Conference report

Summary of outcomes and recommendations from the First International Weed Control Congress, 17-21 February 1992, Melbourne, Australia

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About this document

This "Outcomes Paper" was developed in response to one of the objectives of the First International Weed Control Congress:

"Past achievements in weed research can be reviewed, challenges provided and goals set for future activities".

To ensure as complete an overview as possible, a number of rapporteurs were selected and allocated the task of summarizing the proceedings. These summaries were used by the authors as the basis for the outcomes for each symposium. A draft overall summary of outcomes and recommended actions was then developed by the authors. This draft, together with a summary of each symposium, was then submitted to the co-convenors for their consideration. It is realised that such a paper reflects the bias and shortcomings of the authors. However, due to the review process outlined above it is hoped that these have been minimized.

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Abstract

The key outcomes from the Congress included the need for a single definition for a weed; that efficient weed control has played a major role in ensuring adequate food supplies; that there is a perceived need to reduce our reliance on herbicides; that complementary weed control tactics are needed for this to be achieved; that new herbicides will be more environmentally benign and that minor crops and uses will be disadvantaged by having reduced choice of product; that biological control is a useful tactic but will not dramatically reduce herbicide use; that biology and ecology studies, including weed crop competition, are not well co-ordinated nor directed and are rarely positively incorporated in practice; that there are too little data on the economic and environmental impact of weeds and weed control practices; that the greatest need is for efficient weed control, on a local basis, for developing nations; and that education and training is inadequate in many countries. Recommendations on processes to address these and other 'outcomes' have been developed.

Introduction

The first International Weed Control Congress (February 17–21, Monash University, Melbourne, Australia) was the first truly world-wide conference held on weed control. A total of 536 delegates representing 46 countries was attracted to the Congress which was sponsored by the International Weed Science Society and hosted by the Weed Science Society of Victoria.

The theme of the Congress was **"towards the development of more efficient and effective weed control strategies"** and the program was divided into four major symposia held concurrently.

Each symposium was introduced by a Plenary address and each of the 12 sessions within each symposium began with a review by an established scientist followed by three or four submitted papers and sometimes additional invited speakers. In total there were 53 invited papers, 100 submitted papers and about 60 poster displays.

The Congress also included trade exhibits by equipment manufacturers, agricultural chemical companies and related industries. In summarizing the Congress presentations, the rapporteurs were guided by the objective, "what has been achieved in weed science over the past 50 years, what is the present situation and where should we go in the future", in each of the subject areas discussed.

The Congress was officially opened by Prof. Chester L. Foy, President, International Weed Science Society, who outlined the common goals and objectives of weed scientists on the international scene, and indicated that this Congress had brought together some of the best in the world.

Summary of outcomes and recommended actions

I. There is a need for an agreed single definition for a weed and a categorization process.

Action: The International Weed Science Society to establish a panel to develop both within two years.

II. Weed control practices, particularly the use of herbicides over the past 50 years, have played a major role in ensuring an adequate supply of food, fibre and fuel particularly in the developed nations. This has been achieved with negligible adverse environmental and/or human impact.

Action: The International Weed Science Society to convene a joint Government and Industry panel to develop and distribute literature that advises the public of the achievements of past weed control practices.

III. Most of the 'new' herbicides tend to be more environmentally benign to both humans and other biota, because they target enzyme systems specific to plants. Further, the extensive environmental assessments necessary for registration will make it unlikely that they will adversely affect soil biota or be mobile in the soil. Use of 'natural' herbicides is unlikely to be significant because of the difficulty in obtaining these products and associated registration and development costs.

Action: The International Weed Science Society to initiate a joint Government and Industry panel to develop and distribute literature that ensures that the community and users are made aware of the improved safety of such products.

IV. There is a perceived public need to reduce some users' reliance on herbicides. This will necessitate the implementation of complementary weed control practices such as cultivation, biological control, rotations and grazing. Such practices can be difficult to implement and can lead to increased environmental degradation if care is not exercised.

Action: The International Weed Science

Society to initiate a panel of Government and Industry representatives to develop agreed guidelines and ways of directing funds to projects to ensure that practical complementary (synonyms: integrated or alternative) weed control tactics are developed, extended and introduced by farmers for major crops.

V. Though suggested, it is unlikely that increased emphasis on biological control will lead to dramatic reductions in herbicide use. It is a useful tactic for a limited number of weeds, particularly in environmentally sensitive pasture and rangeland situations. Factors affecting its overall effectiveness include the need to develop complementary management practices, the need for a unified registration process for mycoherbicides, the earlier identification of likely control agents, the need to share information about agents that are useful to other countries, and community expectations that are too high.

Action: The International Weed Science Society to initiate the formation of a Working Group on Biological Control of Weeds to encourage: (i) the development and implementation of a more analytical and structured development and screening process for classical biological control; (ii) the implementation of processes by which biological control researchers share relevant information and develop and extend relevant management practices; and (iii) the development of a unified registration process for mycoherbicides through the newly formed International Bioherbicides Group.

VI. Some argued that many of the studies on the ecology and biology of weeds, including weed and crop competition, are neither well co-ordinated nor directed. Further, the outcomes are rarely positively incorporated in practical control strategies. This conclusion must be of concern in view of the considerable resources devoted to the topic.

Action: The International Weed Science Society to initiate a joint Government (research and education) and Industry panel to review current activities with a view to: (i) establishing a list of projects completed and under way; (ii) establishing a list of future directions with well defined goals: (iii) developing a process for (ii) to be achieved through directed funding.

VII. There are too few data that detail the impact of weeds on humans, other animals and the environment. Further, while studies have shown the benefit, as crop yield gain from weed control, few have converted these into economic terms. The economic and environmental degradation resulting from weed control measures, in the form of soil and water degradation, is one such requirement. Also, the economic and social impact of toxic plants (weeds) to humans needs assessment and the relative energy values of differing weed control strategies will need to be developed.

Action: The International Weed Science Society to establish a panel of Government and Industry personnel to develop a protocol to encourage projects (by establishing specific funding enticements) which assess the economic, environmental and energy impact of weed control options.

VIII. The greatest need is for efficient, effective, economic and environmentally endurable weed control strategies, on a local basis, for people in developing nations.

Action: The International Weed Science Society, through a sub-committee, to stimulate interest in relevant weed control projects through FAO, World Bank, Industry etc.

IX. Changes in weed control practices are reflected by different dominant species; therefore weed control activities are manipulating weed floras, not eradicating them. Future weed control activities should therefore aim to encourage the dominance of the least competitive and easily managed species.

Action: The International Weed Science Society to initiate a panel of Government and Industry personnel to stimulate research which monitors weed floras and manipulates them towards more easily managed species. This would require a redirection of funds.

X. Most markets for herbicides in developed nations are largely mature. Therefore real growth in use will be limited, and changes will mostly reflect the introduction of more environmentally benign herbicides. The most significant growth opportunity is in developing nations where marketing strategies are very different and more difficult than in developed countries.

Action: Industry, through GIFAP, to stimulate a formal meeting with FAO and representatives of governments from developing nations (i) to asses the implications of increased herbicide use, and (ii) to develop protocols for efficient use in such countries.

XI. Education and training of weed control practitioners is apparently declining in most countries. In view of the more complex management strategies required to embrace the public demand for involved complementary weed control tactics that are necessary if reliance on herbicides is to be reduced, this must be a major concern.

Action: The International Weed Science Society should ask regional weed societies to encourage governments to ensure that adequately trained weed extension officers are available to advise weed control practitioners, particularly in countries which promote complementary weed control techniques.

XII. The Weed Science fraternity is too parochial and needs to be encouraged to adopt a more global perspective. This probably reflects the current funding procedures and lack of opportunity to meet with colleagues.

Action: The International Weed Science Society must ensure continued contact between weed scientists from all countries by encouraging further international forums on weed control.

XIII. Weed scientists are too often not working toward, nor extending, solutions for the problems confronting the weed control practitioner.

Action: (i) The International Weed Science Society to encourage all involved in weed science to ensure that their work is relevant to the needs of the weed control practitioner. (ii) Funding organizations to ensure that only projects which are directed toward the solution of problems confronting the weed control, practitioner are funded.

Reports on papers and outcomes from each Symposium

Symposium I. Weed ecology, biology and impact

Session 1 The Plenary Address entitled "Have ecological and biological studies improved weed control strategies?" was presented by Norris (USA). He stated that "knowledge of the biology of plants is the basis for all weed management systems". During the last 40 to 50 years, emphasis has been on herbicide-based weed control programs and most weed biology or ecology research has been directed toward understanding phenomena relevant to herbicide-based control strategies. He then listed many areas of study important to the management of weeds, including taxonomy and identification; morphology and anatomy; physiology and biochemistry; population interference and competition; reproductive biology; dormancy and germination of weed seeds; dynamics of weed seed banks; dissemination, invasion and spread; economic thresholds; genetics and evolution of weeds; allelopathy; and interaction between weeds and other pests. Yet

he concluded that weed biology and ecology studies not related to herbicide use have not been effectively used to improve weed management. Norris offered the following suggestions for future weed science activities:

a) weed science needs to make sure that the public knows what weeds cost them;
b) weed scientists must utilize and extend the present knowledge base. [N.B. This is difficult when certain journals actively discourage the use of references over 10 years old];
c) weed scientists should establish and strengthen research ties with other pest disciplines;
d) weed science needs population dynamics information for major weed species based on outdoor experimentation, including long-term studies;
e) weed science must develop a systems approach to weed management; and
f) weed science should adopt a weed-centred mechanistic approach to research.

He concluded by stating that "a goal for weed management should be to leave less weed reproductive propagules at the end of a cropping cycle than at the outset. This goal can be achieved only if the biology of the weeds is understood and appropriate control strategies developed based on this knowledge."

Session 2 The keynote address was presented by Groves (Australia) who discussed weed ecology, biology and spread. He stated that each weed has some biological attributes that singly or interactively confer ecological advantage over its neighbour. These attributes include seed dormancy, high growth rates, high reproductive output and an ability to disperse widely. He concluded that enhanced weed control practices can be developed when incorporating the results of biological and ecological research. For this to be achieved he suggested that information was needed on the weediness of specific plants in various ecosystems to help develop early control of newly introduced species or to predict weed problems with changes in crop production. In the contributed papers Andreasen *et al.* (Denmark) demonstrated the values of multivariate analysis in relating various edaphic factors to changes in weed flora and Mohammadi (Iran) described the weed flora in forest nurseries of soft and hardwood species.

Session 3 The invited address entitled "Biology, ecology and spread of weeds of temperate crops" was presented by Streibig *et al.* (Denmark). They stated that understanding the biology and ecology of weeds is the first step towards fruitful research in weed science. Basic plant ecology studies of stabilized communities has provided a better understanding of the factors governing the composition and development of plant communities. However, in weed science, we are faced with labile habitats and pioneer species interacting with agricultural activities. Contributed papers supported this principle, either from plant communities (Rashed, Iran; Gerowitt, Germany) or individual species (Carter, Australia) and was further elaborated by Andreasen *et al.* (Denmark) in Session 2.

Session 4 In an invited paper, Horowitz (Israel) discussed the mechanisms of establishment, propagation and dissemination of *Cyperus rotundus*, considered by many to be the worst weed in the world. Establishment of this weed is rapid and its spatial expansion is continuous under a wide range of moisture and temperature conditions. Rhizomes extend in the soil profile and form either tubers in chains or basal buds related to aerial shoots. Tuber sprouting is regulated by apical dominance; dormant buds remain viable in soil for many years. Damage to shoots, tubers or rhizomes triggers sprouting of dormant buds and renewed growth. Wood (Australia) in her contributed paper reported on genetic variation between populations of *Abutilon theophrasti* from six countries using alloenzyme patterns. In contributed papers Pülschen (Germany) described the floristic composition of agrestal species within an altitudinal transect in Ethiopia which showed that African and European species were dominant. Bayliss *et al.* (England) showed that the competitive effect of weeds on wheat is low when nitrogen availability is low and water availability high.

Session 5 (See Plenary Address, Symposium II)

Session 6 In their keynote address Karssen and Bouwmeester (Netherlands) presented data on the seasonal cycles of dormancy and germinability of annual weed seeds under natural conditions. Their relationship to cyclical changes, particularly of temperature, light and nitrate were discussed relative to occurrence of weeds and their control in various crop production practices. This observation, and also those reported in other papers in this session, support the need for further investigations to elucidate the underlying physiological and biochemical mechanisms involved.

Session 7 McIntyre (Canada) provided evidence to show that nutritional factors, especially water and nitrogen, play a major role in inhibiting bud and rhizomes growth of perennial weeds. The data also suggested that the C/N ratio determined whether a bud becomes a shoot or rhizome. However, as emphasized by Norris in his opening plenary address there is a need for such studies to be supplemented by field investigations. McIntyre also stressed the need for studies to elucidate the influence of bud activity on the efficacy of foliar applied herbicides. Other papers in this session presented data from laboratory and field investigations on the physiology and ecology of both terrestrial and aquatic weeds, and discussed the significance of these for the development of more effective control methods. For example, Henskens *et al.* (New Zealand) noted that the reproductive ability of *Achillea millefolium* is high at all but the initial preflowering and pre-seeding stages of development. Pritchard (Australia) showed that root fragments of *Acroptilon repens* could form shoots from at depth of 15 cm and could withstand desiccation for up to three days under certain conditions.

Session 8 Westbrooks (USA) gave an account of the procedures and problems involved in preventing the introduction and spread of noxious weeds in the USA, in an invited paper. He emphasized the importance of preventing their entry, their early detection and eradication. Panetta (Australia) suggested that serious weeds elsewhere should not be introduced, even if they are predicted not to become weedy, due to uncertainty about future climate change. Ransom and Odhiambo (Kenya) showed that maize was more sensitive to *Striga hermonthica* parasitism than sorghum. Schmid (Zambia) found that weed control was one of the most important factors limiting crop production in the semi-permanent and permanent farming systems in Togo. Lane (Australia) described a system to indicate the potential distribution, impact and management options for weeds.

Session 9 (See Plenary Address, Symposium III)

Session 10 In his keynote address Cousens (Australia) pointed out that most weed-crop competition studies had very little influence on weed control practices. However, weed competition data will become important to weed control but information is needed on factors influencing competition for more weed species. Zimdahl (USA), in an invited paper, supported these comments and suggested that future research should emphasize population dynamics of weeds and species comparisons, the effect of the crops on the weeds, and year to year and site to site variability. In other papers a model was presented by Lotz *et al.* (Philippines) to predict yield loss based on relative leaf cover of weeds. Chaudhary and Al-Juwayed (Saudi Arabia) presented information on weed problems in irrigated wheat in Saudi Arabia. Thill and Mallory-Smith (USA) presented results from research on the interaction of nitrogen rate and placement, herbi-

cide type and rate, and spring barley planting density to predict the need for control of wild oats (*Avena fatua*).

Session 11 This session consisted entirely of submitted papers. Neighbourhood analysis was presented as a useful way to measure competitive interactions in a forest ecosystem by Wagner (Canada). A novel use of stem temperature sensors to measure water flow and thus competition for light and water was discussed by Salisbury and Chandler (USA). The method should be of interest to other weed researchers.

Session 12 In an invited paper, Kropff and Moody (Philippines), stated that improved weed management requires a quantitative insight into the crop-weed competition process. Lemerle and Cousens (Australia) showed data on competition between wheat and wild oats as influenced by cultivar, herbicide and environment interactions. Pandey *et al.* (Australia) used a multi-period economic model in an attempt to maximize farmer profit, and reduce herbicide use, for the control of wild oats in small grains. Smith *et al.* (USA) related weed density and weed duration to rice yield. Weed and disease control interactions in *Xanthium strumarium* and peanuts were demonstrated by Brecke and Royal (USA). Their paper showed that cocklebur foliage intercepted the fungicide applied to control *Cercospora* leaf spot thus reducing fungicidal efficacy.

Session 13 (See Plenary Address, Symposium IV)

Session 14 This session consisted of a keynote, two invited and one contributed paper. In the keynote address Koch (Germany) stated that weeds cause food losses of up to 25% in developing countries. Further, in traditional crop production, weed control consumes up to 70% of total labour input. He advocated cropping systems and agronomic practices to replace these labour consuming operations. He thought the introduction of herbicides may also be necessary, but will require appropriate government legislation and education. In an invited paper Towers and Subba Rao (Canada) discussed the weed *Parthenium hysterophorus*, a native species of North America which has invaded Asia, Africa and Australia. This weed is toxic to livestock and causes allergies in humans. Biological control using insect herbivores is under way in India and Australia. The effect of weeds on animal productivity was further discussed by Edgar (Australia) and Dionigi (USA) discussed the impact of microbial weeds on catfish production in the USA.

Session 15 This session covered weed problems in non-agricultural situations. Lonsdale (Australia) stated that management of parks requires knowledge of weed science and the indigenous flora in the area in his invited paper. Crozier (New Zealand) suggested that the best means of controlling unwanted species such as pines is glyphosate though picloram and metsulfuron have also been used when complete deforestation is desired. Mansor *et al.* (Malaysia) reported on a survey of dominant roadside weeds in Malaysia and aquatic weed management was discussed by Bowmer (Australia), who suggested that weeds might be useful to reduce nutrients in water. However, she warned that weeds in aquatic environments may stimulate algae bloom which can be toxic to animals.

Summary of outcomes from Symposium I

(1) The large number of studies on weed and crop competition has had very little influence on weed control practices. This probably reflects an emphasis on single weed/crop interactions whereas in practice a complex of weeds is present.

(2) Future ecological research should emphasise population dynamics of weeds with species comparisons, the effect of the crop on the weeds and year to year and site to site variability.

(3) The models to predict yield losses based on relative leaf area need to be validated.

(4) There is a need to integrate disciplines so that the work on herbicides and ecology have a common focus.

(5) Improved monitoring of new (introduced) weed species is required to ensure action before they become a significant problem. Even so, preventing the introduction of plants into a country, that are weedy elsewhere, is suggested.

(6) More information is urgently needed on the impact caused by weeds, not only to crops, but also to human health, livestock and wildlife. These data need to be presented to the public.

(7) Weed ecology and biology studies need to be directed toward improving weed management by practitioners. In particular, predictions of the effects of changes in management practices on the weed flora, are needed.

(8) The need for more efficient weed control practices, on a local basis, in developing nations was highlighted.

(9) Developing effective weed control plans and strategies in national parks will require ecological knowledge of both native and alien species.

(10) A universal definition of a weed is needed.

Symposium II. Efficient utilization of herbicides

The Plenary Address for this symposium was presented as Session 5 by Evans (England) under the heading "Designing more efficient herbicides." The primary role of the agricultural industry was stated to be "to produce a reliable supply of food for the world's population, safely, and without adverse effects on the environment." Over the past century and more, crop protection chemicals were stated to have played a major role in consistently achieving this objective. The paper addressed the characteristics that will be required in new products for the next century, and illustrated some of the research methodology required to invent them. Evans suggested that the reduction in the amounts of product to a few grams per hectare was a major technological achievement. He also stressed that 'new' herbicides were generally environmentally benign, but the chances of finding new herbicides has lessened.

Session 1 (See Plenary Address, Symposium I)

Sessions 2 and 3 Application of herbicides was well introduced by a keynote address by Göhlich (Germany) and invited papers by Miller (England) and McWhorter and Hanks (USA). They considered the main objectives of good application to be equipment design, minimizing off-target contamination, maximizing biological effects and ensuring human safety. Göhlich discussed the value of drift canopies and air-assist sprayers in reducing drift. The use of herbicides applied in paraffinic oils, with twin fluid nozzles, at volume rates as low as 2.3 L ha^{-1} was shown to control *Echinochloa crus-galli* and *Sorghum halepense*, in an invited paper by McWhorter and Hanks. Some data were presented relating to the influence of adjuvants on efficacy and to rain following applications (James and Rahman, New Zealand). Miller presented data on the performance of spray nozzles and how this relates to the risk of droplet drift. He also outlined a UK project which aimed to target herbicides, on a field scale, by patch and spot application. This was to be achieved by controlling the applied herbicide dose with injection metering of liquid formulations. Other papers in the sessions examined methods by which application techniques could be effectively used to direct herbicides to particular target sites by accurately positioning hydraulic nozzles in relation to crop rows (Harvey and Kleppe, USA) and by using a wiper design to give good herbicide transfer to *Pteridium esculentum* (Hamilton, Australia). Also, Alness (Sweden) described a small plot sprayer that could apply constant, progressive linear, progressive logarithmic or dose changes by steps, and Erasmus (South

Africa) compared formulations and application techniques for the control of *Lantana camara*.

Session 4 The modes of action of herbicides and their associated mammalian toxicity were comprehensively and fundamentally reviewed in the keynote paper by Matsunaka (Japan). Two subsequent papers examined the behaviour of herbicides mixed with other formulations to improve performance either as safeners (Moreland and Corbin, USA) or to take advantage of synergisms to combat resistance or enable overall dose rate reductions (Caseley, England). The dynamic behaviour of two surfactants in explaining droplet retention on leaf surfaces was discussed by Wood *et al.* (Australia). They suggested that dynamic surface tension should give a more reliable indication of retention than static surface tension.

Session 5 (See Plenary Address, Symposium II)

Session 6 The keynote address by Kudsk and Kristensen (Denmark) was a well documented presentation on the factors (temperature, light, humidity, soil moisture, wind) influencing the herbicidal effect of various foliar-acting compounds. The practical relevance of results obtained under experimental conditions when controlling a single environmental factor and extrapolating this to field conditions was also discussed. In an invited paper, Green (USA) described the systematic testing of three sulfonylureas and a range of surfactants, fertilizers and other pesticides. Other papers in this session presented results, using labelled compounds, to demonstrate the effect of light intensity on herbicide activity (Price and Ipor, England), the effects of three organosilicone surfactants (including L-77) on herbicide efficacy (Buick and Field, New Zealand), and the development of an integrated program of herbicide application based on the observation that lower-than-recommended doses may be sufficient to control small weeds of most species (Baldwin *et al.*, USA).

Sessions 7 and 8 In an invited paper, Ferris and Haigh (Australia) reviewed the utility of the CALF herbicide simulation model for improving the safety and reliability of residual herbicides. In other papers, Bhowmilk and O'Toole (USA) reported that nicosulfuron was more efficacious if applied with a nonionic surfactant at low rates but there was no benefit at high rates. Glyphosate was reportedly antagonized more by iron than calcium by Shilling *et al.* (USA). The persistence of atrazine in South African soils was considered in papers by Reinhardt and Nel (South Africa). Blacklow (Australia) found that degradation of chlorsulfuron in acidic sands was due to chemical hydrolysis. Metsulfuron leaching was reported to be better correlated to carbon content than either clay or cation exchange capacity by van Biljon (South Africa). Cultivars of lupins showed differential tolerance to simazine according to Cooper (Australia).

Session 9 (See Plenary Address, Symposium III)

Sessions 10 and 11 In his keynote address, Cussans (England) considered ways of optimizing herbicide use in crops. He considered optimize to mean "reduction in the level of active ingredient to a minimum necessary to meet a defined need by means of integrated approaches." He suggested this to be a laudable aim but that "the subject is more notable for the research to be done rather than for the information that exists." This paper offered little hope for significant reductions in herbicide rates even though in some countries (e.g., Denmark) considerable progress has been made with less than adequate data. In an invited paper by Zedaker (USA), efficient weed control in forests was stated to be limited by inadequate knowledge of crop responses to weed removal, long rotation lengths, complex biota interactions and socio-political pressures to use less herbicide. In one of the contributed papers Noble *et al.* (Australia) reported that fire followed by sub-lethal herbicide treatments had proved to be a promising cost effective control strategy for young coppice regrowth in low rainfall areas. Reynolds (Canada) stated that Canada was committed to an integrated vegetation research program to win over public support. Other contributed papers considered spray topping (Wallace and Maling, Australia) and weed control in sugar cane (McIntyre, Mauritius).

Session 12 In an invited paper, Nalewaja (USA) discussed efficient weed control in wheat and maize on the basis that weed control inputs should provide maximum economical returns in the year of treatment and with consideration of future activities. He found that computer models to predict economic returns were not well accepted and that farmers preferred to use experience to make judgement decisions. He predicted that the introduction of efficient post-emergent herbicides for maize would lead to more economical use. In a contributed paper, Heap and Mitchell (Australia) reported that control of perennial weeds in cereal crops gave no advantage in the year of treatment but significantly improved yields in the subsequent season.

Session 13 (See Plenary Address, Symposium IV)

Sessions 14 and 15 These two sessions dealt with herbicide tolerant weeds. Scalla (France) in an keynote address examined the various physiological and biochemical mechanisms of herbicide resistance. In conditions of selection pressure, nearly all possible mechanisms can be selected, and can even combine sometimes. The recent development of cross-resistance raises the question about the possible role of detoxifying enzymes with broad substrate specificity. In an invited paper Shaner *et al.* (USA) discussed strategies to delay development of resistance to herbicides. They stated that several technical and managerial elements have to be considered. The technical elements include evaluation of the risk of a herbicide to select for resistance, establishment of baseline of resistance in weed populations, and development of detection and monitoring programs.

Nine submitted papers were included in these sessions indicating the tremendous interest in research on herbicide tolerant weeds. Gronwald *et al.* (USA) discussed diclofop resistant *Lolium multiflorum*. This grass species has also shown cross resistance to fluazifop but not to sethoxydim. No difference in absorption, translocation or metabolism was noted so he concluded that diclofop resistance was due to a single nuclear gene exhibiting partial dominance. Multiple resistance was also discussed by Tardif (Australia). Jutsum and Shaner (England) outlined industry's response to herbicide resistance through the Herbicide Resistance Action Committees formed under the auspices of GIFAP, and sub-working groups which recommended and sponsored research and monitoring strategies. Mallory-Smith *et al.* (USA) presented data that supported the hypothesis that sulfonylurea resistance in *Lactuca serriola* and *Kochia scoparia* was caused by altered site of action resulting from mutations. Similar results were discussed by Christopher *et al.* (Australia) who studied sulfonylurea resistance in *Lolium* spp. Itoh *et al.* (Malaysia) discussed paraquat resistance in Malaysia and Davis (Australia) described errors in experimentation programs prior to the confirmation of herbicide resistance in weed species.

There was a great emphasis on models in these sessions, based on resistance patterns. Powles also discussed multiple resistance in *Lolium rigidium* in Australia which has shown resistance to all members of 10 chemical classes due to multiple resistance mechanisms. He pointed out that *Lolium rigidium* is the worst weed of field crops in Australia although it is the most common pasture grass. He called for the adoption of an "Integrated Weed Management System" to prevent a more extensive problem. Papers by Swain *et al.* (Australia) and Christopher *et al.* (Australia) supported this conclusion.

Summary of outcomes from Symposium II

(1) Future herbicides will need to be efficient thus requiring fewer applica-

tions, have flexible use patterns, and have low soil persistence. At the same time they must be environmentally benign by having low resistance and leachability, do no damage to beneficial species and be of low mammalian toxicity. They will be formulated and packaged in a way that enables safe handling and disposal and will be manufactured in a way that ensures they are cheap to market.

(2) Herbicides have played a major role in consistently achieving a reliable, safe and nutritious supply of food over the past 50 years.

(3) Improvements in application technology need to be encouraged to minimize off-target contamination, maximize biological effectiveness and ensure human safety.

(4) In developing countries, efficiency of weed control must be improved to accommodate an increasing population per unit area of arable land. Herbicides will probably be necessary for this to be achieved.

(5) In developed countries, efficient weed control needs to be achieved within the framework of more stringent environmental considerations that reflect perceived hazards from current activities including too great a dependence on herbicides. This is reflected in government regulations (e.g., requiring up to 50% reduction in herbicide rate).

(6) Emphasis should be placed on the development of sustainable systems of agriculture on a regional/local focus in both developing and developed nations. Complementary (syn. integrated) weed management systems will be fundamental to such systems.

(7) Effective strategies to delay the development of weeds resistant to herbicides need to be designed and extended to users.

(8) Herbicide use should be optimized. Knowledge gaps need to be identified and appropriate research initiated to enable users to minimize their use without undue risk to economic productivity.

(9) New herbicides for minor crops and minor uses (e.g., industrial sites, rights of way) will become increasingly rare as the fewer companies involved direct their exploration toward new herbicides for the major markets (e.g., wheat, rice, maize, sorghum, soybeans, sugar-beet, cotton and canola).

(10) No work was presented relating application parameters to herbicide deposits on weeds and the associated control achieved with a range of application conditions. This must be seen as an important omission from the sessions.

Symposium III. Biological and other alternative control measures

The Plenary Address for this symposium was presented by Watson (Canada) as Session 9. He outlined a wide range of available non-herbicide weed control measures. These include hygiene or sanitation, habitat management, physical (hoeing, handweeding), biological control, bioherbicides and grazing systems.

He felt that though herbicide use since the 1940s had brought with it major yield increases, these were not without problems such as herbicide resistant weeds, shifts in weed species, conflict over the use of herbicides (perceived human health and environmental hazards) and reduced ecological and biological research. "Will the future see less reliance on herbicides?" he asked. The best approach will be a combination of herbicides integrated with non-chemical control measures. The choice of method will depend on technology, cultural practices, available resources and farmer preference in a particular situation.

Other points from the address included:

a) To make bioherbicides work well, we need to optimize the interaction between the hosts, pathogen and environment;

b) Manipulative biological control needs appropriate management systems to go with it;

c) For biological control there is a range of problems (issues) which require attention; namely specificity, efficacy, formulation, permanency and adoption;

d) There is a need for complementary tactics, not "alternative" weed control methods. Confrontation between two extremes must be avoided (e.g., the nozzleheads versus ecofreaks);

e) That use of, and dependency on, herbicides would decline.

Session 1 (See Plenary Address, Symposium I)

Session 2 This session dealt with biological control of weeds in the classical sense. In the keynote address by Waage (England) three of the key points to emerge were:

a) Classical biological control of weeds, using insect and pathogen agents, is a successful method with much scope for greater development and for sharing benefits between countries;

b) Support for classical biological control is limited by its long development time and requires considerable promotion with sponsors;

c) Selection of the best agents early in a program would realise substantial economies, but will not come through rules based on ecological theory. Rather it must involve development of experimental methods and models for weed population ecology which can be applied to each case to evaluate the potential impact of particular agents.

In his contributed paper Wapshere (Australia) concluded that ecoclimate is the most suitable method to assess the effectiveness of a biological control agent. Cullen (Australia) noted that current prediction systems are not sufficiently robust and that more ecological principles need to be incorporated into the assessment. Dennill *et al.* (South Africa) reported on the expansion of the host range of an introduced biocontrol agent for the control of *Acacia longifolia*.

Session 3 In his invited address Ooi (Malaysia) reported that weed control in Malaysian plantations has been dominated by herbicide use, but in recent years this has led to a range of problems and biological control methods are now being investigated. For example, *Cordia curassavica*, a weed of plantations, had been successfully suppressed with two classical biological control agents. Potential agents for other weeds are under consideration. In contributed papers, Campbell and Wykes (Australia) reported some success with native insects controlling native weeds if transmitted by humans. Shepherd and Morley (Australia) suggested that low winter temperatures may be the cause of the failure for an introduced moth to persist on *Echium plantagineum*. Similar findings were reported by Dodd (Australia). A method to detect virulent specific strains of rust fungi was described by Chaboudez *et al.* (France) and two potential pathogens for the control of *Heliotropium europeum* in Australia were reported by Hasan (France).

Session 4 Center (USA) reviewed progress towards biological control of *Hydrilla verticillata* (hydrilla), *Pistia stratiotes* (water lettuce) and *Melaleuca quinquenervia* (broad-leaved paperbark) in his invited paper.

In a contributed presentation, Balciunas (Australia) described attempts to find suitable agents of Chinese origin to control the aquatic weeds *Hydrilla verticillata* and *Myriophyllum spicatum*.

Session 5 (See Plenary Address, Symposium II)

Session 6 The theory and successes in bioherbicide research were presented in a keynote address by Templeton (USA). The commercialization of a rust pathogen to control yellow nutsedge in the USA (Phatak) and the possible use of microbial facilitators naturally occurring on the phylloplane of weeds to enhance bioherbicide efficacy by Schisler *et al.* (USA) represent new research avenues with great potential. Makowski and Mortensen (Canada) reported on the discovery, development, commercialization and recent registration of 'Biomal', the first

Canadian mycoherbicide. Such a success will renew, stimulate and/or support interest in bioherbicide research.

Other important issues in the session discussed the potential of using bioherbicide technology in developing countries, the difference between bioherbicide and natural products having herbicidal activity and the possible development of multi-target bioherbicides. The International Bioherbicide Working Group, which has recently been established, was said to have a mandate to improve communication and collaboration between researchers involved in bioherbicide research. This Group will have considerable impact in promoting the use of plant pathogens to control weeds.

Session 7 The first part of this session comprised an invited paper by Auld (Australia) on the development and commercialization of biological control agents. The importance of patents and the development of efficient systems to mass produce and formulate the micro-organisms were emphasized. Formulation of biological products represents a key factor in the successful development of reliable and efficient bioherbicides. More research on formulations was supported to improve efficacy under stressful environments and to enable a reduction in spore concentration.

The use of grazing animals for biological control of weeds was discussed in an invited paper by Popay and Field (New Zealand). The efficacy of a range of animals as biocontrol agents in various agricultural systems was considered. The importance of fencing to assist and improve this weed management practice was briefly discussed. Grazing animals are unfortunately overlooked as biocontrol agents and more co-ordination between weed control measures involving insects, plant pathogens and animals is required.

Session 8 Free Session

Session 9 (See Plenary Address, Symposium III)

Sessions 10, 11 and 12 These sessions explored alternative control methods and included a keynote address by Hurle (Germany), invited papers by Akobundu (Nigeria) and Morgan (Australia) and 12 submitted papers.

Hurle stated that environmental issues and increased public concern about the use of agricultural chemicals has highlighted the need to reassess mechanical weed control methods. The practicality, strengths and weaknesses (advantages and disadvantages) of several alternatives to herbicides were presented. A range of new generation cultivation equipment was shown and its effectiveness for weed control and effect on soil structure and degradation was reported briefly.

Akobundu stressed the need for weed management systems that reduce soil degradation, such as the use of live mulch, in-site mulch, and systems based on legumes and non-legume plants.

In a contributed paper Matic and Black (Australia) found that a combination of spray topping with paraquat, followed by diuron and trifluralin at pre-planting reduced the numbers of *Vulpia fasciculata* by 99%. Müller-Schärer *et al.* (Switzerland) found that *Lolium perenne* suppressed weed growth and reduced insect attack in field-planted leeks. Kon *et al.* (Malaysia) described the use of low rates of herbicides, legume mulches and manual weeding for alley-cropping systems.

In an invited paper Morgan stated that "while there are strategies to reduce herbicide use, they are few and are usually weed specific." It is recognized that an integrated approach to weed control involving efficient herbicide use with various weed management strategies will be the first step in reducing dependence on herbicides.

The integrated use of shading, narrow row spacing, cultivation and herbicides for weed control in corn and soybean was described by Knake (USA). Labrada (FAO) outlined the main weed problems in the tropics and sub-tropics and outlined proposed programs to control them. He concluded that education of farmers was critical to the success of such programs. Enache *et al.* (USA) reported on work that is evaluating the potential of *Trifolium subterranean* as a living mulch. Weed control in 'organic' arable crops comparing mechanical cultivation in the crop, increased crop sowing rates, different row spacings and growing mixtures of crops was reported by Popay *et al.* (New Zealand).

Session 13 (See Plenary Address, Symposium IV)

Sessions 14 and 15 The main point coming from the keynote address by Marshall (Australia) was that good weed control was not of prime importance in 'organic' farming, nor was it possible that cultivation, with a variety of implements, was the only method that could be used. Unfortunately, no crop production data were presented to indicate the significance of this (e.g., to see if other factors might compensate for this lack of control). Also the question of feeding the increasing world population appeared to be of little concern.

The effects of various forms of mulching were reported on by a number of speakers (Worsham and Blum, USA; Teasdale and Mohler, USA; Frans and Semidey, USA; You, China) covering temperate areas in developed and developing countries while one invited paper (Wells, Australia) and one contributed paper (Rizvi, India) covered tropical areas in developing countries. In temperate areas, weed control by cereal (e.g. *Secale cereale*), clover (*Trifolium subterranean*), sunflower (*Helianthus annus*) and hairy vetch (*Vicia villosa*) mulch was attributed to allelopathic effects but was not adequate for optimum yields and follow-up herbicides were considered necessary. Ascribing these effects to allelopathy only was not convincing and other effects of the mulch might have been considered.

Wells, in an invited paper on tropical areas, reported that undisturbed legume crop residues (*Vigna* spp.) provided effective weed control which, combined with N input, substantially increased upland rice and corn yields. He also suggested that seasonal labour shortages in some regions were major problems for both weed control and crop establishment in traditional systems resulting in decreased yields. Lack of herbicide availability in these situations (from poverty, lack of foreign exchange or mistrust of the technology) puts considerable pressure on women and children who do most of the weeding.

The main point arising from the invited paper by Duke (USA) was that although naturally occurring molecules have yielded some potential herbicides, little improvement can generally be expected from further development owing to the already complex and possibly optimal configuration arrived at after thousands of years of evolution. One of the contributed papers in this symposium (Thompson *et al.*, Canada) defined the weed problems of Canadian forests and therefore seemed a little out of place. However, an interesting mix of integrated control measures was described.

Summary of outcomes from Symposium III

(1) The need for complementary (syn. integrated) weed management systems was emphasized using a range of measures. From the reports, research resources are being directed to developing such systems.

(2) To make the most effective use of bioherbicides the interaction between host/pathogen/environment must be optimized.

(3) Biological control is a successful weed control method with much scope for greater development particularly by sharing information between countries.

(4) Support for classical biological control is limited by its long development and establishment times and therefore requires considerable promotion with funding bodies. Speedier selection of the best agents for a program and the development of a screening process to reduce 'ineffective' releases is necessary. This would realise substantial economies and thus encourage more support.

(5) The recently established International Bioherbicide Group needs to ensure improved communication and col-

laboration between researchers and marketers. It also needs to develop uniform guidelines for the issuance of patents; efficient systems to mass produce and formulate micro-organisms and for the registration of products.

(6) Good weed control was considered by some not to be of importance to 'organic' farming. This may have serious consequences for the increase and spread of noxious weed species.

(7) Allelopathic crops and 'weeds' appear not to give adequate control and follow up by another weed control technique is necessary.

(8) Research on complementary (syn. alternative) weed control practices should involve farmers early in the development of new practices if they impinge on farm operations.

(9) Grazing animals as biological control agents have largely been overlooked and yet offer a valuable complementary control measure.

(10) Commercialization of natural chemicals as herbicides appears to be very speculative.

(11) Mechanical control of weeds appears possible in some circumstances. However, the effect of such practices on crop yields and soil degradation require further research effort.

Symposium IV. Herbicide development and marketing weed control

The Plenary Address "Herbicide Development and Marketing of Weed Control in the USA" was presented by Ellis (USA) as Session 13. He reviewed the development of chemical weed control from 1945 to the present time. He felt that the enthusiasm for, and success of, 2,4-D fuelled the search for other synthetic herbicides. By 1980, 90–95% of the cropland planted in the USA was treated with herbicides, with corn and soybeans accounting for 80% of the USA herbicide market. Herbicides have proven to be economically beneficial and critical for high production agriculture. He also reviewed the evolution of regulatory legislation over the years with the creation of the EPA and the FEPCA, both of which have been very costly to the agrichemical industry. Registration costs and development time has soared and fewer products are being discovered. In the long term, this could be devastating to industry and have serious effects on product availability for crops grown over limited areas.

Session 1 (See Plenary Address, Symposium I)

Session 2 In the keynote address, Beyer (USA) stated that the number of chemicals that must be synthesized and tested to find a new product has gone from 15 000 in the 1970s to about 40 000 today. The time required to reach the marketplace now averages 8 years and the cost of developing a new product has risen to about US$50 000 000. Thirteen agricultural companies now account for 80% of the US$26 billion world-wide agrichemical market of which 44% is for herbicides.

Wilcox and Taylor (USA), in a contributed paper, outlined the activity of fluometralin, the only commercial herbicide containing a second ring in addition to the dinitroaniline ring. It shows promise for weed control in citrus and ornamentals.

Session 3 In a submitted paper, Wardle and Rahman (New Zealand) stated that soil biomass comprises mostly bacteria and fungi and can be used as a useful indicator of the level of effects of herbicides on the ecosystem. Landes *et al.* (Germany) described quinclorac, a new rice herbicide, which is selective under various cultural conditions. It has a broad spectrum of grass control activity at 0.25 to 0.5 kg ha^{-1}, either pre- or post-emergence, to the rice crops. Yelverton *et al.* (USA) showed that napropamide and sethoxydim were effective in controlling broadleaf and grass weeds in tobacco seedbeds. They suggested that these herbicides should provide a suitable weed control system to replace methyl bromide fumigation. Pruss and Johnson (USA) reported that a soil applied organic phosphate insecticide can have antagonistic effects on corn treated with primisulfuron; the corn can be severely injured and yields reduced.

Session 4 The invited paper presented by Plumbe *et al.* (France) discussed herbicide development for weeds in temperate crops with wheat, maize and oilseed rape as examples. The contribution of herbicide chemistry in these crops since 1960 was reviewed in the context of changing cultural practices and the appearance of resistant weed species.

In a contributed paper Rahman *et al.* (New Zealand) reported that clopyralid and dicamba caused little effect on the quality and production of asparagus but glyphosate caused severe damage and amitrole was intermediate in effect.

Porpiglia and Gillespie (USA) discovered that there is no correlation between the growth rate of maize and the degree of tolerance to primisulfuron. A bioassay technique, called "principal component analysis", was developed to measure corn variety tolerance to primisulfuron and 2471 corn lines had been tested with this technique. This has reduced the number of commercial complaints. Peek and Kupatt (USA) presented a paper on the successful development and introduction of primisulfuron, and the chemical and biological characteristics were explained. This herbicide reduces populations of *Elytrigia repens*, *Sorghum halepense*, and *Sorghum bicolor*. No resistance to primisulfuron has been reported to date.

In a paper on spray topping of wild oats (*Avena* spp.) in wheat, Medd *et al.* (Australia) showed that seed production could be reduced by up to 99% by applying fenoxaprop-ethyl and flamprop-methyl during the reproductive phase of the weed growing in the crop.

Session 5 (See Plenary Address, Symposium II)

Session 6 In the keynote address, Hooper (Australia) surveyed the registration challenge to meet demands of users (farmers), chemical companies (registrants), environmental activists and consumers of end products (food etc.). He urged more international co-operation in the sharing of technical information and harmonizing of regulation requirements.

In an invited paper, Dalling (Australia) discussed the development of crops resistant to herbicides. Such crops offer several advantages: reduction in total herbicides used; reduced cultivation; more effective weed control including the possible use of new generation, low use-rate herbicides.

Problems include the fact that market niches for many such crops are very small, farmers may resist purchasing twin packages of herbicides and seed, and the product may not always be cost effective. He also discussed the agronomic requirements of such crops.

Green (USA) showed that DPX-E9636 and nicosulfuron provided more effective weed control in corn when applied in multiple post-emergence applications rather than one.

Chun and Shin (Korea) described how the use of herbicides in Korea has caused a shift from annual to perennial weeds which then became serious problems (e.g., *Eleocharis kuroguwai*). The authors reported that bensulfuron-methyl suppresses the vegetative stage of this weed for 30–40 days but then growth returns to normal.

Session 7 Jordan (USA) in an invited paper stated that CAST's role was to communicate the 'science' of agriculture to the 95% non-scientists in the population in a way that is understandable and believable. "We (the USA) have the safest, least expensive, healthiest food in the world. However, a relatively small group of popular activists (movie celebrities etc.) continue to persuade the public otherwise." CAST aims to reverse the tide through education at all levels (schools, political etc.).

In a second invited paper, Matthews (Australia) discussed methods of improving the safety of herbicides to the environment. Methods include new techniques of formulation (encapsulation, water soluble bags, tablets, etc.) and new application methods (direct injection to spray boom, closed systems) which will reduce exposure to the applicator and reduce the risk of environmental contamination.

Exposure to pesticides was further discussed by Lavy *et al.* (USA). They suggested that the chance of exposure to pesticides is very low to the general public, but much higher to the applicator. Among applicators, dermal exposure accounts for 85–99% of absorbed toxicants, inhalation 0.1–15% and ingestion 0.001–5%. Chemical monitoring confirms that training reduces applicators' exposure. The effectiveness of ethidimuron for the control of brush on grazing land was discussed by Fourie (South Africa) who found that carrying capacity (animals) and the yield of grass can be doubled following treatment.

Session 8 In an invited paper Moody (Philippines) discussed efficient herbicide use in tropical crops. He pointed out that herbicides are not widely used and hand weeding is still the norm. He stressed the need for companies to be mindful of the social implications of herbicide use. Herbicides used tend to be the least expensive and concentrated formulation. Further, application is primitive, innovative and yet effective. Lack of training and education leads to non-performance and/or crop injury. Training needs to be simple, fundamental and useful by people with very limited resources and education.

Azmi *et al.* (Malaysia) reported that in rice growing areas there has been a gradual shift from easy-to-control broadleaf weeds and sedges to difficult-to-control grasses, including several strains of *Echinochloa crus-galli*. Baki and Azmi (Malaysia) discussed various weed control programs for rice; the main culture discussed was dryland hill top rice where water management is less than satisfactory.

Session 9 (See Plenary Address, Symposium III)

Session 10 This session covered environmental issues and reducing herbicide misuse and included four keynote addresses. Graham-Bryce (Netherlands) presented an industry viewpoint. His key points were: industry is part of society which has a commercial incentive and has contributed significantly to environmental protection; industry supports cost effective, reliable and scientifically based evaluation of hazards; the existing well established tiered approach to evaluation needs further international harmonization; it is difficult to establish good indicators for environmental impact; good product stewardship is important while the product is in the marketplace; industry does not want arbitrary targets imposed which are not supported by science (e.g., EEC drinking water limits for pesticides); and objectives of industry and science are compatible. Public confidence can be built through good communication programs.

Blesing (Australia) discussed the role of the farmer in environmental responsibility from three aspects: sustainable cropping (rotations, genetically diverse crops; meeting the needs of soil capability; shallow or deep rooted crops; annuals or perennials etc.); conservative land management (trees on recharge areas, waterways, farm planning etc.) and fertility maintenance (grain protein, soil structure etc.).

Alexandra (Australia) in discussing consumer concerns suggested that: consumer confidence has been eroded by failures in regulatory systems (e.g., organochlorine in meat); more information is needed on the long term impact of herbicides on soil, and that there are very few soil ecologists to do this work; government has a role in funding biological control as it benefits the whole community; weeds may be messengers of a problem in the ecosystem (e.g., an excess of nitrogen), we should fix the system rather than shoot the messenger; and there is increasing consumer concern at the possible contamination of groundwater by pesticides.

Finally, Lloyd (Australia) outlined the government's responsibility for weed control. These include: quarantine; provision for information on weed control to encourage good farming practice; to encourage biological control research to help reduce use of chemicals; to ensure chemicals are tested for safety and effectiveness before they are released, and to require adequate labelling of products with use and safety requirements. This, he pointed out, must be balanced against government's responsibility to encourage food and fibre production for domestic and export markets, and not to impose undue cost burdens or unnecessary use restrictions on weed control.

Session 11 – Media event This was organized to enable a panel of three main media representatives to question a panel of 'experts' on the following topics:

* Public perception of pesticide use
* Opposition to genetic engineering by the environmental movement
* General image of weed science - low profile of scientists
* Impact of weeds in developing countries
* Regulatory standards in developing countries
* Herbicide residues, contamination of water table
* Biological control in national parks.

The event was generally regarded as a valuable experiment which provided a good forum for rational debate on a range of contentious topics.

Session 12 Appleby (USA), in an invited paper, discussed extension and education in relation to herbicides. The following needs were identified: research, extension and teaching must be brought closer together; closer relationships are needed between government and industry; avoid management by slogans (danger of fads taking over from science); more funding is needed for non-chemical work and for research into local problems; wider involvement in weed management decisions and better understanding of decision making process and better communication with the general public.

Education and training in herbicide use in Australia was discussed by Kent (Australia). He reported that courses have been developed co-operatively by the Agriculture and Veterinary Chemicals Association (AVCA), National Farmers' Federation (NFF), the Rural Training Council and Technical and Further Education (TAFE).

Jellinek and Joannides (Australia) in an invited address discussed the role of the field communicator. They felt that farmers need someone who sees the whole picture, whom they can trust and provide links to various information sources. Various community based link models were presented. The issue of on-going funding for the link person was not resolved.

Mitchell (Australia) discussed the roles of government agencies and the public in developing awareness to aquatic weeds. The public is important in ensuring early warning and low cost monitoring of infestations.

Session 13 (See Plenary Address, Symposium IV)

Session 14 This session covered the subject of herbicide marketing. In the keynote address Jackson (USA) stressed that changes in the marketplace challenge us to become more creative and effective marketers. Schmidt (Germany) and Campiranon (Thailand), in invited papers, discussed the development and marketing of herbicides in developing countries. As these countries are unique, strategies that have proved successful elsewhere may not guarantee the same success in developing countries.

Session 15 Free

Summary of outcomes from Symposium IV

(1) There is a need for international co-operation in sharing technical information on herbicides and for harmonizing registration requirements.

(2) Continued improvement in herbicide formulations and application methods are needed to reduce applicator exposure, reduce risk of environmental contamination and maximize product performance.

(3) Care must be exercised in translating results from laboratory and greenhouses to field conditions.

(4) The development and marketing of herbicides in developing nations are unique and require a different approach to that in developed nations. Environmentally safe products that

can be applied with innovative yet primitive application equipment are necessary.

(5) The herbicide market in developed nations is virtually 'mature', therefore, future growth will mostly occur in developing nations.

(6) New 'herbicides' will be more environmentally benign and will gradually replace existing products in the developed nations.

(7) Increased regulatory legislation has been costly to manufacturers and is resulting in fewer products. In the medium to long term this could be devastating to minor crops or limited use areas.

(8) The development of crops resistant to herbicides offers several advantages, e.g., reduction in total herbicide used, reduced cultivation, more effective weed control and the use of new environmentally benign herbicides.

(9) Farmers in the developed nations must accept their share of environmental responsibility by using sustainable cropping systems that conserve land and maintain fertility.

(10) Consumer confidence about herbicide use has been eroded by failures in the regulatory system, and the perceived lack of long term studies on residues.

(11) Weeds should be recognized as messengers of problems in ecosystems.

(12) Closer relationships are needed between government, industry, users and consumers to allay fears about the environmental impact of weed control practices.

(13) Implementation of practical complementary (syn. integrated or alternative) weed control techniques by weed control practitioners is necessary in both the developed and developing nations. This will require a range of extension and education activities, on a local basis, through joint meetings between industry, government and clients.

Wednesday - three activities

(1) Special Plenary Address The Plenary Address by Combellack (Australia) was entitled "The Importance of Weeds and Ways of Reducing Concerns about Methods for their Control." This address included a brief history of weed control practices, definition and classification of weeds, and various weed control strategies. He then assessed the weediness of two plants, *Avena* spp. (wild oats) and *Pteridium* spp. (bracken) based on their morphology, reproduction and spread, taxonomy, seed dormancy, seedling establishment and phenology, management and control, and their negative and positive contributions. He concluded that bracken, because of its toxicity and its weediness in a wide range of land use situations, is probably a worse weed than wild oats. He pointed out that over 2000 papers have been written on wild oats, about five times more than on bracken, and yet the latter was equally well understood. He also discussed the consequences of weeds in general and their impact on availability of food, fuel and fibre, and the crucial need for efficient, effective, economical and endurable weed control strategies for developing countries. The relationship between weed control activities and soil degradation was also briefly considered, as were residues in food, water, air and soil, and he proposed alternative strategies based on reduced herbicide inputs. Also highlighted was the need for a consideration of the energy inputs and outputs from various weed control options. The following were some of the conclusions:

* Weed science has provided weed control practitioners with a range of efficient, effective control strategies;
* Biology and ecology studies are considered far too specific and short term, and relate mostly to annuals;
* The need for efficient, effective, economical and endurable weed control for developing nations is crucial;
* Weed science must assess the energy value of its activities;
* Clear 'best-bet' strategies for individual species need to be developed;
* People should recognise that they are manipulators not eradicators of weeds;
* The public must be given a more balanced perception of herbicide use;
* Weed science should agree on a single definition of a weed and categorization process;
* The interaction between soil degradation and weed control practices needs investigation.

(2) Poster Displays Approximately 50 posters were displayed for viewing on Wednesday, Feb. 19, 13.30-17.00 pm. Due to the diversity of topics and methods of presentation, no attempt is made to summarize this portion of the Congress.

(3) Trade Displays The Congress included trade exhibits by equipment manufacturers and related agricultural industry. There was ample time to visit these displays and to seek additional information from personnel associated with the displays. Many of the industries exhibiting trade displays were also sponsors of the Congress.

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