Session 6A

Meeting the Challenges Facing Arable Crop Protection at the Start of the 21st Century

Chairman:	Jim Orson *The Arable Group, Morley, UK*
Session Organiser:	Dr Peter Lutman *Rothamsted Research, Harpenden, UK*
Platform Papers:	6A-1 to 6A-4
Poster Presentations:	P6A-5 to P6A-11

Crop protection in Europe at the crossroads: challenges facing European farmers

P Kudsk
University of Aarhus, Faculty of Agricultural Sciences, Department of Integrated Pest Management, Flakkebjerg, DK-4200 Slagelse, Denmark
Email: Per.Kudsk@agrsci.dk

National legislation

Farmers in many European countries have for several years had to adapt to strict national legislation on pesticides and their use. The first European countries to adopt national pesticide reduction programmes were Sweden and Denmark in 1986, followed by the Netherlands in 1990. The national programmes of the three countries had in common that they focussed primarily on quantitative reductions in pesticide use and in each country the first target to be achieved was a 50% reduction. In Sweden and the Netherlands, the target was a 50% reduction in tonnes active ingredient used, while in Denmark the target was defined as a 50% reduction in pesticide use and in treatment intensity. The latter turned out to be a much more difficult target to fulfil than the 50% reduction in pesticide volume.

Within the last 10 years, other EU countries such as Austria, Belgium, France, Germany and the UK have implemented national pesticide plans or programmes. In contrast to the pioneer countries, the focus of recent national plans has been on reducing the environmental and health risks and/or impacts associated with pesticide use rather than pesticide volume. The Netherlands and Sweden, presently in their third and fourth national plans, respectively, have also changed their focus from quantitative to qualitative targets. In contrast, in Denmark the primary target is still a reduction in treatment intensity although other targets were introduced in the third and most recent pesticide programme “Pesticide Plan 2004-2009”.

Highlighting treatment intensity as the single most important target resulted in an intensive focus on pesticide dose optimisation in Denmark. An internet-based decision support system, Plant Protection Online (www.plantevaern-online.dk), was developed to assist farmers and advisors on pesticide and dose selection. As a result the average pesticide doses, expressed as a ratio of the standard dose, have been reduced significantly over the last 15 years. For example, the average fungicide dose in winter wheat has been reduced by 60% since 1985, corresponding very closely to the overall reduction in treatment intensity.

A similar trend has been observed for herbicide doses but in contrast to cereal fungicides the number of treatments has increased and consequently the overall reduction in herbicide use is less than for cereal fungicides. Hence, the reductions in pesticide use have not been achieved by replacing pesticides with alternative methods but solely by optimising pesticide use and reducing doses. Recently, a significant increase in treatment intensity, particularly with herbicides, has been observed. This increase in herbicide use is at least partly due to a change in the composition of the weed flora caused by the shift from spring crop dominated rotations in the 1980s to winter crop dominated rotations nowadays.

EU legislation

Besides national regulations, crop protection practices are also markedly affected by the ongoing EU review of active ingredients marketed before the implementation of Directive 91/414 EEC. Following a slow start, the review programme is now gathering speed and the outcomes are having more and more impact on farmer’s options for chemical pest control.

Broadly speaking, it is expected that only 1 out of every 3 existing active ingredient will be included on the positive list (Annex 1) of Directive 91/414 EEC. For example, out of 235 existing herbicide actives only 65 has been included on Annex 1 whilst 86 have been withdrawn and 83 are still being reviewed. In total 40 new active ingredients have been submitted for registration of which 11 have been included on Annex 1 and 29 are still pending.

The most evident consequence of this loss of active ingredients is the lack of effective pesticides in minor crops (for further details see elsewhere in these proceedings). However, effects are also becoming apparent in major crops, particularly in relation to controlling resistant pests and/or preventing development of pesticide resistance. One example is the control of herbicide resistant *Alopecurus myosuroides*, particularly biotypes exhibiting metabolic resistance. Today isoproturon and trifluralin are important components of farmers' strategies. Trifluralin will most likely not be included on Annex 1 and although isoproturon was included, the maximum dose was reduced and national registration is only possible if safe uses with no risk to aquatic organisms can be identified. As a result of this, isoproturon will be withdrawn from the UK market and it seems likely that similar decisions will be taken in other EU countries. Without access to older chemistry, control of resistant *A. myosuroides* will rely on one active ingredient. Another example is *Septoria*, the most important disease in winter wheat in North-Western Europe. Widespread resistance to the strobilurins and the gradual loss of activity to the triazoles may leave farmers with no effective options to control this very damaging disease.

The ongoing revision of Directive 91/414 EEC introduces a new concept, comparative assessment of active ingredients identified as candidates for substitution. The intention of the comparative assessment is to open up the potential for de-registration of active ingredients if, for example, more environmental benign alternatives are available. This could potentially make it even more difficult to implement anti-resistance strategies.

The revision of Directive 91/414 EEC is part of the EU Thematic Strategy on Sustainable Use of Pesticides. For the first time EU regulation is addressing the use-phase. An integral part of the Thematic Strategy is that each country has to establish a National Action Plan that should have objectives to reduce risks and dependence on pesticides. Other important objectives are the establishment of harmonised risk indicators, to be used with existing national indicators, and the definition of community-wide principles of Integrated Pest Management (IPM). Up to now European farmers have largely relied on chemical pest control and true IPM practices have not yet been widely adopted.

As mentioned above the expected scarcity of pesticides within the EU in the future will eventually force farmers to re-think their crop protection strategies and diminish their reliance on pesticides. To support this change more diversified crop protection strategies based on new technologies and including a broader range of strategies are required. The overall objective of the EU Network of Excellence ENDURE is to facilitate this change. ENDURE was initiated on 1 January 2007 and brings together the leading European crop protection competences. ENDURE will establish a European network of expertise and by sharing knowledge and facilities and developing a joint research programme, innovative crop protection strategies will be developed and disseminated to farmers and other stakeholders through a European pest control Competence Centre that will provide up-to-date and validated information.

Importance of pesticides in US crop production

L P Gianessi
CropLife Foundation, 1156 15^{th} St NW Suite 400, Washington, DC 20005, USA
Email: lgianessi@croplifefoundation.org

In the US, herbicides are applied annually to >95% of the acreage of most crops (fruit, vegetable, field) while fungicides and insecticides are applied to >95% of the areas of most fruit and vegetable crops and certain field crops (potatoes, rice). These chemicals are used to reduce populations of weeds, insects, and disease pathogens that would otherwise significantly lower crop yields. The spraying of pesticides is not new in the US. In fact, widespread production of fruit and vegetable crops has always been dependent on fungicide and insecticide spraying, beginning with inorganic substances (copper, sulfur, arsenic) over one hundred years ago. All the commercial apples grown in the US were sprayed with arsenic and lime sulfur as early as 1900. Before the use of the inorganic compounds in the 1800s, 50% of US food production was lost to insects; 70% of the fruit rotted in the orchards; and most fruit and vegetables in the markets had scars from pathogens and insects. Many severely infested fields were abandoned.

The inorganic compounds significantly reduced these losses by 50-80% while the introduction of synthetic chemical fungicides and insecticides in the late 1940s led to further reductions in pest losses - down to 5-10%. Yields of many crops doubled and tripled following the introduction of the synthetic chemical fungicides and insecticides (apples, potatoes, nectarines). In addition to reducing populations of well-established long-time insects and pathogens, insecticides and fungicides are widely-used to control populations of new destructive species (leafminers, whiteflies) which have become widespread only in more recent decades.

The importance of fungicides and insecticides can be understood by the practices of organic fruit and vegetable growers who spray insecticides and fungicides approved for organic use (Bt, spinosad, sulfur, copper). It is often difficult to produce commercially-acceptable organic fruit and vegetables without spraying to kill insects and pathogens.

The use of insecticides has made it possible for farmers to grow crops in regions where insect populations previously made production impossible (e.g. sweet corn in Florida). Their use has made it possible to extend the growing season into the fall in regions where insects had previously-made it impossible to grow late-harvested vegetable crops (cucumbers in North Carolina). The use of insecticides and fungicides are necessary to produce the blemish-free produce demanded by US consumers. Insecticides are also used to meet federal standards which require that processed foods be largely-free of insect contamination.

The widespread use of herbicides dates back sixty years to the introduction of synthetic chemicals. Prior to that time, US growers relied on millions of manual laborers to hand weed fields and numerous tillage trips to uproot weeds. When fields were too wet for weeding work, weeds took over and fields were abandoned. The initial impetus for herbicide use was a ten-fold increase in the cost of agricultural labor in the 1950s. Growers demanded a cheaper alternative. The wage rate has continued to grow and is the biggest constraint on weeding without herbicides. The scarcity and expense of labor for hand weeding severely constrains the expansion of organic growing in the US, which is dependent on manual removal of weeds without herbicide use.

Herbicides also substitute for tillage and make no-till crop growing possible. Soil erosion has been reduced by 360 billion pounds a year as a result of substituting herbicides for tillage on 60 million no-till acres.

Many crops were poorly-weeded before herbicides were introduced and their production increased dramatically following widespread adoption of herbicide spraying (soybeans, rice, peanuts, blueberries). Organic rice growers in the US incur 50% losses in production due to weeds that are not controlled during the growing season.

The use of fumigants has greatly increased the production of crops like strawberries and tomatoes for which yields had been held down by soil-borne insects, pathogens and nematodes. Growth-regulating chemicals, desiccants and defoliants have enabled farmers to harvest uniform crops of apples and cotton in an efficient, low-cost manner.

US government agencies and farm groups have issued numerous reports in recent years that estimate widespread crop losses without the use of pesticides. US production of most fruit and vegetable crops would decline by 50% or more without insecticides and fungicides. Without herbicides, most crops would be grown with some increased labor for manual weed removal. However, the increased labor would not be sufficient to prevent yield losses of 20-30%.

The search for alternatives to herbicides has not produced any method that could be adopted as a cost-effective replacement on the 220 million acres treated with herbicidal chemicals. Herbicides are inexpensive; they provide control of all the major weed species in farm fields; and farmers need only make 1-2 applications for season-long control.

Breeding of crop plants to produce pest-resistant varieties has been a research goal for many decades. However, with the exception of disease-resistant field crops, no commercially-acceptable durable resistance has been introduced for the major insect and disease-causing pathogens of fruit and vegetable crops. Maintaining the disease-resistant field crops has required the constant introduction of new “resistant” varieties as replacements for previously-resistant varieties to which the pathogens adapted. Many biological control research programs have resulted in the release of parasites and predators which attack insect pests. However, the major insect pest species have not been controllable with biological agents and widespread insecticide spraying continues to be necessary.

The importance of pesticides in US crop production should not be underestimated. Despite multi-million dollar public expenditures in the past twenty years, the search for alternatives has not produced any effective set of pest control practices that could effectively replace the widespread use of pesticides in the US, for the foreseeable future.

The benefits of pesticide use in the US are enormous while the risks to the environment are relatively low and to people are miniscule. One reason that pesticides will remain the backbone of pest management in the US is a regulatory system of tests and monitoring that assure the public of their safety.

Herbicide usage and associated problems in China

C X Zhang, Y Liu, H L Cui, S H Wei, H J Huang
Institute of Plant Protection, CAAS No. 2 West Yuanmingyuan Rd., Beijing 100094, China
Email: cxzhang@wssc.org.cn

Weeds, their impacts and chemical control in China

There are more then 1400 weed species in China, and 704 species, belonging to 366 genera of 87 families, are listed as having agricultural importance. Over 80 million ha of crop fields are infested by weeds: 20.47million ha of rice, 18.87 of wheat, 12.4 of maize, 4.78 of soyabean, 9.93 of cotton and 15 of other crops. More than 30 million ha of these are heavily infested. Invasive alien weed species are another concern because of their economic and ecological impacts. Even with the implementation of control measures it has been estimated that 13% of the yields of annual crops are still lost, which is worth over RMB 12 billion.

China started introducing and testing herbicides in 1957 and from then on, efficacy testing and small scale field demonstrations were carried out to familiarize farmers with chemical control. From 1978 to 1990, with encouragement and promotion from the research and extension sectors, more and more Chinese farmers started including herbicides in their weed management strategies, and chemical weed control started to boom. Since 1990, chemical weed control has been widely adopted; herbicides becoming one of the most widely employed tactics for field weed management in China. Currently, approximately 70 million ha of crop fields (75% of paddy rice; 55% wheat; 44% maize; 50% cotton; 61% soyabean; 41% other crops) received herbicide treatments throughout the country.

Major herbicides used in China

Various herbicides have been employed in different crops. For instance, butachlor, propanil, acetochlor, thiobencarb, quinclorac, bensulfuron, pretilachlor and cyhalofop-butyl have been applied in rice in various years; dicamba, triallate, 2,4-D, MCPA, isoproturon, chlortoluron, fenoxaprop-p, metsulfuron, chlorsulfuron and tribenuron in wheat; trifluralin, metachlor, acetochlor, fluometuron in cotton; atrazine, metolachlor, acetochlor, metribuzin, nicosulfuron in maize; acetochlor, fomesafen, alachlor, chlorimuron, imazethapyr and metribuzin in soybean. With the development of chemical weed control, herbicide production and market shares have increased rapidly in China. Herbicide production was up to 0.297 million tones a.i. in 2005 and 0.33 million tones a.i. in 2006 and herbicide sales reached RMB 6 billion in 2005, representing 24.5% of the Chinese pesticide market.

Associated problems

1) Changes in the major weed flora

In the past 2 decades, farming system have changed, agricultural management has been simplified, and changes in the weed flora have accelerated with some previously unimportant annual and perennial weeds becoming increasing problems to Chinese crop growers. For instance, *Leptochloa chinensis*, *Sagittaria pygmaea*, *Juncellus serotinus*, *Leersia hexandra* in rice; *Bechmannia syzigachne*, *Poa annua*, *Bromus japonicus*, *Alopecurus japonicus*, *Calystegia hederacea*, *Cirsium segetum*, *Euphorbia helioscopia* in wheat; *Pinellia ternata*, *Cyperus rotundus* in cotton; *Acalypha australis*, *Commelina communis* in maize; *Myosoton aquaticum*, *Lapsana apogonoides*, *A. japonicus* in oil-seed rape and *C. communis* in soybean, are all becoming problems for Chinese farmers.

2) Carry-over effect of persistent herbicides

Herbicides with long persistence have been widely used in China. About 17 million ha (32%) of crop fields have received chlorsulfuron, metsulfuron, imazethapyr and atrazine treatments in recent years. As a consequence, herbicide injury to various following crops became very serious. In the north-east, crop rotation has been affected. In the Yangzi river region, rice, oil seed rape, maize, cotton and vegetables are suffering badly. Farmers' income has been reduced by 20-30%.

3) Herbicide resistant weeds

Herbicide resistant weeds are not only a problem for developed countries. With increased and more intensive herbicide use in recent years, herbicide resistance is also becoming serious in China. The first reported herbicide resistant weed in China was paraquat resistant *Conyza sumatrensis*, which occurred in Taiwan Province in the 1980s. Then, *A. japonicus, B. syzigachne* and *Echinochloa crus-galli* resistant to chlortoluron, butachlor and thiobencarb, respectively, were reported in the 1990s (Huang & Lin, 1993). Recently, various weeds, including *E. crus-galli, Monochoria korsakowii, S. pygmaea*, and *Scirpus planiculmis*, especially *E. crus-galli*, have become resistant to quinclorac and bensulfuron in rice. Chlorsulfuron and metsulfuron resistant *Alopecurus myosuroides*, chlorsulfuron resistant *B. syzigachne* and 2,4-D or tribenuron resistant *Galium aparine, Descurainia sophia* or *Lithospermum arvense* have been recorded in wheat. *P. annua* and *A. japonicus* are becoming more tolerant to quizalofop or haloxyfop in soybean and oil-seed rape. *Digitaria sanguinalis* is showing resistance to atrazine in maize. *Mazus pumilus, Solanum photeinocarpum, C. hederacea, Conyza canadensis* are showing resistance to paraquat, metsulfuron or glyphosate, respectively. Finally, 2,4-D and glyphosate resistant *C. sumatrensis* and glyphosate resistant *Eleusine indica* have recently been reported in Taiwan Province (Heap, 2007). Farmers are applying higher doses to achieve reasonable weed control, which in turn will certainly make the situation even worse.

4) Sprayers and herbicide application

At present, most Chinese farmers are still using poor quality sprayers, cone nozzles, high spray volumes, and swinging lances for applying herbicides in their fields, which has resulted in uneven application, reduced efficacy, about 60% capitalization wasted, and environment pollution.

Future approaches

Increasing herbicide and crop diversity should be important approaches to alleviate all these problems. Crop rotation, multiple cropping systems, use of herbicide mixtures, and herbicide rotation with different modes of action should be encouraged to reduce the usage of long persistence herbicides. A nationwide weed survey, to identify changes in the weed flora, and the prevalence of herbicide resistant weed species will be beneficial for future weed management and for safeguarding Chinese agriculture.

References

Heap I (2007). International survey of herbicide resistant weeds. www.weedscience.org.

Huang BQ; Lin SX (1993). Studies on carbetamide resistant *Echinochloa cruss-galli* in paddy fields. *Pesticide Science and Management* **14**, 18-21. (in Chinese).

Good Agricultural Practice (GAP) and Integrated Plant Protection (IPP) – two instruments with the same tenor?

G Guendermann
Federal Biological Research Centre for Agriculture and Forestry, Messeweg 11/12, 38104 Braunschweig, Germany
Email: G.Guendermann@bba.de

Good Agricultural Practice (GAP) focuses on practical instructions for plant protection. GAP lays down orientation standards and forms the links between legal rules and authorized plant protection products. Integrated Plant Protection (IPP) goes further than GAP; it is both a model and a complex concept that seeks to balance economic and ecological demands.

The reasons behind the development of GAP were the environmental damage caused by chemical plant protection products and the public discussions of their consequences. In Germany the official plant protection service and the crop-specific associations have together designed the rules for GAP. The Federal Ministry of Food, Agriculture and Consumer Protection published basic principles for carrying out GAP in plant protection on 9 February 2005 (Anon, 2005). In addition the European and Mediterranean Plant Protection Organisation (EPPO) has published general and crop-specific principles referring to cultivation (EPPO, 2003); e.g. Good Practice in Potato Production (EPPO, 2001).

The various components that contribute to IPP as a general rule have not so far been described in detail for most crops. In Germany, particularly in fruit cultivation, the actual guidance is similar to that of IPP. However further development of, for example, threshold damage parameters, information about non-chemical plant protection products, general information and also economic incentives are still needed. IPP has not as yet attained an adequate level of detail.

The proposed amendment of the Directive of the European Council of 15 July 1991 about the introduction of plant production products (91/414/EWG) defines good plant protection practice and integrated plant protection. The definition "Good Plant Protection Practice" concentrates on the correct application of chemical plant protection products; whilst "Integrated Plant Protection" demands a conscientious consideration of all available standards with regard to long term sustainability.

According to Article 13 Paragraph 4 of the draft of the "European Parliament and of the European Council establishing a framework for Community action to achieve a sustainable use of pesticides" the member states should make sure that by 1 January 2014, general standards of IPP are applied. Crop specific integrated plant protection standards should be implemented by the member states thereafter. At the moment there is still debate as to whether the definition of IPP should be described in an Annex to the Directive. The possible content of the Annex will be discussed in this paper. The paramount objective is sustainable plant production.

Consequences for the development of IPP are:

- The basic rules of integrated plant protection will be harmonised in the member states of the EU.
- The user of plant protection actions will become more important. Knowledge will be rapidly transferred from research into practice and this will become faster and more efficient.
- The necessity of application of chemical plant protection products will be decided at a high level, observing the economic- and ecological-effects.
- State measures will define training and further education requirements and will require an increase in the amount of information about who is carrying out plant protection.
- It is up to the member state to decide if it can and will promote the uptake of IPP with the help of laws.

The basic principles of IPP are to be considered in Germany through inclusion in GAP regulations for plant protection and have already been published by the Ministry of Food, Agriculture and Consumer Protection. Crop-specific standards for IPP have not been developed so far, but the appropriate crop associations are working on this task. The advantages and disadvantages of rules with regard to IPP for a specific crop will be presented.

Both GAP and IPP strategies will continue to coexist. It remains the aim that IPP will be used as a crop-specific reference standard, but it could also be used politically as a system for assessing incentive measures, or as a potential benchmark for assessing the effectiveness of transfer standards for GAP.

References

Anon. (2005), Bekanntmachung der Grundsätze für die Durchführung der guten fachlichen *Praxis im Pflanzenschutz, Bundesanzeiger* **57** (58 a), 46 pp.

EPPO (2001), EPPO Standards - Guidelines on good plant protection practice - PP 2/2(2) Potato. *OEPP/EPPO Bulletin* **31**, 183-199.

EPPO (2003) Good plant protection practice - PP 2/1(2) Principles of good plant protection practice. *OEPP/EPPO Bulletin* **33**, 91-97,

Occurrence and chemical control of *Sonchus brachyotus DC* in rape fields

G Qingyun
Plant Protection Institute of Qinghai Academy of Agriculture and Forestry, Xining 810016, China
Email: gqy5312504@163.com

Introduction

This paper reports on the biology and control of *Sonchus brachyotus DC* an important weed in China, especially in oilseed rape.

Materials and methods

Biological characteristics of *S. brachyotus*

Observations have been made of the growth and life cycle of this weed. Measurements have been made of its growth in competition with oilseed rape and studies have been done on the dormancy of seeds. Research has also investigated the germination, sprouting and distribution of underground rhizomes and the impact of temperature on the survival of exposed rhizomes.

Control of *S. brachyotus* in oilseed rape

Clopyralid (3,6- dichloro-2-pyridinecarboxylic acid) - 75% Lontrel SG was applied at 101-169g a.i./ha in field tests for the control of *S. brachyotus* in oilseed rape, from 2004 to 2006. The herbicide was applied at a volume rate of 300L/ha at the 3-5 leaf stages. Percentage weed control and yield responses were recorded.

Results and discussion

The growth and reproduction characteristics of *S. brachyotus*

The growth period of this species lasted around 140 days in the Xining area. At maturity, the average height was 105cm and the stems produced 21.9 leaves, on average. The mean gross weight/plant was recorded as being 56.9g. The shoots emerged in the middle of May. The plants produced 6.2 main stems and the total stem number was 10.2/plant. Flower bud production started in the last ten-days of June and this lasted for approximately 50 days reaching its peak in early July. Open flowers were recorded in the middle of July and the flowering period lasted for 37 days. The peak flowering period was in the last ten-days of July. The fruiting period spanned from the middle of July to early August and lasted for 33 days. Each plant produced an average of 21.8 capsules and each capsule contained a mean of 182 seeds. Thus, on average, each *S. brachyotus* could produce 3974 seeds. However, the highest number recorded was 15,678 seeds/plant. Seeds of *S. brachyotus* were released easily from the capsule and as they are wind dispersed, provide a source for future infestations in the field.

Competition for nutrients between *S. brachyotus* and oilseed rape

S. brachyotus grew vigorously after emergence. Therefore, when this weed is present in oilseed rape it was found to be essential that it should be controlled from the 3 to 5-leaf stage of the crop. The amount of N, P, K in rape was lower than that in *S. brachyotus,* except at the 4 to 5- leaf stage of rape. Consequently, this weed can exert considerable competition for nutrients.

Dormancy of seeds of *S. brachyotus*

Fresh seeds of *S. brachyotus* were dormant, only 1% of seeds germinated after being kept in dry condition for 76 days. After 129 days, 7% of seeds germinated. When buried in soil for 48 days, 3% of seeds broke dormancy and emerged, and after 129 days in these conditions seedlings emerged from 22% of seeds.

The sprouting of underground rhizomes of *S. brachyotus*

Shoots of *S. brachyotus* started emerging in early April and the emergence period came to an end in early July, a period of about 96 days. Peak emergence of shoots was in early May (average temperature 11.8^{0}C at ground level, 16.8^{0}C 10cm above the ground) and 27.6% of the total number of buds emerged during this period. Both higher and lower temperatures were unfavorable to the sprouting of rhizomes. The shoots emerging in the middle and in the last ten days of May accounted for a further 14.5% and 11.4% of total shoots, respectively. The temperature in the middle May was 15.0^{0}C and that in the last ten-day of May 12.1^{0}C, 10cm above the ground. The peak of sprouting period was associated with irrigation in middle and late May.

Distribution of rhizomes of *S. brachyotus*

Rhizomes of *S. brachyotus* had many branches that usually grew horizontally in the soil, or at a slight angle. Approximately 60% of the horizontal branches were present down to a depth of 13.4cm, but the full distribution ranged from 0.1 to 94cm. The gross weight/plant varied from 0.5 to 60g.

Sprouting of rhizomes of *S. brachyotus* excavated in spring and exposed on the soil surface for different periods

When rhizomes of *S. brachyotus* were buried as soon as they had been excavated, the water loss rate and germination were 0% and 100%, respectively. If they were exposed to the air under indoor conditions for 3, 24, 72, 96, 216 hours, the water loss rates and germination become 12.8%, 34.2%, 75.0%, 78.1%, 83.8% and 100%, 85.7%, 14.3%, 0%, 0%, respectively. When rhizomes were exposed to sunshine outdoors for 3, 24 and 216 hours the water losses and germination were 33.1%, 70.0%, 70.0% and 87.5%, 0%, 0%, respectively. Thus, rhizomes of *S. brachyotus* are unable to sprout when they are exposed to sunshine for 1 to 3 days after being exposed by soil cultivation in spring.

Sprouting of rhizomes of *S. brachyotus* after freezing

Experiments showed that when rhizomes were exposed to 0.3^{0}C or 3^{0}C for 4, 17, 24 and 48 hours, they remained able to sprout, and the germination was above 46.6%. The germination was 75.0% after being kept at 3^{0}C for 48 hours. Rhizomes were not able to sprout if they were kept at -10^{0}C and -17^{0}C for 4 ~ 48 hours. The experimental analysis showed that rhizomes on the surface soil can be frozen to death and become incapable of sprouting after ploughing in autumn when the temperature drops to -10^{0}C or below in winter.

Herbicide control in oilseed rape

The results showed that *S. brachyotus* weight in oilseed rape was reduced by 87%, 85% and 89% by the clopyralid treatment in the three years. As the product does not damage rape the productivity of the crops was increased by 14.2%, 13.8% and 17.0%, respectively.

Simple salts as fungicides: potential for potassium bicarbonate with adjuvant to control powdery mildew on wheat

R P Corfield, P S Kettlewell, M C Hare
Crop and Environment Research Centre, Harper Adams University College, Newport, Shropshire, TF10 8NB, UK
Email: pskettlewell@harper-adams.ac.uk

Introduction

It has been shown that the simple inorganic salt, potassium chloride, can reduce the severity of powdery mildew (*Blumeria graminis* (DC.) Speer) disease of wheat (Kettlewell *et al.*, 2000). Other research has shown that another inorganic potassium salt, potassium bicarbonate, can reduce powdery mildew (*Sphaerotheca fuliginea* Poll.) on cucurbits (Reuveni *et al.* 1996). The work reported here tested the hypothesis that potassium bicarbonate can reduce powdery mildew infections on glasshouse-grown wheat in two experiments.

Materials and methods

Wheat seed (cultivar Claire treated with carboxin and thiram) was sown on 19 March 2004 (Experiment 1) and 6 October 2004 (Experiment 2). Plants were inoculated with mildew spores at GS 13-14 and sprayed with potassium bicarbonate with an adjuvant (BREAK-THRU S240; Degussa GmbH, Germany; 0.063% v/v) at varying concentrations (calculated as % w/v) and application volumes between GS 26-27. Either quinoxyfen (Experiment 1) or fenpropidin (Experiment 2) at recommended field rates with the adjuvant were used as standards for comparison, and the untreated controls were unsprayed. Water alone was sprayed as an additional control in Experiment 1. Both experiments were arranged in randomised blocks with ten replicates. Average leaf area affected by mildew was assessed on the adaxial side of the top four leaves 21 days after spraying.

Results

In the first experiment, where disease levels were relatively low, potassium bicarbonate with adjuvant appeared to reduce the severity of mildew compared with the unsprayed (Table 1), but the differences were not significant. In the second experiment, where the mildew was much more prevalent (Table 1), potassium bicarbonate with adjuvant significantly reduced the severity of mildew compared with the unsprayed, although control was superior from fenpropidin with adjuvant. Sprays applying more active ingredient through higher volume and/or higher concentration tended to give better control, although not always significantly.

Discussion

These results indicate that potassium bicarbonate with adjuvant may have potential for enabling conventional fungicide inputs to wheat to be reduced. In order to achieve control approaching that from recommended rates of conventional fungicides, it will probably be necessary to integrate potassium bicarbonate with reduced rates of conventional fungicides. The challenge will be to find the cost-effective and efficaceous combinations or sequences of salts and fungicides.

Table 1. Wheat leaf area (%) affected by powdery mildew 21 days after spraying

Treatment	Experiment 1	Experiment 2
Unsprayed	5.8 (1.54)$^{+}$	60.5
Water 200 l/ha	10.6 (1.69)	-
Water 400 l/ha	10.0 (1.00)	-
$KHCO_3$ 200 l/ha@0.5%	1.0 (1.03)	29.4
$KHCO_3$ 200 l/ha@1.0%	1.2 (0.96)	25.3
$KHCO_3$ 200 l/ha@1.5%	-	28.9
$KHCO_3$ 400 l/ha@0.5%	0.6 (1.17)	24.7
$KHCO_3$ 400 l/ha@1.0%	0.5 (1.36)	30.7
$KHCO_3$ 400 l/ha@1.5%	-	24.4
$KHCO_3$ 600 l/ha@0.5%	-	17.4
$KHCO_3$ 600 l/ha@1.0%	-	15.9
$KHCO_3$ 600 l/ha@1.5%	-	21.4
$KHCO_3$ 800 l/ha@0.5%	-	19.0
$KHCO_3$ 800 l/ha@1.0%	-	15.7
$KHCO_3$ 800 l/ha@1.5%	-	21.7
Quinoxyfen	0.3 (1.30)	-
Fenpropidin	-	5.1
Tukey's MSD (P=0.05)	- (0.75)	8.5

$^{+}$Values in parenthesis are natural logarithms

References

Kettlewell PS; Cook JW; Parry DW (2000). Evidence for an osmotic mechanism in the control of powdery mildew disease of wheat by foliar-applied potassium chloride. *European Journal of Plant Pathology* **106,** 297-300.

Reuveni M; Agapov V; Reuveni R (1996). Controlling powdery mildew caused by *Sphaerotheca fuliginea* in cucumber by foliar sprays of phosphate and potassium salts. *Crop Protection* **15,** 49-53.

Simple salts as fungicides: a case-study with potassium chloride

P S Kettlewell
Crop and Environment Research Centre, Harper Adams University College, Newport, Shropshire, TF10 8NB, UK
Email: pskettlewell@harper-adams.ac.uk

Introduction

Chloride fertilisers applied to the soil are known to suppress a range of diseases in crops (Fixen, 1993). Potassium chloride accounts for 95% of the potassium fertiliser used in agriculture (Johnston, undated). Research at Harper Adams with glasshouse and field experiments in the previous two decades has examined the potential for applying KCl solution as a spray to the foliage of wheat for suppression of disease.

Materials and methods

From 1986 to 1999, a series of glasshouse and field experiments was conducted to test the effects of foliar sprays of KCl on the foliar diseases of wheat: powdery mildew (*Blumeria graminis* (DC.) Speer) and septoria diseases. Details of the experiments have been published elsewhere (Kettlewell *et al.*, 1990; Kettlewell *et al.*, 2000; Mann *et al.*, 2004) or are in unpublished PhD theses (Cook, 1997; Mann, 1999).

Results

The results of the experiments are briefly summarized here since detailed results are too extensive to give and are available in the sources cited above. The research has shown that both powdery mildew (*Blumeria graminis* (DC.) Speer) and septoria diseases can be suppressed by foliar sprays of KCl, although not in every experiment. The optimum concentration, largely determined from glasshouse experiments, appears to be approximately 10% w/v (1.3M). This is equivalent to 20 kg KCl in 200 l ha^{-1} (13 kg K_2O/ha). Sprays applied to glasshouse-grown plants both before and after inoculation have been similarly effective, indicating that foliar KCl can have both protectant and curative action. Suppression of septoria on upper, but not lower, leaves has been achieved from sprays in the field at flag leaf emergence, leading to the inference that KCl appears to have a contact rather than systemic mode of action. Experiments with a range of concentrations of KCl in both glasshouse and field have shown that spore germination and leaf area affected by both powdery mildew and septoria are closely related to the osmotic potential of the applied solution. Furthermore, an inert osmoticum (polyethylene glycol) also controlled the diseases and its efficacy was closely related to osmotic potential. Thus it is suggested that the effect of KCl in disease suppression is mediated through an osmotic mechanism. However, in comparisons with conventional fungicides, it has been found that KCl is usually less efficacious. Grain yield has not been significantly ($P=0.05$) increased by KCl in contrast to the conventional fungicides.

Discussion

Since the suppression of disease has not been sufficiently efficacious to lead to statistically detectable yield increases, it is proposed that a cost-effective way to exploit disease suppression by foliar KCl may be through mixtures with reduced rates of fungicides. This would minimise application cost, since no additional spray pass would be needed. The cost of the KCl would be part of the existing fertiliser cost, since the soil application of KCl could be reduced by the equivalent quantity applied as a spray. Conventional timings of fungicides at stem extension and flag leaf emergence would be compatible with potassium uptake by cereals, since most of the uptake occurs in April, May and June (Anon., 2005). Preliminary evidence that combining KCl with reduced rates of fungicides may be efficacious in suppressing disease was found by Mann *et al.* (2004). They showed that control of septoria disease by one quarter of the recommended application rate of epoxiconazole was significantly improved with KCl. Further research would be needed to examine the compatibility of KCl with a range of fungicides, and to determine the cost-effectiveness of this approach to combined disease control and crop nutrition.

References

Anon. (2005). *Potash for Cereals*. Leaflet 11, Potash Development Association, York, UK.

Cook JW (1997). *The effect of foliar applied fertilizers on leaf diseases of cereals.* PhD Thesis, Open University, Milton Keynes, UK.

Fixen PE (1993). Crop responses to chloride. *Advances in Agronomy* **50,** 107-150.

Johnston AE (undated). *Understanding potassium and its use in agriculture*. European Fertiliser Manufacturers Association, Brussels, Belgium.

Kettlewell PS; Bayley L; Domleo RL (1990). Evaluation of late-season foliar application of potassium chloride for disease control in winter wheat. *Journal of Fertilizer Issues* **7,** 17-23.

Kettlewell PS; Cook JW; Parry DW (2000). Evidence for an osmotic mechanism in the control of powdery mildew disease of wheat by foliar-applied potassium chloride. *European Journal of Plant Pathology* **106,** 297-300.

Mann RL (1999). *Suppression of* Septoria tritici *by foliar potassium chloride on wheat.* PhD Thesis, University of Wolverhampton, Wolverhampton, UK.

Mann RL; Kettlewell PS; Jenkinson P (2004). Effect of foliar-applied potassium chloride on septoria leaf blotch of winter wheats. *Plant Pathology* **53**, 653-659.

Effect of weed competition on RUE and leaf distribution of potato

G H Noormohamadi
Faculty of Agriculture, IA University, Science and Research Branch, Tehran, Iran
Email: gnm@yahoo.com

M R Haj Seyed Hadi
Faculty of Agriculture, IA University, Roodehen Branch, Iran

M Nassiri Mahallati
Faculty of Agriculture, Ferdowsi University of Mashhad, Iran

H Rahimian
Faculty of Agriculture, University of Tehran, Iran

E Zand
Weed Research Department, DDPRI, Tehran, Iran

Introduction

Weed density and relative time of weed emergence have impacts on crop-weed interactions. The timing of weed emergence relative to crop emergence is important to crop growth and yield. Weeds emerging before the crop cause greater yield loss, produce more seed and have higher shoot weights and competitive indices. Potato (*Solanum tuberosum* L.) is one of the most important field crops in Iran due its role in providing food and proteins for an increasing population. The area under cultivation and yield of potato are increasing rapidly, and in 2005 about 170,000 hectares were planted and the mean yield was 25 t ha^{-1}. Redroot pigweed (*Amaranthus retroflexus*) and lambsquarters (*Chenopodium album*) are highly competitive weeds that are widely distributed throughout the cropping area of Iran and cause large potato yield losses. There is limited research on competition between these weeds and potato and there are few references to studies of the effects of various weed densities and relative times of emergence on potato. The importance of these species as weeds has been attributed to their strong competitive ability with crops, flexible germination requirements, and high reproductive capacity. The object of this study was to assess the effects of density and relative time of weed emergence of *A. retroflexus* and *C. album* on resource use efficiency (RUE) and vertical leaf distribution of potato.

Materials and methods

Field experiments were conducted at the research station of Seed Potato Production of Iran in Firouzkooh (33° 55' N, 52° 50' E and 1975 m mean sea level) in 2004 and 2005. The soil of the experiment plots was silty loam in texture and of pH 7.6. The experiments were of a split-split plot design with 4 replications. Individual plots size was 3 m wide by 16 m long. Treatments were 2 weed species in main plots (*A. retroflexus* and *C. album*), weed density in sub plots (2, 4 and 8 plant per meter of row) and relative time of weed emergence in sub-sub plots (8 and 4 days prior to potato and the same time as potato emergence in 2004; and the same time as potato, 2 weeks and 4 weeks after potato in 2005). For each year, primary tillage consisted of spring discing followed by field cultivation before planting. Potatoes (var. Agria) were planted at a density of 5.3 plants per m^2 on 26 May 2004 and 27 May 2005. At the 3-4 leaf stage, weed seedlings were thinned and the field hand hoed to remove undesired weeds that had emerged. Two center rows were used for data collection. Potato and weeds were sampled at 2-week intervals. The canopy was divided into vertical 20 cm layers and leaf and stem dry weight, and LAI measured separately for each layer. Vertical distribution of leaf area, LAD (Leaf Area Density) and light interception were recorded and analyzed with the INTERCOM model (Kropff & van Laar, 1993; Nassiri & Kropff, 1997). Daily solar radiation was obtained from Firoozkouh meteorological station. The daily PAR was assumed to be half of the daily global radiation. The absorbed PAR by species in mixed and pure stands was measured at 2 weeks intervals (Keating & Carberry, 1993). The linear regression line between cumulative absorbed PAR and cumulative dry matter was calculated for each plot. The slope of this line is the radiation use efficiency (RUE).

Results and discussion

Results showed that at higher densities of weeds, LAI and height of potato were reduced and the vertical leaf area distribution, LAD and light interception changed. Increases in weed density (from 2 to 8 plants m^{-1} row) and earlier emergence (first emergence time), increased the weed leaf area percentage in the second layer of the potato canopy from 45 to 50%. Maximum weed LAI and LAD were obtained in the upper layers of the canopy. *A. retroflexus* and *C. album* reached their maximum LAD and light interception 55 to 80 cm above the ground, whilst the maximum for potato was at 40 cm. In other words, the weeds, being taller, had significant leaf area above the potato canopy and thus intercepted more light, and consequently reduced potato growth and yield. Results showed that by increasing weed interference, light interception of potato was reduced. So, at 8 *C. album* plants m^{-1} of row, potato light interception was reduced by 43.3 and 53.5%, respectively, in 2004 and 2005. At the same density *of A. retroflexus* (8 plants m^{-1} row) potato light interception was reduced by 56.5 and 66.8% in 2004 and 2005, respectively. Mean potato yield losses were 25.0 and 22.1% for *C. album* and 35.2 and 29.8% for *A. retroflexus* in 2004 and 2005, respectively. The highest potato yield reduction was related to the earliest weed emergence (8 days pre- potato in 2004 and the same day as potato in 2005).

RUE of potato increased 2.8% with 2 *A. retroflexus* m^{-1} of row, in comparison with the control. This means that this weed suppressed potato by shading. In the first and second levels of density of *C. album* (2 and 4 plants m^{-1} of row) results were similar. For other *A. retroflexus* densities, RUE decreased 19 to 33% in comparison to the control. For higher *C. album* densities these reductions in RUE of potato were 1 to 12%. The highest reduction in RUE of potato was obtained with the earliest weed emergence (in 2004: 22.6 and 19.2 and in 2005: 10.8 and 5.1% for *A. retroflexus* and *C. album* interference, respectively). Average of potato RUE was 1.56 and 1.83 g/MJ intercepted PAR (for *A. retroflexus* treatment) and 1.72 and 1.89 g/MJ intercepted PAR in 2004 and 2005. On average, *A. retroflexus* and *C. album* reduced RUE of potato by 10.5 and 4.6%.

References

Kropff MJ; van Laar HH (eds.) (1993). *Modelling crop - weed interactions*. Wallingford: CAB International. 274 pp.

Keating BA; Carberry PS (1993). Resource capture and use in intercropping: Solar radiation. *Field Crops Research* **34**, 273-301.

Nassiri Mahallati M; Kropff MJ (1997). *Simulation model for crop-weed competition, modified for LAD distribution function and extinction coefficient based on leaf dispersion*. Wageningen Agricultural University, Netherlands.

Potential of plastic barriers to control Andean potato weevil *Premnotrypes suturicallus*

J Kroschel, J Alcazar
International Potato Center (CIP), Apartado 1558, Lima 12, Peru
Email: j.kroschel@cgiar.org

Introduction

Andean potato weevils (*P. suturicallus* Kuschel) (APW) are the most serious potato (*Solanum* sp.) pests in the Andes at altitudes above 3,200 m a.s.l. The weevils hibernate mainly in fields previously planted to potato. Adults emerge at the start of the rainy season, remaining in the field if potatoes are re-planted, or migrating to nearby potato fields. Farmers mainly attempt to control APW using several applications of highly toxic insecticides. Due to their lack of knowledge, sprays are often mistimed or the dosage is inappropriate, so losses are still serious. Knowledge of the migratory behavior of weevils has been used to study the effect of planting repellent plants at field borders. Also, spot applications of insecticide granules in ditches around potato fields have been compared to overall application. These studies suggest that, because APWs do not fly, the use of plastic barriers (PB) could be an effective method of control. We tested the hypothesis that PB established at field borders are effective management tools to stop APW migration to potato fields, thereby reducing tuber damage caused by APW larvae. The objectives were to quantify data on potential efficacy in fallow-potato (F-P) and potato-potato (P-P) systems.

Material and methods

The capability of APW adults to climb different heights of plastic was evaluated in plots of 1 m^2 surrounded by PBs 25, 50, and 100 cm high, within which 30 two-day-old adults of *P. suturicallus* were released. The following 3 days the number of escaped weevils was evaluated. The experiment was repeated three times.

Field studies were subsequently carried out in two communities in the Central Highlands of Peru, in Ñuñunhuayo at 3,840 m a.s.l and Aymara at 3,933 m a.s.l. A total of 21 fields were selected, on which potato had either been grown or which had lain fallow for several years (Factor 1: potato after potato (P-P); Factor 2: potato after fallow (F-P)). Four subplots were established on fields with a minimum size of 900 m^2, of which two, size 225m^2 (15 x 15 m), were surrounded by PBs. The plastic was fixed to wooden stakes and extended 10 cm below the surface and 50 cm above soil. The two PB plots were laid out in a diagonal direction taking into account that weevil migration will occur from different directions. The two other plots served as a control and were treated by farmers according to their APW management practice (Factor 3: potato fields with plastic barriers (PB); Factor 4: farmers practice (FP)). FP consisted of several insecticide applications with highly and moderately hazardous insecticides. In P-P fields, in which a higher initial APW infestation was assumed, one insecticide application was carried out in one of the two PB plots. Each on-farm site was treated as one repetition. In each of the two communities, the treatments PB and FP were tested at five sites for each of the factors 1 and 2. Insect catches from pitfall traps in the fields and along the plastic barriers monitored APW migration dynamics and abundance (data not shown). Treatment efficacy was evaluated at harvest by scoring tuber infestation. In each field, a subplot of 5 x 3 m of row with a total of 10 potato plants in each (50 plants per subplot) was randomly selected. The number and proportion of healthy and damaged tubers per plant were determined. Data were subjected to analysis of variance.

Results

PBs at a height of 50 cm were effective in preventing APW migration to potato fields (data not shown). In fallow-potato systems, FP and PB were equally effective at controlling APW. Tuber infestation reached only 9.7% and 9.8%, and 12.4% and 11.1%, respectively, in the two communities (Table 1). In the P-P system tuber damage was higher, especially at Ñuñunhuayo. Here, on FP plots mean tuber damage reached 41.8% (range, 9.4% to 81.1%). PB without insecticides showed a mean tuber infestation of 35% (range, 16.6% to 44.7%). In P-P systems, tuber infestations were significantly reduced in almost all cases where insecticide was applied only once to PB plots instead of 2-4 times to FP plots.

Table 1. Tuber infestation (%) as influenced by farmers practice (FP) and plastic barriers (PB) in individual farm field experiments in two Andean communities and potato systems.

Fallow – Potato system			Potato – Potato system			
	Ñuñunhuayo			Ñuñunhuayo		
Field No.	FP	PB	Field No.	FP	PB I	PB II
F-1	10.6 a	4.4 a	F-3	17.8 b	34.6 a	4.8 c
F-2	1.7 a	10.3 b	F-4	81.1 a	16.6 b	3.7 c
F-5	8.7 a	4.1 a	F-6	9.4 c	42.8 a	26.5 b
F-9	**	**	F-7	56.7 a	44.7 a	9.7 b
F-10	1.9 a	1.2 a	F-8	44.1 a	36.5 a	15.6 b
F-11	25.6 a	28.9 a				
Mean	9.7	9.8	Mean	41.8	35.0	12.1
	Aymara			Aymara		
F-2	29.3 a	31.6 a	F-1	9.1 b	28.5 a	8.9 b
F-3	9.2 a	5.5 a	F-5	0.6 a	0.0 b	0.0 b
F-4	9.0 a	6.8 a	F-8	10.0 a	7.1 a	1.9 b
F-6	8.2 a	7.8 a	F-9	4.4 b	26.8 a	0.6 c
F-7	6.1 a	3.9 a	F-10	9.1 a	10.7 a	1.7 b
Mean	12.4	11.1	Mean	6.6	14.6	2.6

Means with the same letter are not significantly different at $P \leq 0.05\%$. **Missing values.
PB I and PB II: Without/with one insecticide application.

Discussion

In other studies, we showed that fallow areas are not important APW sources, hence our hypothesis that in F-P systems, PBs should reduce APW migration and infestation. Interestingly, most weevils die along the PB because of starvation or natural control by ground beetles (carabids). However, in a few cases (e.g. field F-2) we observed higher infestation in PB plots. To fully avoid migration requires a PB to be installed at the time of sowing or even earlier since weevil emergence and migration may start earlier. To cope with that, a monitoring system for weevil emergence should be established with participating farmers, who are very interested in employing this new and cheap technology. In P-P systems, PBs prevent new migration but the potato fields are already infested. The advantage here is that on FP plots the infestation continues during the potato growing season; in contrast, in PB-protected plots only the initial APW population needs to be controlled. Especially in P-P systems, we found large numbers of carabids. Research will continue to develop synergies between natural control by carabids and the use of PBs. Potato production without insecticides seems to be possible in the Andes above 3,800 m a.s.l where APW constitutes the only economic biotic constraint.

Developing a comprehensive management program for sudden death syndrome of soybean

J P Bond, M E Schmidt, C M Vick, J H Klein, S K Chong, J S Russin
Southern Illinois University, College of Agricultural Sciences, MC 4415, Carbondale, Illinois, 62901, USA
Email: jbond@siu.edu

Sudden death syndrome (SDS) of soybean, caused by *Fusarium viguliforme (=Fusarium solani* f. sp. *glycines),* has become a prominent disease in many soybean production states in the U.S. Infection by the pathogen begins in the seedling stage and continues throughout the growing season. The infection and colonization damages the root system; however it is the foliar phase of the disease that results in severe yield loss. The initial foliar symptoms are intermittent chlorotic spots that begin at or near flowering. As the severity increases, the spots coalesce to form elongated, interveinal areas that become necrotic. In severe cases, defoliation and pod loss occur leaving only a bare stem with upright petioles. (Roy *et al.* 1997). Epidemics of SDS are greatest when soil moisture is high and soil temperatures are low during the early reproductive stages of the plant. The greatest impact of SDS is in north central states with annual yield losses exceeding 2×10^6 metric tons (Wrather & Koenning, 2006).

Identifying resistant varieties in the commercial sector has been a goal of the SIUC program from the arrival of SDS in Illinois. What emerged from this effort was the largest commercial SDS variety trial in the country. A prerequisite to variety evaluation was the development of a scoring system which came to be known as a foliar disease index (DX). Briefly, DX is a function of a disease incidence (DI) score, representing a percentage of plants in a plot expressing symptoms, and a disease severity (DS) score, rated on a 1 to 9 scale. The DS score is assigned as 1 = 0 to 10% chlorosis or 1 to 5% necrosis; 2 =10 to 20% chlorosis or 6 to 10 % necrosis; 3 = 20 to 40% chlorosis or 10 to 20% necrosis; 4 = 40 to 60% chlorosis or 20 to 40% necrosis; 5 = >60% chlorosis or >40% necrosis; 6 = up to 33% defoliation; 7 = up to 66% defoliation; 8 = > 66% defoliation; and 9 = plant death. The DX score represents a scale of 0 to 100, as $DX = (DI \times DS)/9$. The SIUC commercial variety testing effort has helped to identify a number of resistant varieties that are available to producers and served as germplasm for continued breeding efforts. In addition, this program served to measure the progress in the breeding community toward the development of resistant varieties.

Between the years 2000 and 2004, the number of resistant varieties has increased greatly, and the number of highly susceptible varieties has decreased (Table 1). In 2000, 33% of the varieties were classified as resistant or moderately resistant (symptoms <41% of susceptible check) and 67% were classified as susceptible (symptoms >40% of susceptible check). In 2004, 65% of the varieties were classified as resistant or moderately resistant and 35% were classified as susceptible.

Though host resistance has proven to serve as the most effective management tool, cultural practices were identified that help to reduce the severity of SDS. These practices complement host resistance and help fill the void when resistance is not available, especially in the maturity groups 1-3.

Table 1. Reaction of commercial varieties (maturity groups 3 late and 4) to SDS.

Foliar disease class (% of susceptible check)	Percentage of varieties 2000	 2004
Resistant (0 – 20)	13	25
Moderately resistant (21 – 40)	20	40
Moderately susceptible (41 – 60)	21	21
Susceptible (61 – 80)	20	11
Highly susceptible (81 – 100)	26	3

One study has also compared the impact of three soybean planting dates on SDS foliar disease index. Planting dates chosen represented a normal planting date (May 10), a double crop (June 7) and late planting date (June 27). This study revealed that DX was reduced by 50% for the double crop planting date when compared to soybean planted at the normal planting date. Disease expression was reduced by 89% for the late planting date when compared to the normal planting date. The best recommendation is to delay planting fields with a history of SDS until other fields on the farm have been planted.

Soil compaction has been suspected to increase SDS due to its relationship with soil moisture. At two locations, compacted soils were disrupted with either sub-soiling to a depth of 46 cm or by chisel plowing to depth of 25-30 cm in the fall. In the spring, soybean was planted into alternating strips of tilled or no-tilled soil. At each site, foliar disease was reduced by as much as 50% in the sub-soiling or chisel plow treatment, when compared to no-tilled plots.

Winter cover and green manure crops of rapeseed have been evaluated as a means to reduce SDS. Rapeseed was planted into infested fields in early fall and was either incorporated into the soil or killed with glyphosate prior to planting soybean in the spring. A fallow treatment consisted of planting into soybean stubble. Using a cover or green manure crop reduced foliar disease in a stepwise manner at R6 or full seed stage (Table 2). However, only the green manure treatment reduced the AUDPC (area under the disease progress curve) and increased soybean yield.

Table 2. SDS foliar disease and soybean yield as influenced by a winter cover crop of rapeseed.

Treatment	Foliar disease R6 growth stage	Foliar disease AUDPC	Soybean yield (kg/ha)
Fallow (No winter crop)	25.2 a	157.7 a	4,398 b
Cover crop	16.8 b	103.9 a	4,539 ab
Green manure	5.5 c	37.1 b	4,681 a
P > F	*0.0001*	*0.001*	*0.07*

References

Roy K W; Rupe J C; Hershman D E; Abney, T S (1997). Sudden death syndrome of soybean. *Plant Disease* **81,** 1100-1111.

Wrather J A; Koenning S (2006). Soybean disease loss estimates for the United States, 1996-2006 [online]. Delta Research Center, Missouri Agricultural Research Station. Available from *http://aes.missouri.edu/delta/research/soyloss.stm*.

The pesticide environmental stewardship web site

W G Buhler
North Carolina State University, Department of Horticultural Science, Box 7609, Raleigh, North Carolina, 27695, USA
Email: wayne_buhler@ncsu.edu

R Gardner
Cornell University, 5123 Comstock Hall, Ithaca, New York, 14853, USA

J Wilson
South Dakota State University, Box 2207A, Brookings, South Dakota, 57006, USA

C Ramsay
Washington State University, Box 646382, Pullman, Washington, 99164, USA

Project description and goals

The benefits of using pesticides to protect our resources and improve the quality of our lives are widely recognized. To help ensure the safe use of pesticides, farmers, commercial applicators, and homeowners need convenient access to information on proper pesticide handling and environmental stewardship. There is a wealth of pesticide environmental education material available from universities, other state and federal government agencies, and private industry.

However, resources vary widely in level of detail, often do not convey the interrelatedness of stewardship issues and/or refer the reader elsewhere for important information. Persons who search the Internet for more in-depth coverage of stewardship practices may retrieve documents which are out-of-date, redundant, and/or not clearly applicable to their location.

The Pesticide Environmental Stewardship (PES) Web site is being developed as a central repository for detailed, up-to-date information, educational modules, and self-assessment tools on proper pesticide handling and environmental stewardship. The target audience will be anyone who handles pesticides, or who provides advice or training concerning their use, or has concerns about pesticides in the environment. The goals of the PES Web site are to: 1) summarize general principles of pesticide stewardship; 2) direct users to key resources (links), by stewardship topic; and, 3) provide educational modules and self-assessment tools to improve critical thinking and decision-making skills regarding pesticide/non-pesticide options and potential impacts.

The major Web site topics are: 1) protection of groundwater and surface water; 2) pesticide resistance; 3) drift management; 4) protection of non-target organisms; 5) transportation; 6) storage; 7) calibration, mixing and application; 8) cleanup and disposal; 9) integrated pest management; 10) resources and training; and, 11) recordkeeping.

Collaboration

Four coordinators representing the Midwest, Northeast, Southern, and Western US will work with extension, government, industry, commodity associations, and environmental organizations to identify and/or develop the best resources for PES. The coordinators are associated with the US Pesticide Safety Education Program (PSEP). Dr Wayne Buhler serves as the National Scientific Content Coordinator and represents the Southern region.

Dr Jim Wilson, SDSU, represents the Midwest, Ron Gardner, Cornell, the Northeast, and Carol Ramsay, WSU, the West. Each coordinator will be responsible for one major topic per year. The 2007 topics are protection of groundwater and surface water (R. Gardner), drift management (J. Wilson), recordkeeping (C. Ramsay), and storage (W. Buhler).

Project partners include agrochemical industry members of the Center for Integrated Pest Management (CIPM), national grower organizations, and other non-profit organizations. Additional partnerships are being sought with The Pesticide Stewardship Alliance (TPSA), Responsible Industry for a Sound Environment (RISE), and other stakeholders to provide information and editorial support. CIPM, North Carolina Cooperative Extension, the US Environmental Protection Agency-Office of Pesticide Programs (which implements the US Pesticide Applicator Certification and Training Program), and Syngenta Crop Protection have already committed their support to this project. The project personnel will continuously seek inputs from all interested parties and will maintain independence from specific companies, universities, or states.

Web site construction and maintenance

CIPM will program and manage the Web site. CIPM programmers will use dynamic web content, including database-driven testing and XML-data sharing with partners. The PES Web site will be constructed with a database engine that will allow readers to narrow searches based on location, active ingredient, applicator use category, and target. Free-text querying will also be possible. CIPM also will handle all the computer programming and long-term maintenance of the Web site. The PES Web site will be set up to automatically look for dead links at predetermined time intervals (e.g. once per month) and changes could be made accordingly. As a database system, the URL will remain in one place and the site manager can find out where the new URL is located to edit the link.

Web site recruitment and use

Email, printed brochures, and poster presentations at key meetings will inform the intended audience of the availability of the Web site. CIPM will also advertise the educational opportunities through the United States Department of Agriculture's Regional IPM Centers network, which currently receives in excess of two million hits per month. Any organization receiving PES questions or providing education and information (from registrants and Extension to technical service providers, large and small retailers, and hotlines) will be able to direct individuals to the site. Extension and other educators will be able to use this tool as a part of their Pesticide Safety Education Program to support and enhance their current PES efforts. Educational modules will be developed that provide continuing education credits toward the recertification of licensed applicators, or to prepare the user for pesticide licensing exams.

Future impact

The Web site will increase environmental stewardship by providing the tools needed to make individuals more knowledgeable about PES issues and more confident about assessing alternative actions and their impacts. This project will address several educational priorities. It will provide a 21st century prototype for distance learning, and it will address community health issues by its emphasis on minimizing off-target movement of, and exposure to, pesticides through proper stewardship practices.

Web site address: http://cipm.ncsu.edu/pes