ALLELOPATHIC CROPS – A CHALLENGE FOR WEED MANAGEMENT

Alelopatické plodiny – výzva pro regulaci plevelů

Karl HURLE, Regina G. BELZ

UNIVERSITY OF HOHENHEIM, DEPARTMENT OF WEED SCIENCE, STUTTGART, GERMANY

Summary

Crops that are sufficiently allelopathic to reduce the need for synthetic herbicides offer promising new options for weed management. To date, efforts to breed crops that fight weeds have been of little or no interest due to methodical limitations. Today new technologies, such as molecular biology, offer a mean to impart allelopathic traits to generate highly allelopathic crops which may allow significant reductions of other weed management options.

allelopathy, allelochemical, herbicide, natural products, weed management

Introduction

Natural product-based pesticides are widely used in plant protection, whereby the discovery of toxins for weed management has not been as successful as for insect or plant pathogen management. Phytotoxins can be used for weed management either directly as natural herbicides or as allelochemicals produced by crops. While some naturally occurring phytotoxins are already successfully used as herbicides, the allelopathic delivery of phytotoxins by crops still plays a very little role in weed management of annual crops. Currently, with the development of new technologies, the allelopathic suppression of weeds either by cover crop- or crop-generated allelochemicals as a possible component of an integrated weed management is receiving increased attention worldwide.

Crop allelopathy in weed management

Crop allelopathy can be exploited to manage weeds by the release of allelochemicals from decomposition of plant residues or from intact roots of living plants. In weed management of annual crops, root exudation of the allelochemicals by the crop is the preferred mechanism.

The concept. By use of crop cultivars provided with a built-in herbicidal system capable of producing and releasing sufficient amounts of phytotoxic allelochemicals to interfere with competing weeds, the use of other weed management options, including synthetic herbicides, can be reduced. Through season-long weed suppression by crop cultivars with elevated allelopathic activity, crop competitiveness is efficiently improved to allow a reduction of the over-reliance on traditional herbicides.

Rationale. Several studies demonstrate the selective nature of allelopathy (e.g. Olofsdotter and Navarez 1996, Dilday et al. 1998, Hassan et al. 1998). In a typical agricultural setting, allelopathy alone could therefore not control all present weeds and should be rather considered to be a component of the overall weed management strategy (Wu et al. 1999). Although some reports confirm that weed suppression by crop allelopathy is actually taking place, so far the degree of weed suppression allows only in some cases a reduction in herbicide application. Therefore herbicides will continue to be a key component of most integrated weed management systems in the near future (Nagabhushana et al. 2001).

Engineering allelopathic crops. To increase allelochemical production to levels effectively controlling weeds, strongly allelopathic crops are needed. The initial step towards the development of allelopathic cultivars in breeding programs is the evaluation of crop germplasm for cultivars that are likely sources of high allelopathic activity. Corresponding screening programs were recently done for e.g. rice (Fujii 1992, Dilday et al. 1994, 1998, Olofsdotter and Navarez 1996), wheat (Spruell 1984, Wu et al. 2000), and oat (Fay and Duke 1977). The following steps are the identification of the allelochemicals involved, the determination of critical enzymes or key genes for allelochemical synthesis, regulation, tissue-specific production and secretion, completed with the manipulation of genes associated with allelochemical production or secretion by traditional breeding or transgene technology (Duke et al. 2000). There are two fundamental approaches for generating a more allelopathic crop. The most obvious is the enhancement of an existing pathway of an allelochemical. Since the whole or parts of the biosynthetic pathway of the phytotoxic hydroxamic acids in rye and maize, or of sorgoleone in *Sorghum* spp. is already known, they are good candidates for the enhancement of the production of existing allelochemicals (Duke et al. 2001). The second approach is the impartment of the biosynthesis of a new compound that the species does not make, by the introduction of either a one-step conversion of an existing compound or a whole new multi-enzyme pathway (Duke et al. 2001).

Status. Currently, crop allelopathy plays a very little role in weed management of annual crops and the allelopathic activity of only a few crops, e.g. rye is to some extend used (e.g. Barnes and Putnam 1983, Shilling et al. 1986, Pérez and Ormeño-Nuñez 1993, Fujii 2001). There appears to be little or no interest in genetically engineering of allelopathic crops and a highly allelopathic crop variety has not yet been developed by traditional breeding. Modern biotechnological approaches might be more successful, but so far genetic manipulations targeting allelochemical pathways are at a very preliminary stage (Duke et al. 2002).

Up to now efforts to manipulate allelochemicals in crops have been largely unsuccessful, since imparting such traits in crops with traditional breeding methods proved to be extremely difficult. Even though modern biotechnology provides the tools needed for a genetic manipulation, there is still a lack of identified gene sequences encoding the biosynthetic enzymes. The following isolation and amplification or transfer of critical

genes into another species is a likewise major challenge to molecular biology (Duke et al 2001, 2002).

Future trends. Currently, there is a growing international interest in producing allelopathic crops and strategies for transgene approaches have been proposed. Undoubtedly efforts towards the genetic manipulation of allelochemical pathways are at a very preliminary stage and still face numerous difficulties, but there are some promising strategies for the manipulation of pathways and moreover modern biotechnology now provides the tools needed to implement highly allelopathic crops.

Research in the field of crop allelopathy for weed management may therefore presumably follow biotechnological approaches resulting in highly potent transgenes.

Conclusions

The idea of exploiting allelopathy for weed management has a long tradition. In recent years crop allelopathy attracted growing attention and the potential of allelopathic suppression of weeds proved to be substantial. Crops being sufficiently allelopathic to control weeds offer challenging new options for weed management and would be an efficient enrichment of integrated weed management strategies. In the past the concept of allelopathic crops struggled with methodical limitations and therefore, was paid only little attention. Today advancements of modern biotechnology offer the tools for the development of strongly allelopathic crops via gene manipulation, allowing an effective weed management with reduced herbicide input or even without herbicides (Duke et al. 2000).

Without doubt, allelopathic crops are a future challenge for biotechnology, but new technologies and strategies are now available to make significant progress in this area and may leverage allelopathic crops as a new option to manage weeds.

References

Barnes, J.P., Putnam, A.R.: Journal of Chemical Ecology 9 (8): 1045-1057, 1983.

Dilday, R.H., Lin, J., Yan, W.: Australian Journal of Experimental Agriculture 34: 907-910, 1994.

Dilday, R.H., Yan, W.G., Moldenhauer, K.A.K., Gravois, K.A.: Allelopathy in rice (Ed. M. Olofsdotter), 7-26, 1998.

Duke, S.O., Bearson, S.R., Dayan, F., Kagan, I.A., Michel, A., Scheffler, B.E.: NATO Awarded Research Workshop: Enhancing Biocontrol Agents and Handling Risks, 96-105, 2001.

Duke, S.O., Dayan, F.E., Romagni, J.G., Rimando, A.M.:Weed research 40:99-111, 2000.

Duke, S.O., Rimando, A.M., Baerson, S.R., Scheffler, B.E., Ota, E., Belz, R.G.: Journal of Pesticide Science 27: 298-306, 2002.

Fay, P.K., Duke, W.B.: Weed Science 25: 224-228, 1997.

Fujii, Y.: Proceedings of International Symposium on Biological Control and Integrated Management of Paddy and Aquatic Weeds in Asia, 305-320, 1992.

Fujii, Y.: Journal of Crop Production 4 (2): 257-275, 2001.

Hassan, S.M., Aidy, I.R., Bastawisi, A.O., Draz, A.E.: Allelopathy in rice (Ed. M. Olofsdotter), 27-38, 1998.

Nagabhushana, G.G., Worsham, A.D., Yenish, J.P.: Allelopathy Journal 8 (2): 133-146, 2001.

Olofsdotter M., Navarez, D.C.: Proceedings of the Second International Weed Control Congress, 1175-1181, 1996.

Pérez, F.J., Ormeño-Nuñez, J.: Weed Research 33, 115-119, 1993.

Shilling, D.G., Worsham, A.D., Danehower, D.A.: Weed Science 34, 738-744, 1986.

Spruell, J.A.: Dissertation Abstracts International, B Sciences and Engineering 45: 1102B, 1984.

Wu, H., Pratley, J., Lemerle D., Haig, T.: Weed Research 39: 171-180, 1999.

Wu, H., Pratley, J., Lemerle D., Haig, T.: Australian Journal of Agricultural Research 51: 937-944, 2000.