

# IPPS

The International  
Parasitic Plant Society

## Proceedings of the 8<sup>th</sup> INTERNATIONAL PARASITIC WEEDS SYMPOSIUM

In collaboration with the  
4th International Weed Science Congress (IWSC)

Durban (South Africa), June 24-25, 2004

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The 8<sup>th</sup> International Symposium on Parasitic Weeds  
International Convention Center, Durban, South Africa  
24-25 June 2004

## FOREWORD and ACKNOWLEDGEMENTS

The Durban Symposium on Parasitic Weeds, organized by the International Parasitic Plant Society (IPPS) is the 8<sup>th</sup> in a series of international meetings dedicated to this special group of plants that has a tremendous impact on world agriculture and forestry. We are pleased with the relatively large number of contributions to this Symposium that together gave updated reports on the achievements in many different aspects of parasitic weed research, including basic aspects like host-parasite interaction and biodiversity, and more applied aspects that relate to parasitic weeds management.

We are grateful to the organizers of the 4<sup>th</sup> International Weed Science Congress (IWSC), and in particular to Baruch Rubin and Charlie Reinhardt who so kindly agreed to have the Parasitic Weeds Symposium as a satellite meeting at the same venue, and helped with linking the Congress sessions on parasitic weeds with our Symposium. This allowed IWSC participants to take part in presentations and discussions during our Symposium, and exposed the parasitic weed researchers to the broader scope of weed science.

Much work was done in the development of the Symposium Program, and the Symposium happened to be a great success thanks to the efforts put by members of the International Scientific Organizing Committee, who reviewed all abstracts and helped in the decisions behind the formation of the final program.

The Executive committee of the IPPS started organizing the Symposium as early as January 2003, but all technical issues could be finalized only shortly before the Symposium. We owe special thanks to the Committee Members Jim Westwood and Jos Verkleij for their continuous involvement in the decisions behind the meeting.

We wish to thank Chris Mulder, Chairman of the local organizing committee of the IWSC, for his support in providing the venue. The International Convention Center (ICC) was an important partner in the success of the meeting. We thank the Congress Secretariat, and in particular Gill Slaughter and Kerry de Lange, for their kind help in all aspects of local arrangements.

Unfortunately Durban did not prove to be a safe place. We extend our best wishes to all Congress participants who were hurt while walking in the city.

And last but not least, we are grateful to all Symposium Participants for their contribution, both in scientific presentations and in fruitful discussions. They were the actual key to the success of the Symposium.

Danny Joel

25 June 2004

**Detailed program – Thursday June 24****IWSC Plenary lecture**

8:00 – 9:00	DM Joel	The parasitic weeds problem and its fate in the 21 <sup>st</sup> century
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**Progress in parasitic weed research .** Chair: DM Joel, F Kanampiu, P Westernman

9:00 – 9:30	J Ransom	New methodologies for the management of parasitic weeds
9:30 - 10:00	P Westerman	Demography of parasitic weeds and its impact on management
10:30 - 11:00	G Ejeta	Understanding key developmental processes in parasitic weeds
11:00 - 11:15	J Westwood	Manipulating host defences to enhance resistance to <i>Orobanche</i>
11:15 - 11:30	B Rubin	EPSP-synthase presence and activity in broomrape
11:30 – 11:45	K Yoneyama	Determination and quantification of strigolactones
11:45 – 12:00	D Müller-Stöver	Enhancing the efficacy of a fungal biocontrol agent against <i>Orobanche</i> through combination with resistance-inducing chemical
12:00 - 12:15	B Abu-Irmaileh	Manure fermentation reduces <i>Orobanche</i> infestation on tomato
12:15 - 12:30	JH Grenz	Evaluating strategies to control the parasitic weed <i>Orobanche crenata</i> – a simulation study using APSIM

**Workshop on Striga management.** Chair: J Ransom

16:30 - 16:45	Emechebe	Ways to manage <i>Striga</i> infestations without herbicides
16:45 - 17:00	B Haussmann	Arresting the scourge of <i>Striga</i> by combining marker-assisted backcrossing and farmer-participatory selection
17:00– 17:15	J Rodenburg	Yielding ability, resistance and tolerance as independent selection criteria for breeding against <i>Striga</i>
17:15 – 17:30	Gworgwor	Systems approach for ecological management of <i>Striga</i> in cereal-based cropping systems in northern Nigeria
17:30 – 17:45	Reinhardt	Prospects and limitations for <i>S. asiatica</i> control in sorghum/desmodium intercrop
17:45 – 18:00	VW Lenzemo	Field inoculation with arbuscular mycorrhizal fungi reduces <i>Striga</i> performance on cereal crops and has the potential to increase cereal production
18:00 - 18:15	H Traoré	Pathogenicity of <i>Fusarium</i> spp. isolates and metabolites to <i>Striga hermonthica</i> in Burkina Faso
18:15 - 18:30	A Murdoch	Linking laboratory and field studies of dormancy in <i>S. hermonthica</i> : is delayed planting an option for integrated control?

**Friday June 25****Genetic variation in parasitic weeds.** Chair: J Verkleij and B Roman

8:00 - 8:20	J Westwood	ISSR characterization of <i>Orobanche minor</i> populations in the U.S.
8:20 - 8:40	B Roman	Biodiversity of <i>Orobanche crenata</i> in the Mediterranean region (review)
8:40 - 9:00	B Haussmann	Genetic variability of <i>Striga hermonthica</i> (review)
9:00 - 9:20	M Timko	Genetic variability and host specialization in <i>Striga gesnerioides</i>
9:20 - 9:40	J Verkleij	Analysis of genetic variability in the closely related species <i>S. hermonthica</i> and <i>S. aspera</i> by RAPD and SCAR markers

**Physiological and molecular aspects of parasitic plants (I).** Chair: K. Yoneyama and J Westwood

10:30 - 10:50	SF Shamoun	Tissue culture of western hemlock dwarf mistletoe ( <i>Arceuthobium</i> )
10:50-11:10	WJ Zhou	Callus production of <i>Orobancha</i> and its novel aseptic infection on host roots
11:10 - 11:30	G Glatzel	Active vs passive mineral nutrient uptake in mistletoes– a still unresolved question?
11:30 - 11:50	D Cameron	Using the broad-spectrum hemi-parasitic angiosperm to investigate compatible and incompatible interactions
11:50 – 12:10	M Timko	Mapping and cloning of race-specific resistance genes to <i>Striga gesnerioides</i> and <i>Alectra vogelii</i> in cowpea
12:10 – 12:30	R Dorka	Endogenous rhythms of nutational movement in <i>Viscum album</i> l. correlates with high level of jasmonic acid

**Physiological and molecular aspects of parasitic plants (II).** Chair: G. Ejeta and M. Timko

14:00 - 14:20	Y Takeuchi	Fluridone promotes conditioning and germination of parasitic weed seeds
14:20 - 14:40	G Gbèhounou	Seed germination of <i>Rhamphicarpa fistulosa</i>
14:40 – 15:00	G Dinelli	Germination ecology, emergence and early host parasitization of <i>Cuscuta campestris</i> Yuncker
15:00 – 15:20	H Eizenberg	Growing degree days - a predictive tool for <i>Orobancha</i> parasitism
15:20 – 15:40	M De Mol	Water relations and development of the European mistletoe <i>Viscum album</i>

**Parasitic weeds control.** Chair: F. Kanampiu and J. Hershenhorn

16:30 - 16:50	Y Goldwasser	Utilizing herbicide-resistant tomato to manage <i>Orobancha aegyptiaca</i>
16:50 - 17:10	J Hershenhorn	<i>O. aegyptiaca</i> control in tomato
17:10– 17:30	F Kanampiu	<i>Striga</i> control in maize using herbicide seed coating technology
17:30 – 17:50	A Menkir E	Use of inbreeding as a tool to improve resistance to <i>Striga</i>
17:50 – 18:10	AC Franke	On-farm testing of <i>Striga hermonthica</i> control technologies
18:10 – 18:30	A Elzein	Seed treatment technology: an appropriate delivery system for controlling <i>Striga</i> spp. with <i>Fusarium oxysporum</i> Foxy 2
18:30 - 18:50	G Malidza	<i>Orobancha</i> control in imidazolinone-tolerant sunflower hybrids

**POSTERS.**

WJ Song	Changes in <i>Orobancha</i> germination in response to conditioning temperature and GR treatments
A Okazawa	Characterization of photoreceptors from <i>Orobancha minor</i> Sm.
WM Al-Khateeb	Influence of salinity on the interaction between tomato and <i>Orobancha cernua</i>
K Yoneyama	Effects of nutrients on the production of germination stimulants
M Haidar	Blue light induced changes in inositol 1,4,5-trisphosphate in dodder ( <i>Cuscuta campestris</i> ) seedlings
JR Qasem	Host range of <i>Orobancha ramosa</i> among some cultivated and wild grown plant species
D Gidoni	Is host range potential related to genetic diversity in <i>Orobancha</i> ?
JR Qasem	<i>Osyris alba</i> occurrence in Jordan: new hosts and importance
D Plakhine	Variation in the response of resistant sunflower to <i>Orobancha</i>
O Ou'draogo	Identification of resistance mechanisms of some sorghum varieties towards <i>Striga hermonthica</i>
C Mallory-Smith	Integrated management of <i>Orobancha minor</i> in <i>Trifolium pratense</i>
T Nadler-Hassar	Natural tolerance of <i>Cuscuta</i> spp. to herbicides inhibiting amino acid biosynthesis
A Kamara	Cereal-legume rotation to control <i>Striga</i> and improve on-farm yield of maize in Northern Guinea
W Lanini	Management of <i>Cuscuta</i> in tomato with resistant varieties and herbicides
N Gworgwor	The effect of Arbuscular Mycorrhiza (AM) fungi on the control/management of <i>Striga hermonthica</i>
H Buschmann	Induced Resistance: An effective Method for the Control of Parasitic Weeds?

*Plenary lecture*

**THE PARASITIC WEED PROBLEM AND ITS FATE IN THE 21<sup>ST</sup> CENTURY**

**DM Joel**

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Ramat Yishay 30095, Israel. [dmjoel@volcani.agri.gov.il](mailto:dmjoel@volcani.agri.gov.il)*

Parasitic weeds cause heavy damage in world agriculture and forestry. These include the root parasites *Striga* (witchweed) and *Orobancha* (broomrape), mistletoes such as *Arceuthobium* and *Viscum*, and the climber *Cuscuta* (dodder). The globalization of parasitic weeds, the evolution of new races and the increase in virulence pose a continuous threat to many key crops. Minor crops are also threatened.

While quarantine measures, herbicide treatments, the employment of bio-agents, weeding, intercropping and the use of resistant crops, catch crops or trap crops remain relevant in parasitic weeds management, the available methods should be improved using Precision Agriculture.

Genetic manipulation of host plants may offer new means for the control of parasitic weeds. This includes the possible manipulation of developmental and metabolic pathways. Thus, a detailed understanding of parasitic mechanisms and of host-parasite interactions is required. This should lead to the development of parasite-specific herbicides and allow genetic interference in parasite populations, which should provide additional protection against parasitic weeds.

Both proteomic and genomic approaches should soon provide data on the genes that are involved in the reaction of host plants to parasitic plant attack, and on virulence genes that are responsible for the numerous mechanisms employed by the parasites. Based on this knowledge additional sources for resistance may be developed, employing specific antibodies, gene silencing, local release of toxins, and the use of deceptive signals.

*Invited lecture*

**NEW METHODOLOGIES FOR THE MANAGEMENT OF PARASITIC WEEDS**

**JK Ransom<sup>1</sup>, F Kanampiu<sup>2</sup> and J Gressel<sup>3</sup>**

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Parasitic weeds continue to be devastating pests of major food crops, particularly in the developing world. *Striga* and *Orobancha* are the two most important genera of parasitic weeds and cause the greatest losses in Africa, southern Europe and western Asia. Integrated control practices which focused on factors such as crop rotation, tolerant varieties, soil fertility management, and herbicides have shown value in reducing losses, but have been poorly adopted and have failed to slow the spread of these pests. The purpose of this paper is to review the most recent methodologies that have been developed for the control of *Striga* and *Orobancha*, particularly those that are deemed to have potential for widespread adoption by small-scale farmers. The most promising new *Striga* control practice in maize is coating seeds of genotypes with resistance to ALS-inhibiting herbicides with herbicides such as imazapyr and pyrithiobac prior to planting. Extensive on-farm testing in several countries in Africa with two species of *Striga* has demonstrated the cost effectiveness of this technology when densities reach crop-damaging levels. Glyphosate resistant crops hold promise, though their use is currently constrained by the lack of registration of transgenic crops in most countries where *Striga* and *Orobancha* are endemic. The use of bio-control such as crop seed applied pathogens of *Striga* and *Orobancha* may have an impact in controlling these species before they emerge. The development and deployment of resistant varieties holds increasing promise as sources of resistant are identified and their mechanisms of action are better understood.

*Invited lecture*

**DENSITY DEPENDENCE IN THE STRIGA-HOST INTERACTION AND ITS CONSEQUENCES FOR STRIGA MANAGEMENT**

**PR Westerman, T van Mourik, TJ Stomph and W van der Werf**

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Farmers in the semi-arid regions of Africa can choose among a large number of strategies to control *Striga hermonthica*, a root hemi-parasite of grain crops. The decision to employ a particular method of control will - among other things - depend on its effectiveness. The objectives of this study were 1) to identify density dependent and independent stage transitions in the *S. hermonthica* life cycle and quantify these in a greenhouse trial and 2) to evaluate control strategies in a long term perspective by modeling the seed bank dynamics. In the experiment, sorghum plants were exposed to four seed densities of the parasite (20 000 – 350 000 seeds m<sup>-2</sup>). Below ground *S. hermonthica* development was assessed at 30 day intervals until crop maturity. Above ground development was assessed weekly. All stage transitions appeared to be density independent, except attachment of the *S. hermonthica* seedling to the host root. At 60 d post-emergence of the host, a fixed proportion of the seeds had attached to the host root system, but this was followed by a large and strongly density dependent mortality during the next 30 days, resulting in almost constant numbers of attached parasites per host, irrespective of the initial infestation level. Density dependence was included into the model to evaluate its impact on effectiveness of different control strategies. It was found that seed bank dynamics was not sensitive to control strategies that have their effect before the density dependent stage, but very sensitive to control strategies that affect *S. hermonthica* post-attachment.

*Invited lecture*

**UNDERSTANDING KEY DEVELOPMENTAL PROCESSES IN PARASITIC WEEDS**

**G Ejeta and PJ Rich**

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Research on the biology of parasitic weeds has been underway for several decades. Recent advances in the various disciplines applied to the study of parasitic weeds have greatly expanded our knowledge base. Evidences drawn from these studies have allowed us to develop a growing understanding of the biological processes by which these unique plants grow and develop in coordination with their hosts. Generally, parasitic weed seeds have specific dormancy and environmental conditioning requirements that must be met before they germinate. Germination of weed seeds proceeds in response to signals derived from host plants. Differentiation of radicle cells into the haustorium marks the beginning of the parasitic phase of the weed's life cycle. The biological and chemical aspects of haustorial initiation have evolved to require assurance of proximity to the host with this transition. Post-attachment haustorial development allows the parasite to establish vital vascular connections as well as metabolic and osmotic linkage with the host plant. Finally, the weed matures and sets seed completing the life cycle and bringing the process full circle. This paper focuses on the shared biology of root parasites, with examples drawn mainly from *Striga* and *Orobanch* spp. We present a review of our current knowledge of the biology of parasitic weeds to offer perspectives on developmental processes in plants as well as opportunities for genetic manipulation in host plant resistance.

**MANIPULATING HOST DEFENSES TO ENHANCE TOBACCO RESISTANCE TO  
*OROBANCHE AEGYPTIACA***

**EM Winston, OP Hurtado-Gonzales, CL Cramer, and JH Westwood**

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An intriguing question for parasitic weed control is whether a normally susceptible host plant contains the potential to defend itself from parasitism, but somehow fails to activate the most effective response. Previous research has indicated that *Orobanche* parasitism triggers its host to activate some defense responses more than others. Specifically, *Orobanche* induces defenses associated with the localized production of phytoalexins much more than those associated with salicylic acid (SA) signaling, pathogenesis-related (PR) proteins, and systemic acquired resistance. To better understand the potential for enhancing host resistance, we have tested strategies for inducing those defenses that are not normally activated by the parasite. One strategy was to engineer a parasite-triggered hypersensitive response (HR) in tobacco by expressing the TMV replicase gene under control of the *Orobanche*-inducible *CHS8* promoter. Expression of the replicase protein in plants containing the N gene leads to a gene-for-gene interaction that causes HR in leaves. When these hyper-responsive transgenic tobacco were challenged with *O. aegyptiaca*, parasitism was reduced to less than half that of wild-type plants. In addition, we have studied the levels of tobacco PR-1a protein in response to the SA analog, BTH. Treatment of plants with this compound greatly induced PR-1a production in leaves, but little in roots. Treatment of plants with BTH to stimulate SA-mediated defenses did not consistently enhance resistance to *O. aegyptiaca*. These studies suggest that host resistance capacity can be increased in susceptible hosts, but caution that the defense capabilities of plant roots differ significantly from those of leaves.

**EPSP-SYNTHASE PRESENCE AND ACTIVITY IN *OROBANCHE AEGYPTICA* PERS.**

**L Zygier and B Rubin**

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Glyphosate inhibits the biosynthesis of aromatic amino acids by inhibition of EPSP synthase, a key enzyme in the shikimate pathway, resulting in accumulation of shikimic acid in sensitive plants. The aims of this study were to examine if the Egyptian broomrape (*Orobanche aegyptiaca* Pers.) has an active EPSP synthase and its response to glyphosate. <sup>14</sup>C-glyphosate applied to the second leaf of transgenic glyphosate-resistant (R) and -sensitive (S) tomato (*Lycopersicon esculentum*) is rapidly translocated to various host sinks (apex and roots) and to broomrape tubercles developing on the tomato roots. Broomrape tubercles accumulated more <sup>14</sup>C-glyphosate than the apical meristem and roots of the host, indicating that broomrape is a strong sink. Glyphosate applied to the foliage of R and S tomato plants inoculated with *O. aegyptiaca* resulted in severe damage to the parasite. In addition, shikimate was accumulated in the apex and roots of the S plants but not in the R plants. Broomrape tubercles parasitizing both R and S tomato accumulated high levels of shikimate. The accumulation of shikimic acid in the tubercles growing on the resistant host confirms that there is an active EPSP synthase in broomrape. These results suggest that the parasite confers the capacity to synthesize aromatic amino acids independently of the host plant, raising the question why does the broomrape need this enzyme if assimilates and amino acids are supplied by the host.



## DETERMINATION AND QUANTIFICATION OF STRIGOLACTONES

**K Yoneyama<sup>1</sup>, Y Takeuchi<sup>1</sup>, D Sato<sup>1</sup>, H Sekimoto<sup>2</sup> and T Yokoka<sup>3</sup>**

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Seed germination of root parasitic weeds *Striga* and *Orobanche* is strongly elicited by strigolactones such as strigol, sorgolactone, alectrol, and orobanchol. Trace amounts of these known strigolactones in root exudates can be analysed by using the high performance liquid chromatography (HPLC)-connected to tandem mass spectrometry (LC/MS/MS). So far, orobanchol produced by red clover, and strigol and strigyl acetate produced by cotton have been quantified. In both cases, young and actively growing roots were found to be major source of germination stimulants. Distributions of germination stimulation activity after reverse-phase HPLC purification of ethyl acetate extracts of root exudates indicate that there are several strigolactones whose structures are yet to be elucidated. For example, sorghum was found to produce a novel strigol isomer as well as sorgolactone and strigol. At least 4 novel strigolactones, 1 dehydro- and 3 tetrahydro-strigol isomers, were detected in tomato root exudates. These results clearly demonstrate a wide distribution of strigolactones in the plant kingdom, indicating that strigolactones may have some important biological functions in plants.

## ENHANCING THE EFFICACY OF A FUNGAL BIOCONTROL AGENT AGAINST OROBANCHE CUMANA THROUGH COMBINATION WITH A RESISTANCE-INDUCING CHEMICAL

**D Müller-Stöver, H Buschmann and J Sauerborn**

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*Fusarium oxysporum* Schlecht. f. sp. *orthoceras* (Appel & Wollenw.) Bilai was found to attack all developmental stages of the parasitic weed *Orobanche cumana* Wallr. Fungal propagules were matrix-incorporated in granules made from wheat-flour and kaolin ('Pesta') that efficiently controlled the parasitic weed in greenhouse experiments. However, in a field trial carried out in Israel, control efficacy was lower compared to the pot experiments and the soil population of the fungus decreased to less than 10 % of the initial numbers within two months. Thus, the most important objective of the present investigations is enhancing the efficacy of the biocontrol agent. In pot experiments with different sunflower cultivars, the application of *F. oxysporum* was combined with a treatment of Benzo(1,2,3)thiadiazole-7-carbothioic acid S-methyl ester (BTH) that is known to induce resistance against *O. cumana* in sunflower. The combined treatments always performed best regarding the control of *O. cumana* and resulted in a reduction of emergence of up to 100 %. In first laboratory experiments, virulence and growth of the fungus was generally not affected by the addition of BTH to the growth medium, except for a short time after incubation or after the incorporation of high dosages of BTH (30 or 90 ppm) when the growth of the fungus was reduced compared to the untreated controls. Results are presented on how to optimise the integration of the two control measures.

## MANURE FERMENTATION REDUCES *OROBANCHE* INFESTATION ON TOMATO

**BE Abu-Irmaileh<sup>1</sup> and AM Abu-Rayyan<sup>2</sup>**

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Controlling *Orobanche* species in many crops has been continuing for the past decades with only limited success. Fumigants such as methyl bromide and herbicides are the only direct control practices. However, their application requires specific technology that is beyond the capability and affordability of subsistent farmers in small farming systems. In addition, chemicals are not totally safe to the environment. In this research, fermenting *Orobanche*-contaminated manure for a period of six weeks reduced the ability of *Orobanche* seeds to infest tomato, as *Orobanche* dry weights and the total number of shoots and attachments were reduced. Air-tight covering of the soil surface of plots amended with manure for fermentation by black polyethylene sheets for six weeks reduced the ability of *Orobanche* seeds, which were buried at 15-20 cm depth, to infest tomato. All species of *Orobanche*; *O. ramosa*, *O. cernua*, or *O. crenata* responded similarly to manure fermentation. Fermentation of poultry manure was more effective than cow and sheep manures. Fermenting manure in the planting row for six weeks prior to planting was effective in reducing *Orobanche ramosa*, on tomato plants.

Fermentation of manure could offer a new environmentally safe procedure to manage *Orobanche*, using farm resources and could improve the sustainability of crop management. It would also be an effective asset in organic farming.

## EVALUATING STRATEGIES TO CONTROL THE PARASITIC WEED *OROBANCHE CRENATA* IN FABA BEAN – A SIMULATION STUDY USING APSIM

**JH Grenz<sup>1</sup>, AM Manschadi<sup>2</sup> and J Sauerborn<sup>1</sup>**

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The angiosperm parasite *Orobanche crenata* inflicts considerable damage upon legume production in Mediterranean countries. No single control method has proven both effective and practicable due to the complexity of host-parasite interactions. Experimental evaluation of potential integrated control strategies would be time- and labour-consuming, yet only render location-specific results. The use of simulation models can help overcome these restrictions. The objective of our work is to provide a model that can be a useful tool in assessing the impacts of control options and strategies against parasitic weeds.

This study reports on the development, evaluation and application of a generic module within the framework of the Agricultural Production Systems Simulator (APSIM) that allows quantification of parasitic weed impact. A mechanistic model of host-parasite interactions was calibrated with experimental data on the association faba bean-*O. crenata* from Syria and evaluated with independent data from Turkey. The evaluation showed that APSIM can realistically reproduce observed courses of growth and development of host and parasite. In order to facilitate long-term simulations, algorithms calculating seed bank dynamics and effects of control measures were added. The enhanced model was used with historic weather data to simulate effects of various sowing strategies and weeding schedules on faba bean yield and *O. crenata* seedbank. The results demonstrate that APSIM can provide the quantitative information needed to identify effective control strategies. The generic nature of the model means that it can be easily adapted to suit other host-parasite associations.

## **Striga Workshop**

### **WAYS TO MANAGE STRIGA INFESTATIONS WITHOUT HERBICIDES IN WEST AND CENTRAL AFRICA**

**AM Emechebe**

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The obligate root-parasitic flowering plants, *Striga* spp., are a major constraint to crop production in sub-Saharan Africa. *Striga hermonthica* constitutes the most important biological constraint to the production of maize, sorghum, pearl millet, and, more recently, upland rice in the savanna agroecological zones of West and Central Africa (WCA). *S. gesnerioides* is an important pathogen of cowpea, especially in the northern Guinea and Sudan savannas and the Sahel. Farmers in WCA traditionally manage *Striga* infestations by physical destruction (hoe-weeding and hand-pulling), long fallow periods, crop rotation, mixed cropping and application of organic and inorganic fertilizers. The IITA and its partners in WCA are developing and promoting an integrated *Striga* management (ISM) programme. Important components of the programme include, planting *Striga* – free host crop seeds; rotating non-host trap crop cultivars (specifically selected for efficacy to stimulate suicidal germination of seeds of the *Striga* strain prevalent in the area of intended use) with host crop cultivars; growing *Striga*–resistant/tolerant host crop cultivars; late weeding to destroy *Striga* before seed set; appropriate use of fertilizers (especially those that enhance soil suppressiveness); and biological control with fungal pathogens of *Striga*, rhizobacteria pathogenic to seeds or suppress their germination, and ethylene-producing bacteria. In promoting farmers' adoption of technology components acceptable to them, IITA and its partners are adopting farmer-participatory learning approach, including training farmers on *Striga* biology/ecology, testing of control options in farmer – managed trials and demonstration plots, and stakeholder participatory scaling out and up processes.

### **ARRESTING THE SCOURGE OF STRIGA ON SORGHUM IN AFRICA BY COMBINING THE STRENGTHS OF MARKER-ASSISTED BACKCROSSING AND FARMER-PARTICIPATORY SELECTION**

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Molecular markers for resistance of sorghum (*Sorghum bicolor*) to *Striga hermonthica* were mapped in a population of F<sub>3:5</sub> lines developed from the cross N13 × E36-1. The resistant sorghum line N13 is characterized by “mechanical” resistance. The genetic map spanned 1599 cM, with 157 markers distributed over 11 linkage groups. To evaluate *Striga* resistance, the mapping population was divided into Set 1 (116 lines tested in 1997) and Set 2 (110 lines evaluated in 1998). Field trials were conducted in five environments year<sup>-1</sup> in Mali and Kenya. Heritability estimates for Area under the *Striga* Number Progress Curve (ASNPC) in Sets 1 and 2, respectively, were 0.81 and 0.82. Across sites, composite interval mapping detected 11 and 9 QTL in Sets 1 and 2, explaining 79 and 82% of the genetic variance for ASNPC, respectively. Five QTL were common to both sets, with the resistance alleles deriving from N13. Since their effects were validated across environments, years and independent genotype samples, these QTL are excellent candidates for marker-assisted selection. In a new project (years 2004-2007), *striga* resistance of farmer-preferred sorghum varieties in Eritrea, Kenya, Mali and Sudan will be enhanced through a combination of marker-assisted backcrossing and farmer-participatory selection. A simultaneous socio-economic study of the sorghum seed supply systems in these countries will be undertaken to guide the design of effective seed interventions by partner institutions so that improved materials efficiently reach farmers. Linkage with technology exchange will boost promotion of the improved varieties as component of integrated *Striga* control.

## YIELDING ABILITY, RESISTANCE AND TOLERANCE AS INDEPENDENT SELECTION CRITERIA FOR BREEDING AGAINST *STRIGA*

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The hemi-parasitic weed *Striga hermonthica* causes serious yield losses to susceptible cereals in the semi-arid tropics. Yield under *Striga* infestation depends on yielding ability and levels of resistance and tolerance of the crop genotype. Selection of the best genotypes for breeding requires suitable measures for each characteristic. Objective of this research was to find practical selection measures that are representative, discriminative and consistent over years.

Ten sorghum genotypes were studied. Resistance to non-emerged stages of the parasite was studied in agar-gel assays and pot trials. Yielding ability, tolerance and above-ground expression of resistance were evaluated in the field. Sorghum was grown with and without *Striga* infestation in a split-plot design in three successive years (2001-2003) characterised by different *Striga* infestation levels.

Yield under *Striga*-free conditions provides an estimate of yielding ability. *Striga* number at harvest was not as fair, discriminative and consistent over years as other resistance measures, particularly number of *Striga* infection days (ASNPC) and maximum emerged *Striga* number. The latter is less laborious than ASNPC and corresponded reasonably well with below-ground observations. Relative yield loss was not an unambiguous measure of tolerance as it is influenced by infection level and therefore confounded with resistance. A linear correction for infection level was found to be unsatisfactory.

Screening for yielding ability and tolerance requires *Striga*-free plots adjacent to infested plots. For yielding ability and resistance, suitable selection measures were identified. Development of a selection measure for tolerance will require additional information on the relation between yield loss and infection level.

## DEVELOPMENT OF A SYSTEMS APPROACH FOR ECOLOGICAL MANAGEMENT OF *STRIGA* IN CEREAL BASED CROPPING SYSTEMS IN NORTHERN NIGERIA

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In field trials between 1995 and 1998, trap crops (groundnut, bambara-groundnut and sesame) and seed dressing with brine (NaCl) were used to investigate their effectiveness on the management/control of *Striga hermonthica* in sorghum and millet. Intercropping of sorghum with groundnut significantly reduce *Striga* infestation up to 50% in sorghum in both years, but without significant increase in yield. Alternating stands of sorghum and bambara groundnut within the same row reduced *Striga* shoot count in all the varieties with a range of 51 – 91% reduction than in alternate rows or sole sorghum of each variety significant increase in yield in all the varieties compared with their soles. In the millet-sesame trial, the 1:1 alternate stand on the same row cropping pattern significantly reduced *Striga* infestation more than the millet:sesame same stand cropping pattern, especially with ICSV-IS-91116 variety in both years where zero *Striga* emergence was observed. Seed dressing with 1.5 M brine was found optimal for controlling *Striga* emergence resulting in increased crop growth and grain yield, irrespective of the sorghum variety. In conclusion, it is evident that the farmers in this dried semi-arid ecological zone of Nigeria have a choice of any option of a control strategy to achieve a good degree of *Striga* management/control in their sorghum or millet based cropping system. Such options also offer a long term effect of depleting *Striga* seed bank in the soil and such options are ecologically sound and accessible to the farmers.

## PROSPECTS AND LIMITATIONS FOR *STRIGA ASIATICA* CONTROL IN SORGHUM/DESMODIUM INTERCROP

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*Sorghum bicolor* (L.) Moench is often severely restricted by *Striga asiatica* (L.) Kuntze parasitism, and successful management of the weed requires integrated control practices. Objectives: to investigate the influence of *Desmodium intortum* exudates on *Striga* seed germination, and to determine optimum timing of *Desmodium* establishment, and population density, for effective control of *Striga* in a sorghum/*Desmodium* intercrop system. In a pot experiment, treatment combinations of three sorghum varieties; three transplanting dates for *Desmodium*; in the presence or absence of *Striga*, were employed. In the second pot experiment, four sorghum/*Desmodium* intercropping ratios and three sorghum varieties were used. In the laboratory, the effects of different plant parts, leachates and extracts of *Desmodium* were tested on *Striga* seed germination. Pot experiment results showed that *Striga* population varied significantly among sorghum varieties, sorghum / *Desmodium* intercropping ratios, *Desmodium* establishment date, and their interactions. *Desmodium* reduced *Striga* emergence in sorghum by 100% when intercropped at 1:3 sorghum:*Desmodium* ratios, and with *Desmodium* transplanted 30 days prior to sorghum sowing. However, this treatment combination also caused significant reductions in sorghum yield. Compatibility between sorghum and *Desmodium* was evident at the 1:1 plant ratio. Laboratory results showed that exudates of *Desmodium intortum* induce suicidal germination of *Striga*. Segments of *Desmodium* roots, leachate from live plants, and leachate extracts induced germination of *Striga* seeds. Findings apparently explain why the practice of *Desmodium*/sorghum intercropping is effective for controlling *Striga asiatica*. Further research, especially on the metabolites and mechanisms involved, is warranted.

## FIELD INOCULATION WITH ARBUSCULAR MYCORRHIZAL FUNGI REDUCES STRIGA PERFORMANCE ON CEREAL CROPS AND HAS THE POTENTIAL TO INCREASE CEREAL PRODUCTION

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The witchweed *Striga hermonthica* seriously affects cereal production in Africa. Severity and intensity of *Striga* correlate negatively with soil fertility status. Arbuscular mycorrhizal fungi (AM) have been observed to negatively influence *Striga* performance in pot experiments. The objective of this study was to validate results of the tripartite interactions AM fungi, cereals and *Striga* obtained under controlled conditions, in the field. Maize and sorghum were grown in the field in north Cameroon during the cropping seasons of 2000 for maize, 2001 and 2002 for sorghum. Both cereals were grown in the presence or absence of *Striga* seeds, with or without inoculation using a mixed soil inoculum of AM fungi. Infection of maize by *Striga* resulted in a 20% cob yield reduction. In 2001, *Striga* infection of sorghum led to a reduction of only 7% of panicle yield whereas in 2002 a significant 26 % reduction of panicle yield was obtained. With AM fungi inoculation, a significant reduction (30% and over 50% on maize and sorghum, respectively) in number of *Striga* shoots was noted. Harvested and dried *Striga* shoots from AM inoculated plots weighed significantly less: 40% reduction on maize, 46% and 63% reduction on sorghum in 2001 and 2002, respectively. Negative performance of *Striga* with AM fungi inoculation did not result in significant increase in cereal yield suggesting presence of effective AM propagules that needed boosting early in the cropping season in those fallow fields. Managing AM is an option in integrated management of *Striga* on cereals for sustainability.

**LINKING LABORATORY AND FIELD STUDIES OF DORMANCY IN *STRIGA HERMONTHICA*: IS DELAYED PLANTING AN OPTION FOR INTEGRATED CONTROL?**

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Dormancy is an important attribute associated with the ability of seeds in the soil seed bank to germinate and emerge in response to favourable environmental conditions. A Sudanese seedlot of *Striga hermonthica* was subjected to prolonged conditioning (up to 19 weeks) at a wide range of temperatures (17.5°C to 35) and water potentials (0 to -2.25 MPa) and urea concentrations (0 to 3.16 mM). The non-linear empirical mathematical modelling approaches used by Kebreab & Murdoch to describe responses of *Orobancha* were tested on these data. Being a much more extensive data set than that available for *Orobancha*, the hypothesis that loss of primary dormancy is independent from induction of secondary dormancy could be tested for the first time and was rejected. Implications will be discussed. These models were then applied to seeds of the same Sudanese seedlot subjected to conditioning in the soil in a glasshouse, providing a reasonable fit. The final validation was a comparison with the behaviour of a naturally-occurring seedbank in the soil of Northern Ghana. With calibration, the effect of delayed planting on emergence of *S. hermonthica* could be modelled. While the modelling exercise contributes usefully to our understanding of the biology and population dynamics of the weed, it is also true that the rate of induction of secondary dormancy was too slow for delayed slowing to be a viable option for small-scale farmers.

## **Genetic variation in parasitic weeds**

### **ISSR CHARACTERIZATION OF *OROBANCHE MINOR* POPULATIONS IN THE U.S.**

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*Orobanche minor* (Sm.) is native to Europe, but has spread to Africa, Australia, New Zealand, Japan, and the US. Within the last 15 years, several populations of *O. minor* have been discovered in the US. Our objective was to analyze these populations using DNA fingerprinting to discern patterns of introduction and spread of the weed. Tissue was obtained from populations in Thomas Co., Georgia; Due West, South Carolina; North Augusta, South Carolina; Washington Co., Virginia; and Clackamas Co., Oregon. DNA samples from 10 individuals from each population were PCR-amplified using inter-simple sequence repeat (ISSR) primers, and resulting bands were separated by polyacrylamide gel electrophoresis. From nine primers, 219 bands were scored, with 72 of these showing at least one polymorphism. Overall, the level of genetic polymorphism is low, with individuals within populations having nearly all bands in common. This is not surprising for populations originating from just a few founder plants. Although not all populations were distinguishable, differences were detected among certain ones. Specifically, the Due West and Georgia populations are closely related to each other, as are the North Augusta and Virginia populations, but these two main groups are clearly different. The Oregon population is unique, but shares more in common with the Virginia/North Augusta than the Georgia/Due West populations. This pattern suggests that the populations are the result of 2-3 separate introductions into the US, and also that some populations appear to have a common origin.

### **BIODIVERSITY IN *OROBANCHE CRENATA* IN THE MEDITERRANEAN REGION - A REVIEW**

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The study of population genetic diversity of *Orobanche* species is of great importance since the understanding of the variability within and between pathogenic populations is essential if selection programs need to target sources of resistance. According to *Orobanche crenata*, isozymes and DNA based markers have been used to determine the level of variation among populations. Both types of markers have detected a general low genetic differentiation among populations and a high proportion of variation at the intrapopulation level. In this sense, the first study of *O. crenata* diversity using isozymes found a high genetic variation within population with the largest genetic distance between the Syrian and the Spanish populations (Verkleij and Pieterse, 1994). A similar study was also carried out with ISSR markers including three *O. crenata* populations from Israel and three from Spain detecting a lower genetic differentiation among the Spanish populations and a significant differentiation between these two regions (Román et al., 2002). Paran et al., (1997) also used RAPD markers to determine differences between populations growing on different hosts and found that most of the intraspecific variation in two populations growing on carrot and vetch in Israel was among individuals and not among hosts nor between regions. (Paran et al., 1997).

The further development of population genetic studies of *O. crenata* will require the use of co-dominant marker systems as microsatellites and more extensive sampling of populations from different regions and different hosts.

## GENETIC VARIABILITY OF *STRIGA HERMONTHICA* - A REVIEW

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Genetic variability of the allogamous species *Striga hermonthica* can be divided into variation between and variation within individual populations or ecotypes. In West Africa, *S. hermonthica* populations with specific adaptation to sorghum or millet have been reported whereas others attack both hosts. The strength of intercrop specialization depends on the cultivation history of the field but precise mechanisms of adaptation are unknown. Molecular marker profiles were able to distinguish between West versus East African populations. There is also evidence for intracrop specialization in terms of different sensitivity to germination stimulants of *S. hermonthica* populations from Kenya versus Mali or Niger. High selection pressure, reducing the genetic variability of *S. hermonthica*, has been reported on populations parasitizing resistant sorghum varieties and supports the hypothesis of adaptation to resistant host cultivars. Due to its outcrossing behavior, intra-population variation of *S. hermonthica* is almost as big as the inter-population variation. Hardy-Weinberg-Equilibrium has been found for two iso-enzyme loci in 13 *S. hermonthica* populations from West Africa. Genetic differences among *Striga* populations most likely contribute to the frequently highly significant genotype-environment interaction variances for *Striga* resistance in multi-location field trials. A better understanding of the virulence variation among and within *Striga* populations is urgently required. Standardized cross-infestation experiments, studying the genetics of *Striga* virulence, developing co-dominant marker systems to estimate population-genetic parameters in *Striga* populations, and subsequent modelling of the evolution of virulence could be possible approaches towards a better understanding and therefore a more effective deployment of resistance genes against this noxious parasite.

## GENETIC VARIABILITY AND HOST SPECIALIZATION IN *STRIGA GESNERIOIDES*

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There have been few attempts to analyze genetic variability of *Striga* species and the relationship between genetic variability of the parasite and its host range and virulence is not known at this time. AFLP profile analysis was carried out using total genomic DNA extracted from individual plants collected from different populations throughout the suspected distribution of each of the five West African races of *S. gesnerioides* parasitic on cowpea (i.e., SG1 -Burkina Faso, SG2 - Mali, SG3 - Niger, Nigeria, SG4 - Benin, and SG5 - Cameroon). Populations of *S. gesnerioides* parasitic on other legume host species were also included in the analysis. Our studies indicate that genetic variability within and between populations of the individual races of cowpea *S. gesnerioides* is relatively low. However, a significant level of genetic variation exists among the SG1, SG2, SG3, SG4, and SG5. SG1 and SG3 were most closely related, and SG2 and SG4 were most diverged. Clear differences were recognizable between *S. gesnerioides* parasitic on cowpea and those on other legumes such as *Indigofera*.

In addition to providing novel phylogenetic information for *Striga* spp., the studies allowed us to identify molecular markers that effectively discriminated individuals representative of each of the five West African races. Work is underway to expand our analysis to other areas where additional races of the pathogen may be present. Our progress to this end will be discussed.



**ANALYSIS OF GENETIC VARIABILITY IN THE CLOSELY RELATED SPECIES *STRIGA HERMONTHICA* AND *S. ASPERA* BY RAPD AND SCAR MARKERS**

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In Africa, *Striga* is the greatest biological constraint on food production. *Striga hermonthica* (Del.) Benth. and *S. aspera* (Willd.) Benth. are recognized as separate species, but due to their close morphological similarity it is difficult to distinguish them in areas where they coexist, especially in E. Africa. Both species can be crossed artificially and hybrids seem to be more virulent than their parents, although it is unknown whether hybridisation occurs naturally in the fields.

*Striga* from several geographic regions of Africa and a few F1 and F2 hybrids were tested. A genetic analysis was performed by means of DNA profiles derived from genetic polymorphism RAPD-PCR markers using AMOVA. Parental and hybrid populations were separated with the help of AMOVA and the Arlequin software package.

The among population variation differed between *S. hermonthica* (33%) and *S. aspera* (50%); this high value for *S. aspera* might be explained by the relatively small population size and geographic isolation.

After constructing a phylogenetic tree using UPGMA four major clusters of *Striga* populations were found: *S. hermonthica* from West African, *S. aspera* and two *S. hermonthica* groups from East Africa. The hybrids appeared to cluster to their maternal parent.

Two SCAR markers were developed and in combination it was possible to distinguish the two species *S. aspera* and *S. hermonthica*; furthermore *S. hermonthica* populations from West Africa could be distinguished from those from East Africa. With the help of these markers it should also be possible to distinguish the hybrids from each other.

## **Physiological and molecular aspects of parasitic plants**

### **ADVIANCES IN TISSUE CULTURE OF WESTERN HEMLOCK DWARF MISLETOE (ARCEUTHOBIUM TSUGENSE SUBSP. TSUEGENSE)**

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Western hemlock dwarf mistletoe (*Arceuthobium tsugense* subsp. *tsugense*) is one of the most damaging parasite of hemlock plantations of Western North America. Research results suggest that the parasite reduces the timber production in coastal British Columbia by up to 4 million cubic meters annually. The goal of the research was to develop tissue culture system for the parasite to investigate the optimal conditions for radicle growth, germination, anatomy, and callus production. A factorial experiment was used to evaluate the effects of Harvey's medium (HM) and White medium (WM), temperatures (15 °C and 20 °C), presence or absence of light, and plant growth regulators (auxin- 2,4- D) and (cytokinin- BAP) at varying concentrations (0.001- 1.0 mg/L). Viable seeds were aseptically transferred to tissue culture media. There were 30 seeds per treatment for HM (6 replicates with 5 seeds per plate) and 10 seeds per treatment for WM (2 replicates with 5 seeds per plate). Selected specimens were fixed in 2.5% glutaraldehyde, dehydrated in alcohol, embedded in Technovit 7100, sectioned, and stained in toluidine blue for examination under light microscope. The optimal conditions for radicle elongation were WM at 20 °C in the presence of light and without plant growth regulators. Holdfasts were produced at the tips of radicles, and callus arose from split holdfasts. Factors that promoted holdfast production were HM, light, and 1 mg/L 2,4-D. Callus development from split radicles and split holdfasts were optimal on WM with 0.5 mg/L 2,4-D and 1.0 mg/L BAP at 20 C in the dark.

### **CALLUS PRODUCTION OF OROBANCHE AND ITS NOVEL ASEPTIC INFECTION ON HOST ROOTS**

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Root parasites of the genus *Orobancha* are serious weeds in agriculture. This paper describes the development of an *in vitro* culture system and completely aseptic infection of host roots using calli of *O. ramosa*, *O. aegyptiaca* and *O. minor*. Better callus inductions were obtained from B5 culture media with 3.6% PDA, vitamins, 3% sucrose, 600 mg/L casein, 5% coconut water, and various hormones. GA<sub>3</sub> increased the percentage of callus formation. With 2,4-D more calli were induced after adding kinetin, but all media containing 2,4-D induced the soft undifferentiated calli. Hard and much differentiated calli with root-like protrusions developed after adding NAA to kinetin containing medium. Shoot meristem initiated at the distal end of *O. ramosa* callus on MS medium containing GA<sub>3</sub>. A requirement for infection was the differentiation of root-like protrusions from the callus, which were developed under the influence of 0.5-1.0 mg/L IAA, and of 0.2 mg/L NAA with 5.0 mg/L kinetin. These protocols produced root protrusions and pad-like structures that resembled attachment organs of *Orobancha*, and proved effective in parasitizing host roots. Direct contact with the medium inhibited haustorium development and prevented infection. To overcome this problem we isolated certain root portions from the medium by inserting thin glass plates under the host roots. Calli were then placed on the raised root portions and successfully infected the roots, leading to the development of young *Orobancha* plants with normal vascular systems that directly connected to the host.

## ACTIVE VS PASSIVE MINERAL NUTRIENT UPTAKE IN MISTLETOES – A STILL UNRESOLVED QUESTION ?

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In a hypothesis published in 1983 the principal author attributed enrichment of mineral nutrients in mistletoe foliage as compared to host foliage largely to entrapment of elements, which are cycled in the host but are not retranslocated from the mistletoe to the host. This hypothesis has been repeatedly challenged by arguments for active uptake by some specific absorption mechanism of mistletoe haustoria (e.g. Bowie and Ward, 2003). In order to shed more light on this question a fairly large population of *Scurrula elata*, a common Loranth in Nepal, was studied on four hosts, namely *Lindera pulcherrima*, *Lyonia ovalifolia*, *Rhododendron arboreum* and *Viburnum erusbescens*. A very pronounced enrichment of potassium and phosphorus was evident both in terms of element mass content in the foliage and potassium/nitrogen as well as phosphorus/nitrogen ratios. Statistical analyses showed that potassium and phosphorus in host leaves sampled proximal and distal from the mistletoe attachment area did not show significant differences in potassium and phosphorus content as well as K/N and P/N ratios, which would have to be expected if active uptake by the parasite depleted potassium and phosphorus from the xylem sap supplying the distal foliage. This supports the view that passive uptake and lack of recycling was the main cause of the observed selectivity.

## USING THE BROAD-SPECTRUM HEMI-PARASITIC ANGIOSPERM, *RHINANTHUS MINOR*, AS A TOOL TO INVESTIGATE COMPATIBLE AND INCOMPATIBLE HOST-PARASITE INTERACTIONS.

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*Rhinanthus minor* is a facultative root hemi-parasite widely distributed throughout northern-temperate grasslands. It has a wide host range, observed to be in excess of 50 species however the parasite will attempt to form haustoria on virtually any plant root. In addition, not all hosts prove equally good at supporting the parasite and performs significantly less well when growing on non-leguminous forbs when compared with grasses and legumes with the latter two groups of species suffering the most damage in terms of biomass accumulation and reproductive output. Because of these catholic properties *R. minor* represents a powerful tool for understanding how hosts and non-hosts are able to respond to infection.

Using stable isotope tracers (<sup>15</sup>N) allied with histological (Light microscopy and Scanning and Transmission Electron Microscopy) and spectroscopic techniques (Fourier Transform Infrared [FTIR] microspectroscopy) we show variable successful and unsuccessful defences against the parasite ranging from lignification and hypersensitive root death in the forbs to complete susceptibility in the grasses.

A greater understanding of defence responses against such a broad-spectrum parasite may provide a model from which to develop new lines of crops resistant to/tolerant of parasitic weeds.

**MAPPING AND CLONING OF RACE-SPECIFIC RESISTANCE GENES TO *STRIGA GESNERIOIDES* AND *ALECTRA VOGELII* IN COWPEA**

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Based on the differential resistance reaction exhibited by various cowpea cultivars/breeding lines, five distinct races of *S. gesnerioides* parasitic on this crop have been identified in West and Central Africa. These are SG1 -Burkina Faso, SG2 - Mali, SG3 - Niger, Nigeria, SG4 - Benin, and SG5 – Cameroon. It is also likely that additional races of the parasite exist outside this region. Similarly, evidence for multiple races of *Alectra vogeli* in West Africa also exists, although the characterization of these races is far less advanced. Several race-specific *Striga* resistance genes have been mapped in the cowpea genome and these genes fall into two clusters. Markers linked to the *S. gesnerioides* race 1 (SG1) and race 3 (SG3) resistance genes *Rsg*<sub>1</sub>, *Rsg*<sub>2</sub>, and *Rsg*<sub>4</sub> (present in the resistant cowpea lines B301, IT82D-849 and Tvu 14676, respectively), map to Linkage Group 1 (LG1). The *S. gesnerioides* race 1 (SG1) resistance genes *Rsg*<sub>3</sub> and *Rsg*<sub>994</sub> found in Suvita-2 and IT81D-994, respectively, mapped to LG6. Molecular markers linked to resistance to SG4 and SG5, as well as resistance to *A. vogelii* present in IT81D-994 are under development. SCAR markers linked to SG1 and SG3 resistance were used to screen a cowpea BAC library in an attempt to use map-based cloning to isolate the *S. gesnerioides* resistance genes. Progress towards the cloning of these genes will be presented.

**ENDOGENOUS RHYTHMS OF NUTATIONAL MOVEMENT IN *VISCUM ALBUM* L.  
CORRELATES WITH HIGH LEVEL OF JASMONIC ACID**

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*Viscum album* L. is used as an anti-tumor remedy. Each year the meristems of adult mistletoes differentiate synchronously into vegetative and generative primordia. Some compounds in mistletoe organs show large seasonal differences in these stages of development. During the growth period in the following year the primordia unfold bifurcated shoots which grow at first negative geotropically, followed by 4-5 weeks of nutational movements. We investigated these rhythms using mistletoes on host trees under constant conditions. The movements were recorded with a computer based time-laps imaging system and analyzed by special software.

We found small-amplitude nutational movements with circadian periods and higher-amplitude nutations with periods up to 78 hours. Both, exogenous and endogenous factors seem to control these movements. At the end of the nutational movements the shoots change from a vertical position to a more radial one.

This change to the typical spherical shape with more or less uniform distances between the shoots might be caused by a volatile compound. We have not yet analyzed volatile compounds, but found high levels of the plant hormone jasmonic acid and 12-Oxo-phytodienoic acid by GC-MS. The level increased during the nutations hundred-fold. Most of the jasmonic acid appeared as (+)-7-iso-jasmonic acid indicating its *de novo* synthesis. This is the first time these compounds were found in mistletoe.

Fingrut and Flescher (Leukemia, 2002(16), 608-616) showed that jasmonic acid induces apoptosis and suppresses cell proliferation in various human cancer cells. These findings and ours suggest that jasmonic acid is a novel anti-cancer compound in mistletoe.

## FLURIDONE PROMOTES CONDITIONING AND GERMINATION OF ROOT PARASITIC WEED SEEDS

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In our study on regulation of germination of parasite seeds, fluridone, an inhibitor of phytoene desaturase (PD) in carotenoid-biosynthesis pathway, was found to promote conditioning and germination response of the holoparasite *Orobanche minor*. In addition, fluridone could partially eliminate inhibitory effects of high temperature and light on conditioning and germination of *O. minor* seeds. Therefore, we examined effects of fluridone on the conditioning and germination of another important group of root parasites, *Striga* species (*S. hermonthica* and *S. asiatica*). Fluridone promoted conditioning and germination of both *Striga* species. Furthermore, fluridone alone applied during conditioning elicited seed germination of *S. asiatica*. In addition, in the germinated seeds of *S. asiatica*, haustorium-like structures with root hairs were observed. Germination was not induced by fluridone alone in *S. hermonthica* but haustorium-like structures developed after germination. Among the PD inhibitors, fluridone was more active than norflurazon, but diflufenican was inactive in these assays. Therefore, fluridone and norflurazon may be used for reducing seedbank of these root parasites by promoting conditioning and germination.

## A STUDY ON GERMINATION OF SEEDS OF *RAMPHICARPA FISTULOSA* (HOCHST.) BENTH. - A NEW PEST OF RICE

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*Ramphicarpa fistulosa*, from the family Scrophulariaceae is a facultative root hemiparasitic weed, which has recently become a primary pest of lowland rice in several countries in West Africa, where rice production is encouraged for food security and to limit importation. In 1996, *R. fistulosa* was identified by farmers in the Republic of Bénin as a new pest, which hampers rice production, inflicting 40 to 100% yield loss. Being considered in general as a secondary pest, biology and ecology of *Ramphicarpa* species have received little attention from researchers. In order to help define a management strategy of the new pest, germination studies were conducted *in vitro* on seed populations collected from two inland valleys in 1999 and 2001. Seeds were surface sterilized, using sodium hypochlorite, and submitted to germination tests on filter paper imbibed with distilled water or water-soluble root exudates of rice seedlings. Germination patterns of the seed populations were studied using regression analysis. The results indicated that root exudates of the readily parasitized rice variety *Farox 304-4-1-2* did not stimulate germination of the seeds. At room temperature (28-30 °C), when exposed to daylight, seeds of *R. fistulosa* require a conditioning period of two to three weeks on moist filter paper before they will germinate. Maximum germination level reached is increased if seeds are hidden from light during the conditioning period. Seeds of *R. fistulosa* are short lived, with longevity of approximately one year. These three findings, which are of practical importance, were not reported before.

## GERMINATION ECOLOGY, EMERGENCE AND EARLY HOST PARASITIZATION OF *CUSCUTA CAMPESTRIS* YUNCKER

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*Cuscuta campestris* Yuncker is a parasitic weed belonging to Convolvulaceae family and is widespread both in temperate and sub-tropical ecosystems. As concerns the ecology of this parasitic weed, several aspects are still unclear such as maximum host-weed distance for parasitization, role of phenological stage of host, criteria of host choice and longevity of seeds. The aim of the present work was to investigate both germination and dormancy ecology of *C. campestris* Y. seeds and physiological mechanisms involved in early parasitization of sugar beet seedlings. The parasitic weed is characterized by an evident primary dormancy which is removed by scarification. Germination was negligible at 10°C and optimal at 30°C, while it was not influenced by light. Seed burial induced a cycling of induction and breaking of secondary dormancy. The emergence was inversely proportional to the depth of burial. The emergence was observed only for seed buried within the first 5 cm of soil profile. The number of weed plants reaching the host was exclusively influenced by the distance between weed and crop and was independent on host phenological stage. Weed tropism towards host was due to the perception of light (far-red) transmitted by green parts of sugarbeet plants. On the contrary, the parasitization of the hosts (emission of haustoria by *C. campestris*) was heavily influenced by host phenological stage. The results suggested that *Cuscuta* preferably parasitized hosts with high chlorophyll content. Finally, the germination of *Cuscuta* seeds after a 12 years was approximately 15%, evidencing the persistence of this parasitic weed.

## GROWING DEGREE DAYS - A PREDICTIVE TOOL FOR *OROBANCHE* SPP. PARASITISM IN CERTAIN CROPS

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Temperature is strongly related to the dynamics of *Orobanche* spp. parasitism on its hosts. In previous studies, we have described the relationship between temperature and the parasitism process of *O. aegyptiaca*, *O. minor*, and *O. cumana*, in tomato, red clover, and sunflower, respectively. Temperature data collected from studies conducted under controlled conditions and in the field were converted to growing degree days (GDD). Reanalysis of the data from those studies enabled us to develop a predictive model for the parasitism dynamics based on GDD for *O. aegyptiaca*, *O. minor*, and *O. cumana*, in tomato, red clover, and sunflower, respectively. *Orobanche* development was classified into stages according to the sizes: S1 - 1 to 2 mm; S2 - 3 to 4 mm; S3 - 5 to 10 mm and S4 - greater than 10 mm including shoots. The predictive models were developed independently for each host based on the temperature range that reflects climatic conditions during the crop season. The model predicts lag, log and maximum phase for the four parasitism stages in relation to GDD in all the three crops. The model was validated and confirmed in field experiments. In future related studies, the proposed predictive models might benefit us as base models that will be used to optimize chemical control of the parasite and to alter sowing dates in order to avoid or reduce parasitism rate.

**WATER RELATIONS AND DEVELOPMENT OF THE EUROPEAN MISTLETOE *VISCUM ALBUM* L.**

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*Viscum album* L. is a hemiparasitic flowering plant. The development of its endophytic system has not been described in detail until now. Classical light microscopical methods and high resolution 3D X-ray computed tomography were used on poplar (*Populus x canadensis* Moench, Salicaceae) infected with mistletoe (*Viscum album* L., Viscaceae) to understand water flow and development of the endophytic system. Short, broad xylem elements in the haustorium of the mistletoe form direct vessel-vessel connections at the interface host-mistletoe. They facilitate water transport to narrow xylem elements, which transport water longitudinally, before bending radially outwards and forming a central cord to the aerial parts of the mistletoe. The position of the meristematic area depends on the developmental phase the haustorium is in. The mistletoe develops the central cord of xylem elements in direction of the hosts wood. When it reaches the vascular cambium of the host, the intercalary meristem merges with the meristematic tissue forming this central cord. In this way it connects, in older mistletoes, the vascular cambium of the host with that of the mistletoe. Therefore, it does not only enable longitudinal, but also radial growth of the haustorium. Three dimensional reconstructions were made to visualize the endophytic system. Plans for further research are described.

## **Parasitic weeds control**

### **OROBANCHE AEGYPTIACA CONTROL IN TOMATO**

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*Orobanche aegyptiaca* is the most troublesome weed on processing tomato in Israel. Recently, *O. aegyptiaca* parasitism in tomato was also reported in other Mediterranean countries such as Turkey, Greece and Italy. Experiments conducted in pots under greenhouse conditions indicated that three foliar applications of MON 37500 (sulfosulfuron 75%) at 50 or 100 g/ha control effectively and selectively *O. aegyptiaca* parasitizing tomato. It was also determined that foliar applications must be followed by upper irrigation in order to activate the herbicide. In the present study we tested the efficacy of MON37500 to control *O. aegyptiaca* on tomatoes in the field. Additionally, the efficacy of activating the herbicide by sprinkler or moving pivot irrigation methods was compared. Experiments were conducted in 5 locations with various levels of *O. aegyptiaca* natural-infested fields. Three sequential treatments of 80 g/ha sulfosulfuron 14 and 28 days after tomato seedlings establishment, resulted in excellent control of the parasite. *O. aegyptiaca* shoots decreased from 21 shoots/m<sup>2</sup>, in the non-treated control to 0.8/m<sup>2</sup> in the treated plots. Tomato yield decreased accordingly, from 94 tons/ha in the treated plots to 56 tons/ha in the non-treated control. The same control efficacy was achieved when the herbicide was activated with sprinkler irrigation or by moving pivot.

### **CONTROL OF OROBANCHE CERNUA IN IMIDAZOLINONE-TOLERANT SUNFLOWER HYBRIDS**

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Sunflower breeding for tolerance to imidazolinone-based herbicides began in 1997, and many sunflower seed companies and institutes are actively developing so-called Clearfield\* sunflower hybrids tolerant to imidazolinone-based herbicides. Clearfield\* production system for sunflower holds a lot of promise, including possibility of selective *Orobanche cernua* control.

Field trials were conducted during 2001-2003 in northern Serbia to determine efficacy of imidazolinone-based herbicides on *Orobanche cernua* in Clearfield\* sunflower hybrids. Used in the study were experimental hybrids from Nidera, Mycogen and commercial hybrid Rimi 2 from Institute of Field and Vegetable Crops. The following herbicides were studied: imazamox (20-48 g a.i. ha<sup>-1</sup>) and imazamox + imazapyr (33-39.6 + 15-18 g a.i. ha<sup>-1</sup>). Field studies focused on effects of herbicides and application timing (from one to eight pairs of sunflower leaves) on crop tolerance and *O. cernua* control.

The efficacy of the herbicides in *O. cernua* control reached 100% at the time of sunflower flowering. At harvesting, the efficacy either remained the same or dropped a few percent depending on herbicide rates and time of application. Application of herbicides at the later stage of sunflower growth proved more effective. The yields obtained in the untreated check were significantly lower than those obtained in the treatments with herbicides. The phytotoxicity of the herbicides was transient and acceptable.

Our results are indicative of the significant advancement and possibility *O. cernua* i control by growing imidazolinone-tolerant sunflower hybrids and application of imazamox and imazamox + imazapyr.



## UTILIZING HERBICIDE-RESISTANT TOMATO TO MANAGE *OROBANCHE AEGYPTIACA*

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*Orobancha aegyptiaca* is one of the most serious hindrances in tomato production throughout the Mediterranean region. Previous studies have shown that glyphosate applied onto a host crop effectively controls *Orobancha* spp. by rapid translocation and accumulation in the root-attached parasite. However, susceptibility of host crops to glyphosate has been an obstacle in application of this approach. Preliminary studies were conducted with tomato line 1232, engineered with the plasmid pMON894, encoding a glyphosate-tolerant form of the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS). A single foliar treatment of glyphosate (540 g ae/ha) was applied on glyphosate-resistant tomato (GRT) plants 14, 24 or 34 days after planting (DAP). Glyphosate applied at 14 DAP caused severe damage to tomato flowers and prevented fruit set but did not control late *O. aegyptiaca* inflorescences development. Glyphosate applied at 24 DAP controlled 98% of *O. aegyptiaca* but caused damage to tomato plants and flowers, resulting in 39% reduction in tomato fruit yield compared to the non-treated control. The late treatment (34 DAP) caused only slight damage to tomato plants and completely controlled *O. aegyptiaca*, resulting in a two-fold increase in tomato fruit yield over the non-treated control. This study exhibits the potential of timely applied glyphosate in GRT for effective *Orobancha* control. Further studies are in progress to determine effective application rates and timing.

## STRIGA WEED CONTROL IN MAIZE USING HERBICIDE SEED COATING TECHNOLOGY

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CIMMYT and Weizmann Institute of Science has developed a unique approach for *Striga* control in maize. It combines low-dose of a systemic acetolactate synthase (ALS)-inhibiting herbicide seed coating applied to imidazolinone-resistant (IR) maize seed that leaves a field virtually clear of emerging *Striga* flower stalks season-long. This maize allows application of high localized herbicide levels on or near the crop seed, but a dose a tenth that would be used as a spray application. On-station and on-farm studies over several seasons in Eastern and Southern Africa demonstrate 30 - 45 g/ha imazapyr are optimal for seed coating for effective *Striga* control in various environments. Low-dose herbicide seed dressing on IR-maize also controls *Striga* without impacting sensitive intercrops when they are planted 15 cm or more from maize hills. This allows small-scale farmers to continue intercropping while using maize seed treated to control *Striga*. This technology increases yields in *Striga* infested fields greater than three-fold at an effective cost of less than US\$4 per hectare. The added cost of this 1 ton/ha added yield is equivalent to about 25-50 kg/ha maize yield depending on market prices, suggesting potential benefit:cost ratios >25:1, even under the least favorable circumstances. This technology coupled with pulling rare *Striga* escapes (some of which could be resistant to the herbicide) can deplete the *Striga* seedbank reducing infestation of susceptible rotation crops, delaying the evolution of resistant populations and be used as a stopgap until genetic crop resistance becomes available. CIMMYT breeding activities has produced high yielding and disease resistant IR-maize inbred lines, hybrids, and open pollinated varieties adapted in *Striga* infested agro-ecologies in sub-Saharan Africa will soon be available.

## USE OF INBREEDING TO IMPROVE RESISTANCE TO *STRIGA*

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*Striga* is a parasitic weed posing a serious threat to maize production in sub-Saharan Africa. *Striga hermonthica* (Del.) Benth is the most widespread species affecting maize and other cereals in Africa. Most tropical maize varieties are susceptible to this parasite and may suffer 100% yield loss under heavy infestation. IITA has used inbreeding as a tool for improving resistance/tolerance to *striga* in tropical maize. Repeated screening of lines from diverse germplasm in the field and in the screen house under artificial *striga* infestation has yielded resistant inbred lines. Some of these lines evaluated for three years exhibited significant differences in the number of *striga* plants attached to the roots in pots and in the number of emerged *Striga* plants on ridges in the screen house. The number of *striga* plants attached to the roots in pots was positively correlated with *striga* damage symptom rating ( $r=0.51-0.61$ ,  $p<0.01$ ) and number of emerged *striga* plants ( $r=0.76-0.79$ ,  $p<0.0001$ ) in the field. The number of emerged *striga* plants in the screen house was also positively correlated with the number of emerged *striga* plants ( $r=0.82-0.85$ ,  $p<0.0001$ ) in the field. We found some inbred lines with many *striga* plants attached to the roots that supported few emerged *striga* plants, suggesting that different mechanisms of resistance to *striga* may exist in this set of inbred lines. Evaluation of diallel crosses of some resistant inbred lines in Nigeria and Benin Republic under *striga* infestation for two years, also showed that the inbred lines combined positive GCA values for grain yield with negative GCA values for *striga* damage symptom rating and number of emerged *striga* plants. In another recent study, synthetic varieties formed from *striga* resistant inbred lines supported lower number of emerged *striga* plants and produced higher grain yield under *striga* infestation. These results suggest that inbreeding is effective in fixing alleles for resistance to *S. hermonthica* in maize.

## SEED TREATMENT TECHNOLOGY: AN APPROPRIATE DELIVERY SYSTEM FOR CONTROLLING *STRIGA* SPP. WITH *FUSARIUM OXYSPORUM* FOXY 2

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Coating sorghum seeds with *Fusarium oxysporum* Foxy 2 for *Striga* control seems an attractive option for minimizing the inoculum amount, establishing the biocontrol agent in the potential infection zone, and offering a simple, easy and economical delivery system. The coating materials tested were arabic gum (AG10, 20 40%), carboxymethylcellulose (CMC1%, 2%) and pectin (LS 440, LM-5 CS) 1%, while the fungal inoculum include fresh and dried chlamydo spores produced using different substrates and microconidia. Foxy 2 survived the seed treatment processing and showed excellent viability on seeds for at least 8 months of storage after coating. 40% arabic gum with dried chlamydo spores was the best inoculum and coating material tested. Regardless of the type and form of inoculum and coating materials tested, Foxy 2 was able to colonize all sorghum roots. Foxy 2 markedly reduced *Striga* emergence and dry weight and increased the percentage of the diseased emerged *Striga* shoots. Coating sorghum seed with dried chlamydo spore inoculum homogenized into 20% arabic gum (as adhesive) showed the highest efficacy of 81% and 77%, (i.e., percent reduction in healthy emerged *Striga* shoots) using either sterilized or non-sterilized soil, respectively. In root chamber bioassays, the application of Foxy 2 in combination with AG40% significantly caused disease in 77% of the germinated *Striga* seeds and in all tubercles after 25 days of sowing.

**ON-FARM TESTING OF *STRIGA HERMONTHICA* CONTROL TECHNOLOGIES IN THE  
NORTHERN GUINEA SAVANNA**

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An integrated *Striga hermonthica* control strategy may consist of a broad range of component technologies, such as crop rotations, plant host resistance, improved field management and biological control measures. In the present study, two *Striga* management practices were compared with farmers' traditional cereal-based cropping systems in two sets of farmer-managed trials in the northern Guinea savanna of Nigeria. The tested component technologies were cultivation of trap crops (soybean, groundnut and cowpea), which stimulate suicidal germination of *Striga*, and the use of *Striga*-tolerant maize varieties. The first set of trials compared an integrated *Striga* control with farmers' practice, while the second set contained two additional treatments to separate the effects of each component technology on *Striga* infection in maize. In 1999-2003, data on field management, effectiveness of *Striga* control and crop yields were yearly collected from 48 participating farms.

In both sets of trials, integrated control was highly effective in reducing *Striga* infection in maize, when compared with farmers' normal practices. No clear relation between nitrogen fertilizer application rates and *Striga* infestation was observed. The results of the second set of trials suggested that both component technologies (a legume trap crop and *Striga*-tolerant maize) were equally effective technologies for *Striga* control, but that combining the two technologies resulted in substantial synergistic effects. Thus, it was demonstrated that solely relying on *Striga*-tolerant maize as a means to control *Striga* was less effective and resulted in lower cereal yields than the integrated control.

## **POSTERS**

### **CHANGES IN GERMINATION OF OROBANCHE SEEDS IN RESPONSE TO CONDITONING TEMPERATURE AND PGR TREATMENTS**

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Broomrapes (*Orobanche* spp.) cause great damage to crop production, and their seeds have special germination requirements including pre-treatment in a warm moist environment for several days (conditioning) prior to the exposure to germination stimulants (GR<sub>24</sub> etc.). Experiments were conducted to investigate the germination response and viability of parasitic *Orobanche* seeds subjected to the treatments of various temperatures (13, 18, 23 and 28°C) and plant growth regulators during seed conditioning. The highest germination percentages (64.7%, 77.9% and 53.1%) were observed respectively in *O. aegyptiaca*, *O. minor* and *O. ramosa* seeds conditioned at 18 °C for 7 days following terminally germinated at constant 18 °C in the dark. GA<sub>3</sub> (30-100 mg/L), norflurazon and fluridone (10-100 mg/L), and brassinolide (0.5-1.0 mg/L) increased seed germination, while uniconazole low as 0.01 mg/L significantly reduced germination rates of three *Orobanche* spp. The promotive effect of GA<sub>3</sub> and norflurazon (10-50 mg/L) and inhibitory effect of uniconazole (0.05 mg/L) were evident even when they were treated for 3 days. Germination of *Orobanche* seeds was much lower when the unconditioned seeds immediately exposed to 10<sup>-6</sup> M GR<sub>24</sub>. This GR<sub>24</sub> induced inhibition, however, was alleviated or even eliminated by the inclusion of GA<sub>3</sub> or norflurazon (10-50 mg/L). On the other hand, the inclusion of uniconazole could aggravate this inhibition, particularly in the case of *O. ramosa* where no seeds were germinated when applied with 0.1 mg/L uniconazole.

### **CHARACTERIZATION OF PHOTORECEPTORS FROM OROBANCHE MINOR SM.**

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Holoparasitic plants, including *Orobanche* spp., had lost the photosynthetic ability and the photosynthetic genes have been lost or altered dramatically in some species. Light is not only used as energy for photosynthesis but also as signal to regulate plant development. Whether the photoperception systems are intact or not in the holoparasitic plants is not clear. Since light affects the conditioning and germination of *Orobanche minor*<sup>1</sup>, part of the photoperception systems seems to still remain in *O. minor*. There are three families of signal-transducing photoreceptors; red/far-red light-absorbing phytochromes and UV-A/blue light-absorbing cryptochromes and phototropins in higher plants. We cloned the phytochrome and cryptochrome homologous cDNA from *O. minor* and designated as *OmPHYA* and *OmCRY1*, respectively. Both of the deduced amino acid sequences of *OmPHYA* and *OmCRY1* showed about 70% sequence identity with those of the photosynthetic plants. From the Southern blot analysis, it was showed that either gene is a single copy in the genome of *O. minor*. The expression of the mRNAs of those photoreceptors was quantified by real-time RT-PCR under dark- and light-conditions. It was revealed that light affects those mRNA expression levels. *OmPHYA* fused with sGFP (*OmPHYA*:sGFP) was expressed in the protoplasts of *Arabidopsis thaliana* and onion epidermal cells to observe their subcellular localization. *OmPHYA*:sGFP was in the cytoplasm under the dark condition and moved to nucleus after irradiation of far-red light. These results indicate that those photoreceptors still have some functions in *O. minor*.

1. Chae, SH *et al.*, *Physiol. Plant.*, **120**, 328-37, 2004

## INFLUENCE OF SALINITY ON THE INTERACTION BETWEEN TOMATO AND *OROBANCHE CERNUA*

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Tomato seedlings (20- days old) were transplanted to *Orobancha cernua* infested and non-infested soils. All plants were maintained under 0, 25, 50 and 75 mM NaCl soil salinity levels throughout their growing period under greenhouse conditions. Plants grown in *O. cernua* infested soil and under 0, 25, and 50 mM NaCl salinity regimes showed significant reduction in their growth and their total soluble carbohydrate and protein contents in contrast with those grown in non-infested soil. However, under 75 mM NaCl salinity level all plants showed similar growth values whether they were grown in *O. cernua* infested or non-infested soil. Starting at the fifth and through out the eightieth week after transplantation there was a significant increase in plant height in the control, 25 and 50 mM NaCl irrigated plants over other treatments. Irrigation with either tap water (control) or 25 mM NaCl solution didn't significantly affect the number of *O. cernua* shoots (4.8 and 5.2 shoots) and number of attachments (11.2, 11.0 attachments). However, irrigation with 50 mM NaCl significantly reduced the emergence of *O. cernua* (2/plant) and the number of attachments (4.4 attachments). Furthermore, irrigation with 75 mM NaCl resulted in complete elimination of *O. cernua* emergence.

## EFFECTS OF NUTRIENTS ON THE PRODUCTION OF GERMINATION STIMULANTS

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Broomrapes (*Orobancha* spp.) are root holoparasites causing enormous damage to agricultural production in large parts of the world. Seeds of broomrapes germinate only when they perceive germination stimulants produced by and released from the host and non-host roots. Broomrapes prevail on nutrient-deficient soils and their emergence is suppressed by the application of fertilizers. In fact, we have shown that nutrients did affect germination stimulation activity of root exudates of red clover (*Trifolium pratense* L.), a host of clover broomrape (*O. minor* Sm.). However, nutrients may affect the production of germination inhibitors as well. In the present study, effects of nutrients (N, P, K, Ca, and Mg) on stimulant production were examined with red clover plants grown hydroponically. Among the stimulants produced by red clover, orobanchol was quantified using the HPLC / tandem mass spectrometry (LC/MS/MS).

**BLUE LIGHT INDUCED CHANGES IN INOSITOL 1,4,5-TRISPHOSPHATE IN DODDER  
(*CUSCUTA CAMPESTRIS*) SEEDLINGS**

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Dodder (*Cuscuta* spp.) is one of the most dangerous and fastest spreading parasite in potato and tomato producing areas of Lebanon and in several Middle Eastern countries. Being an obligate stem parasite, young dodder seedlings use the light environment to detect and parasitize leaves and stems of various herbaceous dicots, where they develop haustoria that are essential for survival. Previous studies revealed that blue light stimulates and red light inhibits prehaustoria development in young dodder seedlings. In this study, evidence was obtained for the involvement of inositol 1,4,5-trisphosphate (IP<sub>3</sub>) in the mediation of prehaustoria development, prior to host attachment, to blue light. Blue light induced a significant increase in the level of IP<sub>3</sub>, with a peak at about 30 min. Thereafter, the level of IP<sub>3</sub> declined to the resting value after 3 hours of blue light. Irradiation with 10 min red light pulse applied directly at the end of 0.5-4 h blue light significantly reduced IP<sub>3</sub>, while high levels of IP<sub>3</sub> were observed after 10 min far-red pulse. These studies are the first in vivo demonstration of a possible role for IP<sub>3</sub> as a second messenger in the blue light signal transduction process in prehaustoria development in dodder. At a more applied level, our results suggest that identifying the light signal transduction(s) of prehaustoria development may provide novel targets for weed scientists through altering or knocking out this pathway.

**HOST RANGE OF BRANCHED BROOMRAPE (*OROBANCHE RAMOSA* L.) AMONG  
SOME CULTIVATED AND WILD GROWN PLANT SPECIES**

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Studies on the host range of *Orobanche ramosa* L. through screening different summer and winter crops, medicinal herbs, and a large number of weed species, for their possible attack by the parasite revealed great variation among species in their abilities to stimulate *Orobanche* seed germination and allow parasite attachment. *Datura metel*, *Ferula communis*, *Solanum incanum*, and *Rumex acetosella* were heavily infested weeds. Most attacked crops and medicinal herbs were *Cucurbita moschata*, *Apium graveolens*, *Carum carvi*, *Petroselinum sativum*, *Carthamis tinctorius*, *Capsicum frutescens*, *Capsicum annum*, *Trigonella foenum-graecum*, *Brassica oleracea* var. *Capitata*, *Brassica caulorapa* and *Trachyspermum ammi*. In contrast, weeds including *Convolvulus arvensis*, *Antirrhinum orontium*, *Carduus pycnocephalus*, *Diplotaxis eruroides*, *Papaver rhoeas*, *Polygonum aviculare*, *Ranunculus arvensis*, *Solanum conora*, *Solanum nigrum*, *Spergula arvensis*, *Urtica pilecifera* and *Urtica urens* showed extremely low infestation. Among crops, *Corchorus olitorus*, *Cucumis melo* var. *flexosus*, *Ammi visnaga*, *Brassica nigra*, *Brassica oleracea* var. *Botrytis*, *Daucus carota*, *Linum usitatissimum*, *Lupinus alba* and *Raphanus sativus* were the least infested. Results showed that *L. usitatissimum* can be considered as a trap crop, while *T. ammi* is a real catch species. However, many of the plant species tested were not attacked, suggesting different mechanism of resistance or lack of seed germination stimulants. Considering the number and size of *Orobanche* shoots great variations between species were found. Some of the reported trapping crops (e.g. *L. usitatissimum*, *C. frutescens*, *C. annum*, *T. foenum-graecum*, *Coriandrum sativum*, and *Brassica campestris*) were attacked. *L. usitatissimum* showed an extremely low infestation but other species were highly infested.

## IS HOST RANGE POTENTIAL RELATED TO GENETIC DIVERSITY IN *OROBANCHE* ?

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In previous reports we demonstrated significant and consistent inter-specific variations among the five major broomrape species in Israel. RAPD-based analysis was used to evaluate the magnitude of intra-specific genetic variability within *Orobanche* species with relation to inter-specific genetic distances.

When summing up all data collected from RAPD analysis using numerous different primers we found out that only 5% of the bands were polymorphic in *O. cumana* grown on sunflower, compared to 11% in *O. cernua* grown on tomato.

The intra-specific genetic distance rates found for *O. cumana* and *O. cernua* were however significantly lower than those found for *O. crenata* and *O. aegyptiaca*. Additionally, most of the genetic diversity within the latter two species was found among individuals rather than between geographically distant populations of each species.

Whereas sunflower is almost the only host for *O. cumana*, and *O. cernua* only attacks three plant species (tomato, eggplant, potato), *O. aegyptiaca* and *O. crenata* are known to attack a large variety of host plants from different plant families. Accordingly, a correlation was found to exist between the intra-specific genetic diversities and host-range potentials in the weedy species of *Orobanche*.

## OSYRIS ALBA OCCURENCE IN JORDAN: NEW HOSTS AND IMPORTANCE

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A field survey carried out during the period from 2002 to 2003 revealed the presence of *Osyris alba* L. a root hemi-parasitic weed of Santalaceae on 19 plant species belong to 13 botanical families in the central part of Jordan. Host plants including perennial woody herbs, forest trees and fruit trees of high economic importance. New host species were added to our existing knowledge on host list of this parasite. Among the most affected fruit trees are olives (*Olea europea* L.), grapes (*Vitis vinifera* L.), almonds (*Prunus amygdalus* L.) and figs (*Ficus cariaca* L.), and of forest trees are *Cupressus sempervirens* L., *Acacia cyanophylla* Lindl and *Casuarina equisetifolia* L. The distribution of the parasite and its intensity of infestation on different hosts were also recorded. The work represent the first record on this parasite and its hosts in the country and reflects the parasite physiological tolerance and adaptability to different host plants differ in their growth habit and physiology, among which certain common weeds or wild species such as *Sarcopoterium spinosum* (L.) Spach. may be considered as a potentially high candidates in increasing the infested area in the country. The work casts a lot of doubt on the local farmers awareness of the problem.

## VARIATION IN THE RESPONSE OF RESISTANT SUNFLOWER TO *OROBANCHE CUMANA* POPULATIONS IN ISRAEL

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*Orobancha cumana* parasitizes sunflower in Israel. In recent years, several resistant sunflower varieties were bred in Israel and reduced the damage caused by *O. cumana*. No differences in *O. cumana* response to the resistant sunflower varieties was identified until 1999. Studies indicated that only race C was present in Israel, with very low inter- and intra-specific diversity. However, in 2000 *O. cumana* infected the resistant sunflower 'Ambar' in two fields in the northern part of Israel. In 2001 and in 2002, *O. cumana* parasitized resistant sunflowers in three more fields. In order to determine the virulence of *O. cumana* toward the resistant sunflower varieties under controlled conditions, five populations of the parasite were collected from fields in which resistance was broken. Another *O. cumana* seed lot, which was collected on susceptible sunflower in Alonim in 1997 and that does not infect the resistant sunflower varieties served as a reference. The resistant Sunflower cultivar 'Ambar' and the susceptible cultivar 'D.Y.3' were separately planted in pots that were pre-inoculated with seeds of the various *O. cumana* populations. *O. cumana* from Alonim (our reference) failed to attack the resistant sunflower in all pots. However, three virulence levels were found for the three *O. cumana* population originating from the other fields. In the current note we report for the first time on the occurrences of a new virulent race(s) of *O. cumana* in Israel.

## IDENTIFICATION OF RESISTANCE MECHANISMS OF SOME SORGHUM VARIETIES TOWARDS *STRIGA HERMONTHICA*

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The integrated control of *Striga* recommends several components of which notably the use of resistant varieties. A fundamental question remains always unresolved: which is the demonstration of the resistance? It is then crucial to identify the resistance mechanisms of some varieties in order to improve the breeding outputs. The objective of the study is to rule on the behavior of some sorghum varieties towards *S. hermonthica* by identifying the mechanisms of resistance. The method of in vitro culture, Lane *et al.* (1991) was used to appreciate the behavior of every variety under artificial infestation of *Striga*. This method consists in growing host plants in oblong culture boxes containing GF/A paper and the nourishing solution. The method of outdoors culture in jars containing sterile soil mixed with sorghum and *S. hermonthica* seeds, confirms the results already obtained with the culture in vitro. Varieties CMDT-45, 97-SB-F5D5-63 and Ntenimissa gave for the test in vitro *Striga* which stayed in stages of forming haustorium and endophyte. The highest rate of necrosis, 39%, is obtained with Malisor-84-1. The test of opened air culture reveals that *S. hermonthica* makes a late emergence, 67 days after sowing with variety CMDT-45 and 97-SB-F5D5-63. The study reveals CMDT-45 and 97-SB-F5D5-63 as the most resistant varieties towards *S. hermonthica*. In addition, varieties CMDT-45, 97-SB-F5D5-63, Ntenimissa and Malisor-84-1 can be used in breeding program with the aim of the use of their various mechanisms of resistance to *S. hermonthica* in the creation of new varieties of sorghum.



## INTEGRATED MANAGEMENT OF *OROBANCHE MINOR* IN *TRIFOLIUM PRATENSE*

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Since the discovery of *Orobancha minor* in red clover (*Trifolium pratense*) fields in the USA in 1998, there has been a concerted effort to develop an integrated management system for its control. The biology of *O. minor* prevents the use of only one weed control tactic; therefore, biological based practices were combined with chemical weed control. Wheat (*Triticum aestivum*) was found to be a false host that stimulated germination of *O. minor* seed; however, *O. minor* does not attach and develop on wheat. Therefore, wheat can be used to reduce the *O. minor* seed bank. Imazamox herbicide provided effective *O. minor* control with sufficient crop safety. Optimal herbicide application timing is difficult given that *O. minor* attached to red clover remains below ground for several months prior to emergence. Consequently, a growing degree day model for *O. minor* development was constructed and will be used to determine the optimum herbicide application timing based on *O. minor* attachment and early growth. The commercialization of imazamox resistant wheat provided another possible control option. Imazamox resistant wheat was interseeded with red clover with the expectation that the wheat will cause suicidal germination of the *O. minor*. In addition, imazamox can be sprayed over the wheat and red clover without killing either crop but would control any *O. minor* that had attached to the red clover. The integrated *O. minor* management system will improve *O. minor* control and maintain a viable cropping system for red clover producers.

## NATURAL TOLERANCE OF *CUSCUTA* SPP. TO HERBICIDES INHIBITING AMINO ACID BIOSYNTHESIS

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*Cuscuta* spp. are non-specific above-ground holoparasites that can cause significant yield reductions. Control of this parasite is difficult, but herbicide resistant crops might be used to manage *Cuscuta* spp. Assays with isolated *C. campestris* segments indicate that two key enzymes in the biosynthesis of amino acids (acetolactate synthase and 5-enolpyruvylshikimate-3-phosphate synthase) are present in the parasite. Dose response assays on *Cuscuta* spp seedlings in the absence of a host showed that *C. campestris*, *C. gronovii* and *C. subenclusa* were much more tolerant to glyphosate than the seedlings of sorghum and RR canola. *C. campestris* seedlings were also tolerant to imazamox but not to glufosinate. In the greenhouse *C. campestris* was unaffected by glufosinate while growing on glufosinate resistant canola but glyphosate and imazamox inhibited the growth of the parasite growing on glyphosate and imidazolinone resistant canola. However, the parasite recovered after 3 weeks, suggesting that it is tolerant to these herbicides.

## CEREAL-LEGUME ROTATION TO CONTROL *STRIGA* AND IMPROVE ON-FARM YIELD OF MAIZE IN NORTHERN GUINEA SAVANNA: I. EFFECTS OF ONE-YEAR ROTATION

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On-farm trials were conducted in 2001 and 2002 in the northern Guinea savanna of Nigeria to evaluate integrated *Striga hermonthica* control measures under farmer-managed conditions. These included intercropping a *Striga*-resistant maize variety with cowpea and also cropping this maize in rotation with legume trap crops – soybean and cowpea. Intercropping *Striga*-tolerant maize variety, Acr. 97TZL Comp. 1-W, with cowpea (*Vigna unguiculata* L.) or rotating it with the soybean (*Glycine max* (L) Merr.) cultivar TGX1448-2E) or cowpea cultivar IT93K452-1 proved effective in reducing *Striga* incidence and infestation compared with two years of continuously cropped maize as control. However, maize grain yield was considerably reduced when intercropped with cowpea, probably due to competition effects from the cowpea crop. Maize grown after soybean had increased grain yield of 28% compared with the control. After cowpea, the yield increase was 22%. This was due to a reduction in *Striga* infestation and damage, and increased N supply to the subsequent maize crop.

## MANAGEMENT OF *CUSCUTA* IN TOMATO WITH RESISTANT VARIETIES AND HERBICIDES

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*Cuscuta* (dodder) is a parasite that attacks a wide range of host species, including tomatoes. The dodder seedling coils around the host stem, penetrates its tissue and vascular system, and exploits the host by withdrawing nutrients and water. Thus, the vigor of the host is lowered and tomato production is reduced from 25 to 75%. The objectives of this study were to evaluate several tomato varieties for tolerance to field dodder (*Cuscuta pentagona*) and to test three sulfonylurea herbicides for selective post-attachment control of dodder in tomatoes. Several tomato varieties have been observed to have some level of dodder resistance. Greenhouse and field studies were conducted to compare growth and yield of these varieties along with known susceptible varieties. Additionally, tomatoes with attached dodder, was treated with various rates of rimsulfuron, halosulfuron, or sulfosulfuron, to assess selective dodder control. Four tomato varieties were confirmed as having resistance to dodder – H9492, H9553, H9992, and H9888 – all from Heinz Seed company. Dodder was observed to coil around these varieties, but attachment was either not successful or very poor as indicated by poor dodder growth. In field trials, dodder growth in these varieties was very limited and dodder seed production was reduced by over 90%. Sulfosulfuron treatment at 60 g/ha resulted in over 70% dodder control at harvest, while halosulfuron and rimsulfuron were not effective. The combination of resistant tomato varieties and sulfosulfuron treatment resulted in over 95% field dodder control, with no loss in crop yield.

## THE EFFECT OF ARBUSCULAR MYCORRHIZA (AM) FUNGI ON THE CONTROL/MANAGEMENT OF *STRIGA HERMONTHICA* IN SORGHUM

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In a pot experiment, the effect of arbuscular mycorrhiza (AM) fungi species was investigated for the potency of various fungi for the control of *Striga hermonthica* (Del.) Benth. in sorghum (*Sorghum bicolor* (L.) Moench). There were five AM fungi species tested – *Glomus intraradice*, *G. albidum*, *G. mosseae*, *G. fasciculatum* and *G. etunicatum*, which were infested with *S. hermonthica* seed plus without AM fungi + *Striga* seed and without both AM fungi and *Striga* seed as check and control treatments, respectively. A tolerant sorghum variety – Warwabashi was used. These treatments were laid out in a randomized complete block design (RCBD) replicated 6 times, which were kept in a conditioned growth chamber. The results showed that *Striga* emergence on sorghum was significantly reduced by *G. mosseae* and the growth and total dry matter yield of sorghum were increased compared with the rest of the AM fungi species, but comparable to the control treatment. This study indicates that AM fungi have the potential to reduce damage by *S. hermonthica* on sorghum. The results are therefore potentially important for soil management, as perhaps the breeding for resistance to *S. hermonthica* could have consequences for mycorrhizal responsiveness of sorghum. It could be necessary to compare various sorghum cultivars that differ in *Striga* tolerance for mycorrhizal responsiveness.

## INDUCED RESISTANCE: AN EFFECTIVE METHOD FOR THE CONTROL OF PARASITIC WEEDS?

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Parasitic weeds of the genera *Orobanche* and *Striga* are serious pests and cause significant yield losses in various crops. Because of their life strategies that are intimately coupled with the development of the host plant these weeds are difficult to control by means of e.g. herbicides. Hence there is a need for the development of efficient control strategies. In recent years methods based on induced resistance (IR) had been successfully developed in order to control bacterial, fungal or viral plant pathogens. IR is based on the activation and strengthening of natural resistance mechanisms in crops by either salicylic acid like chemicals (systemic acquired resistance, SAR) or plant growth promoting rhizobacteria (induced systemic resistance, ISR). We could show that IR is protecting crops efficiently against infestation with parasitic weeds. Application of IR inducing chemicals or microorganisms reduced the infestation of sunflower with *O. cumana* to 98% as well as the infestation of tobacco and tomato with *O. ramosa* to 84% and 80% respectively. Especially analogs of salicylic acid proved to be efficient resistance inducing agents and can be used either on their own or in combination with other control methods in an integrated *Orobanche* management strategy. However, induced resistance stimulated with the evaluated products is not effective to control *Striga hermonthica* in maize or sorghum.

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