assured Produce Scheme' which gives specific guidance on minimum pesticide use for each crop and provides an independent audit of pesticide use in line with each specific Crop Protocol and also safe storage practices. Membership of this scheme has now become a prerequisite for supply to the major produce buyers in the U.K.

The ability of producers to produce vegetables containing very low or no pesticide residues depends on the nature of the product, location of production, the pest and disease pressures and the range of pesticides which are approved for use on the particular crop. Many of the older active ingredients do have a propensity to leave residues in the harvested portion of the crop. Most modern pesticides have been developed with very different chemistry to produce much lower residues at the time of harvest. Growers would be very happy to use them; however as producers of minor crops they find that very few of the modern materials are being labelled for use on their crops, at least in the first five years after the pesticide is launched onto the market. The vegetable industry therefore remains open to consumer criticism that their products contain pesticide residues.

CONSUMER DEMAND FOR REDUCED ENVIRONMENT IMPACT.

An increasing proportion of consumers are interested not only in the food itself but also the method by which it is produced and the impact of production on the environment. This interest does derive from general concerns about large scale production using intensive methods as well as negative publicity about the effects of agriculture on the countryside. Farmers are being encouraged to farm with greater respect for the indigenous wildlife on their farms and to provide or restore suitable habitat for a whole variety of vertebrates and other organisms. While large scale growers who own the land they farm may be able to do this, growers with smaller operations or those renting land will be far less able to comply.

Most growers, however, should be able to provide small amounts of land to provide habitat to enhance the population of arthropod predators e.g. with grassy strips forming 'beetle banks'. Many producers are introducing integrated crop management systems (ICMS). Increased care when selecting pesticides should result in fewer non target species being affected by pesticide application. Producers would be willing to use more selective pesticides if more were available to them i.e. they had labels for their particular crops. In developing countries, the prices charged by distributors for modern, new selective pesticides are often so high that they become unaffordable for large scale field production.

CONSUMER DEMAND FOR FOOD PRODUCED WITHOUT WORKER EXPLOITATION

In recent years there has been greater attention to social issues in production of food, particularly fears about potential exploitation of labour. This attention has grown from publicity about the exploitation of children in some industries such as textiles and mining. The consumer does have a genuine concern that the food they are buying has not been produced by systems that include inconsiderate treatment of employees or small farmers. There will now be, in response, the introduction of formal 'Ethical Auditing' of production, which is already being conducted in other industries including the production of footwear in developing countries. The concern here is not just with production in remote parts of the world, but also with workers in developed countries where wages are paid that are close to or at the minimum allowed under local national law.

CONCLUSION

The vegetable grower faces a myriad of demands and concerns from consumers which are translated into a requirement for a very professional approach to production, including aspects of environmental management, close control over inputs and social responsibilities. This includes a capacity for enhanced record keeping. It is becoming increasing likely that only those producers who can conform with these requirements are those whose future in the industry will be secure, in the face of an ever more competitive market place which increased world free trade will bring.

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Weed control and crop quality; the conflicting demands in organic and conventional farming systems

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ABSTRACT

Weeds can effect crop quality through a number of routes. These include direct contamination by seed, fruiting bodies, buds and flower structures through to indirect contamination where the weed has provided a host to a pest or disease contaminant.

The level of weed control required to achieve an acceptable level of contamination depends upon the end market and the production system, organic or conventional, used to grow the product.

INTRODUCTION

The presence of weeds in cultivated crops is well documented. Historically the major limitation to agricultural output was the availability of sufficient nutrients, which resulted in short rotations to enable fertility to be restored by legumes or ley periods. This undoubtedly prevented weeds from becoming overbearing. The use of fertilisers has enabled more lengthy rotations often without these restorative periods and consequently weeds have become an increasing problem in most arable systems. The development of a range of selective and non - selective herbicides has enabled farmers to control weeds across all major crops and research in recent years has focused on defining economic thresholds based on weed competivity to enable farmers to make justified controlled decisions. Weed management, in contrast to weed control, has become increasingly important as farmers strive to adopt integrated crop management. Programmes are driven by customer demand, economics and a need to recognise weeds as part of the agro-ecosystem and therefore environmentally desirable in measured amounts. However, the main objective of research has been related to crop yield rather than crop quality.

Issues relating to quality have become increasingly important with the development of mechanical harvesters. More than a century ago crops were gathered by an army of labourers in a predominantly manual operation (Orwen *et al*, 1971). The advantage of such a system was that quality assessment could be made of each sheaf, head or fruit as labourers were in close proximity to the product. The increasing cost and competition for labour has led to more and more mechanisation (Oerke *et al*, 1994), with quality control less and less dependent upon inspection by the human eye. A number of important crops are now harvested and packed without close operator involvement.

Changes in consumer shopping and eating habits have also had a profound effect on crop quality requirements. Over the past thirty years consumers have switched their purchasing of fresh fruit and vegetables from the traditional specialist greengrocer to supermarkets.

This has led to the requirement for a more uniform specification, since the greengrocer tended to select, weigh and pack produce for the customer with the objective of providing an average sample of a wholesale lot, which helped to minimise wastage while generally maintaining customer satisfaction. The trading format of supermarkets is based entirely on self - selection with a significant proportion of produce in pre-packed form. To be attractive to the customer individual items and the contents of prepacks must all be of uniform quality. Hence grading considerations must commence at an earlier stage of production or packing.

Of even greater significance to the grower is the huge increase in demand for prepared foods for both retail sale and catering establishments. The provision of such foods delegates the responsibility from the purchaser to remove any contamination from the product to the supplier. Over 50% of meals are now eaten outside the home increasing the demand for rapidly preparable fresh ingredients, with many catering establishments relying on the majority of their ingredients being pre-prepared. This also reduces labour costs and once again shifts the onus for food purity back to the producer.

In the light of these significant changes in production, processing, retailing and consumer practice over the past 40 years, weed control and crop quality issues have become increasingly important with growers striving to achieve ever higher standards. The remoteness of the consumer from producer and the greater distances over which food is transported has also led to other quality concerns. These issues relate to freshness, chemical residues from the production system and ironically the extent to which some products are processed, often involving the incorporation of additional ingredients.

Today a grower is faced with great complexity with regard to quality standards, which vary according to season, time in the season, availability of alternatives, precise destination of product (freezing, canning, freshmarket, prepack, speciality etc) and varying customer demands. Among these demands is the desire that the product be grown in environmentally sensitive manner. Within all crop sectors this has led to the development of integrated crop management (ICM) which provides a more holistic approach to crop production requiring that cultural, biological and mechanical techniques of weed control are considered in the first instance, with herbicides as a secondary option. ICM however still relies on artificial fertilisers and pesticides and concerns over residues in produce, nutritional content, taste and environmental impact have led to a much greater demand for organic produce. Purchasers of organic food tend to look beyond the visual quality of the product and the price and consider the wider impact of the production system, although it is important to note that organic purchasers also show a diverse set of preferences depending on where they source their organic produce from. This paper will deal with the conflicts in both conventional and organic sectors and consider how the ultimate destination of the product also has some bearing on the levels of weed control required.

CONVENTIONAL CROP PRODUCTION

The consumer expects a product which is fresh, free from contamination and belmishes, perfect shape and size, plentiful and regularly available, easily identified and cheap. Such produce will inevitably require more inputs than ones which do not match these specifications (Chapple, 1997). These demands have caused farmers to specialise in the production of particular crops, often determined by soil type, and to grow considerable acreages in order to spread the high capital cost of specialist equipment. This in turn has put pressure on rotations, increasing the problems caused by weeds and volunteers.

COMBINABLE CROPS

Wheat

The conventional wheat market consists of three quality levels; crops produced for milling which will need to be high in grain protein (>11%) and have high hagbergs (>250); those produced for biscuit manufacture which will need to be soft wheats with lower protein requirements (9-10.5%) and lower hagbergs (180-250) and those destined for animal feed where specific quality traits are less important.

The most serious threat posed by weeds is the presence of volunteer cereals in milling crops, which might reduce the sample quality. This is most likely to occur where feed wheat crops are grown in close succession. However since milling wheats tend to be grown as first wheats in order that sufficient fertility is present to achieve high protein levels this problem is not common. A more frequent source of contamination is cleavers *(galium aperine)* and wild oat seed *(avena sp.)*. Cleavers respond vigorously to the high levels of nitrogen applied to milling crops and the seed can be of similar density to smaller grains in the sample, making separation difficult. Cleavers are frequently present in other break crops most notably oilseed rape which is the most popular crop to proceed milling wheat. Wild oats are a problem because of their persistence in the weed seedbank and ability of the species to germinate in both the autumn and spring. Contamination is caused by the presence of weed seed in the sample. Both weeds are becoming an increasing problem as the area of winter cereals being grown increases (Oerke *et al*, 1991). Cleavers and wild oat seeds tend to be ripe at harvest time and consequently the moisture content of the weed seed does not cause difficulties in crop drying and storage. Flower parts, buds and fleshy, unripe seeds such as those from fat hen *(chenopodium album)*, black-bindweed *(bilderdykia convolvulus)*, pale persica *(polygonum lapathifolium)* and knotgrass *(polygonum avicalare)* can cause deterioration of grain in storage.

Weeds can also effect quality indirectly. Annual meadow grass *(poa annua)* produces a mass of tillers with dense fibrous root mass which can readily intercept nitrogen fertiliser applied to the crop. This can result in severe reductions in grain protein levels. High levels of weed can delay harvesting by retaining excessive moisture within the canopy. This can result in a reduced hagbergs and in severe cases can result in grain sprouting in the ear. The most serious contaminant of wheat is probably ergot (*claviceps purpurea*) which is, thankfully, rare. This fungus, parasitic on rye and a number of grasses, has long been known to induce distinct poisonous effects to man and domestic animals when ingested in sufficient quantity (Long, 1917). The fruiting bodies of the fungi can end up similar in size and density to grain if fractured in the combine.

The presence of perennial weeds such as couch grass *(agropyren repens)* and creeping thistle *(cirsium arvense)* in the crop can be dealt with effectively pre-harvest with a treatment of glyphosate (Anon, 1999). The treatment also acts as a desiccant to the crop and reduces the number of green grains in the sample responsible for lowering the overall hagberg. In this situation the necessity to treat a weed problem may result inadvertently in an improvement in crop quality. This may give £5-£20 extra per tonne over feed wheat values, reduce drying costs and allow easier harvesting.

Malting Barley

The process of malting depends on changes occurring within the barley seed so it is important that grains should be of the same size and condition as well as possessing high germination capacity (Duly, 1928). The presence of immature wheat in the sample or weed patches such as couch grass in the crop will interfere with each of these desired attributes, converting a premium crop into a lower value feed product. This can result in a financial penalty of between £15 and £50 per tonne, depending on the season.

Oilseed Rape

Contamination occurs where weed seeds form an admixture with the crop sample, which may reduce yields of oil from the crush or cause taint. Poppy seed *(papaver rhoeas)* is difficult to remove although the public might regard the presence of poppies in a rape crop as attractive and desirable. Removing charlock is even more problematic as it is, like rape, a crucifer and hence resistant to the same spectrum of herbicides as rape. Cleavers are also a frequent contaminant of this crop.

ROOT CROPS

Sugar Beet

The main direct threat to crop quality from weeds comes from weed beet *(beta maritima)* which can arise in a crop through ground keepers or from seed shed from previous bolters. Weed beet are very woody and if delivered to the sugar factory create problems in slicing and sugar extraction (Jaggard *et al*, 1989). Control methods include the use of resistant varieties, delaying drilling, hoeing, pulling or topping. Weeds such as fat-hen and knotgrass can reduce harvester efficiency which extends the lifting period. This may result in beet being lifted in wetter conditions with more soil contamination. Each load entering the factory is assessed and a so called 'dirt tariff' applied according to soil levels.

Potatoes

Having a vigorous growing habit and being tuberous precludes potatoes from suffering directly from the effects of weeds. The major problems caused to crop quality arise from volunteers, which provide a host to potato blight, virus and potato cyst nematode (PCN). A key aspect of current PCN control is integrated crop management which dictates long rotations giving a minimum of 5 years break between crops. This is proving hard to achieve because of lack of suitable potato land. The potential of volunteers to reduce the effectiveness of this control measure could have serious consequences for PCN control and consequently crop quality.

Competitive weeds such as fat-hen, nettles (*urtica urens*), creeping thistle and docks (*Rumex sp*) can, in dense patches, prevent spray penetration to the crop canopy which can limit the effectiveness of blight control.

Heavy infestations of couch grass can cause problems at lifting by bringing masses of rhizomes, soil and stones up into the lifter along with the crop, increasing tuber damage. Failure to achieve the quality standards required can result in severe financial loss, particularly with crops grown on contract for processing. In the worst case this may result in the product being suitable only for stock feed.

VEGETABLE CROPS

The problem of weeds in a conventional vegetable crop is more severe because unlike most broadacre crops much of the produce is sold fresh or where processed it at least remains in an identifiable state. Hence any weed contamination is very visible.

Peas

Peas for the fresh market present little problem as shelling is carried out by hand just prior to cooking. This market is small compared to that of frozen peas, where the crop is mechanically harvested, and peas shelled from their pods prior to the hasty dispatch to the freezing plant. Any part of a weed species plant which is similar in shape, size or density to an individual pea is likely to cause problems. Great care is needed in selecting fields at an appropriate position in the rotation. Crops to avoid in proceeding years include linseed, since the seed capsule is almost identical to a pea and potatoes which, after flowering, bear small green fruits. Weeds such as sow thistles *(sonchus spp.)* and poppies also bear flower heads and seed heads which their immature state are similar to peas. Weeds may also create a "greenbridge" from the previous crop providing sustenance for slugs and small snails which can also become a serious contaminant particularly in wet years. The convenience nature of the product means that tolerance levels are effectively zero. Where a problem is identified the consignment is double colour sorted (at extra cost) and may be reduced from premium to economy pack status. Severe contamination will render the crop unmarketable.

Oilseed rape volunteers can cause problems, the shed seed being able to persist in the soil for in excess of three years (Lutman *et al*, 1998). The maturing volunteers inhibit the efficiency of the viners and increase losses while the plant juices increase the moisture levels and potential for taint in the sample.

Customer demands that peas be 'freshly' frozen to reduce taint and off flavours developing has meant a reduction in the time from vining to frozen state from 4 - 2½ hours with premium peas frozen in 90 minutes, thereby putting additional pressure on quality control.

Brassica Crops

Weed control in brassicas is helped by the use of transplants which enables crop establishment to take place in the absence of weeds and avoids the non-competitive early stages. Harvesting is still carried out manually and this enables separation of weeds from crop and enables operatives to discard contaminated florets or heads.

There has been a general change in brassica cultivation in the UK over the past 20 years with large acreages now grown on what were traditionally arable farms. This has led to break crops such as oilseed rape volunteers becoming problematic. The problem is two fold; volunteer rape can act as an alternative host for diseases such as club-root which can severely reduce crop quality and yield and provide altenaria innoculum which causes blackspot in Brussels sprouts. Weeds which flower during the harvesting period of the crop can cause quality problems by petal drop, particularly in curds or florets. In the cool and humid conditions of the packhouse and distribution chain this can encourage grey mould (*botrytis cineria*) infection which can contaminate the product.

The colour of petals is also important. The white petals of wild radish (*raphanus raphanistrum*) in a crop of cauliflower is less of a problem than the yellow petals of charlock (*sinapsis arvensis*) in a calabrese crop. Fat-hen is not a problem in cauliflowers harvested up to mid-August but after this shedding seed can contaminate emerging curds. This is particularly serious in wet conditions as the green seed capsules emulate caterpillar faeces and will consequently be rejected by the customer.

Tall growing weeds like charlock, red shank (*polygonum persicaria*) and fat-hen can also reduce crop quality by shading the crop. In calabrese this can cause stem elongation and reduced floret or head size. Customers prefer a higher ratio of floret to stalk. Fat-hen also provides an alternative host to the mealy cabbage aphid which attacks all brassica crops. The aphids often colonise the lower leaves of developing fat-hen plants before moving onto the crop, causing leaf distortion and discoloration.

Tall growing weeds are not a problem in Brussels sprouts but masses of basal weeds can cause quality problems by creating a damp micro-climate which encourages both disease and slug damage, particularly on the lower buttons. Their presence also prevents effective spray penetration. Despite all efforts and even where brassica crops are harvested for fresh market and processing it is estimated that over 40% of the crop will not be marketed.

GLASSHOUSE CROPS

Glasshouse crops largely avoid weed problems by the use of soil-less modules and polythene mulches. Certain crops, most notably butterhead lettuce (*lactuca sativa*) are still widely grown in soil and where this is unsterilised chickweed (*stellaria media*) can be a problem. The trailing, ground hugging habit of the weed reduces air movement around the lower leaves and creates a damp humid environment which predisposes the crop to mildew, rhizoctonia and grey mould infection. This increases the amount of trimming required at harvesting and reduces cutting efficiency. When values are low this can be sufficient to render the crop uneconomic to harvest resulting in total loss.

ORGANIC PRODUCTION

The control of weeds in organic farming systems relies exclusively upon cultural, biological and mechanical techniques. The use of chemical herbicides is not permitted (Leake, 1998). This presents both a problem and an opportunity for organic producers. The problem is that most multiple retailers will not accept organic produce of lower specification than conventionally grown crops which means more time and effort is spent grading for these markets and that grade-outs may be higher. Most problematical are organic convenience foods since the consumer expects identical standards to conventional products. Once again not only is there a danger that parts of the weed may contaminate the packed product but the presence of other species of plants within the crop can provide habitat for other contaminants such as insects. One of the perceived advantages of organic production is that it generates greater biodiversity. However, the presence of a moth in a mixed pack of pre-prepared salad is currently as unacceptable to the organic consumer as to the conventional.

There is, however, a school of thought within the organic movement that the provision of "processed", convenience type organic produce is incompatible with the overall organic ethos, particularly where the product has travelled great distance to be sold through multiple outlets. The preferred option is to sell locally through farm shops, farmers markets or box schemes with mail order as a last resort. In these more locally based systems delivering minimally packaged and unprocessed products, the presence of weed material with the produce may be seen as an enhancement of quality; the ultimate proof that no chemical herbicide has been used. There is also a bond of trust developed between producer and consumer and a more personalised service than can ever be achieved at a supermarket outlet.

In general weed contamination problems associated with organic crops are more severe than those of conventional although this is not necessarily so. Weed control can, on occasions, exceed that achieved in conventional systems, but is more erratic and unpredictable. Certain crops are not grown organically in the UK for instance sugar beet, because of the lack of a sufficient market. Other crops are grown with regard to other quality issues, such as peas where sowings are carried out early to allow vining before pea moth larvae hatch.

A number of specific quality problems have been experienced at the CWS organic farm trials (Leake, 1999). These included severe contamination of a spring bean crop with fat-hen, thistle heads and poppy seed capsules that could not be screened out, resulting in a completely unmarketable crop, and a crop of milling oats with cleavers which although screened still resulted in the presence of cleaver seeds in the milled product.

Volunteers also present a major problem in the absence of chemical control methods. This includes all the major crops as well as clover which is used to build fertility. However, the more diverse rotations practised by organic growers does tend to reduce the pressure in some crops. For example, at the CWS organic farm wheat is only grown two years in every seven, while on the adjacent conventional farm it is grown every other year. Crops such as oilseed rape are not grown because there is no price premium and spring cropping is more prevalent, diminishing the dominance of autumn germinating weeds experienced in conventional systems.

A very recent food quality concern expressed by organic consumers is the threat posed by cross-pollination with genetically modified (GM) conventional crops. To eliminate this risk it has been proposed that no organic crops be grown within 6 miles of any GM crops. While this is arguably enforceable in the year the GM crop is grown, the issue of volunteers emerging in subsequent years and the growth of plants on roadside verges from GM seed spilt in transit releasing pollen is unresolved.

CONCLUSION

Weed control issues have become in some cases more important to crop quality than they are to yield. There is a conflict between providing zero contamination levels and minimising the use of control measures (mechanical or chemical) to reduce environmental impact. Consumer tolerance of very low contamination levels would reduce the level and number of weed control treatments required and increase, in certain crops, the percentage of the crop harvested and marketed. This would result in direct consumer benefits in the form of lower prices. While growers strive to develop ICM the demand for cosmetically clean produce has not diminished. The increase in demand for organic produce may lead to greater tolerance developing in the future.

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