EFFECT OF TEMPERATURE AND CHEMICAL ADDITIVES ON THE EFFICACY OF THE HERBICIDES GLUFOSINATE AND GLYPHOSATE IN WEED MANAGEMENT OF LIBERTY-LINK® AND ROUNDUP-READY® SOYBEANS

by

Wendy A. Pline

Kriton K. Hatzios, Chairman

Plant Pathology, Physiology and Weed Science

ABSTRACT

The introduction of herbicide resistant crops offers producers many more options for weed control systems. These crops allow environmentally safe, non-selective herbicides to be used as selective herbicides, broadening the spectrum of weeds controlled, while not harming the crop. As these crops are very new on the market, investigation of their performance under various environmental conditions as well as in various weed control programs is needed. Liberty-link® soybeans are resistant to the herbicide glufosinate, because of the incorporation of a gene encoding phosphinothricin acetyl-transferase (pat), which is able to detoxify glufosinate. Roundup-Ready® soybeans are transformed with an altered, non-sensitive form of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), which confers glyphosate resistance. Field and greenhouse studies were conducted to determine the efficacy of glufosinate and glyphosate on annual and perennial weeds. Also to determine whether the use of ammonium sulfate (AMS) or pelargonic acid (PA), a 9-carbon fatty acid, as additives of glufosinate or glyphosate would increase their efficacy, while maintaining their safety on the transgenic soybeans. Three annual weeds: common lambsquarters, giant foxtail, sicklepod, as well as two perennial weeds: common milkweed and horsenettle were included in studies. Uptake, translocation, and metabolism of 14C-glufosinate + AMS or PA, were studied in the five weeds in order to determine the basis for their differential
weed sensitivity to glufosinate, and the effect of the two additives. The effect of
temperature on Liberty-Link® and Roundup-Ready® soybeans after application of
glufosinate or glyphosate was investigated. Injury was quantified by measuring
chlorophyll content of herbicide treated soybean trifoliates. Uptake, translocation, and
metabolism studies of $^{14}$C-glufosinate and $^{14}$C-glyphosate in transgenic soybeans were
conducted to determine the potential cause for the observed temperature-dependent
sensitivity. Since glufosinate is a synthetic analog of a naturally occurring bacterial toxin,
it was tested for possible bactericidal activity on the soybean pathogen *Pseudomonas syringae*. Greenhouse and field-studies showed that the 5 weeds responded differently to
glufosinate and glyphosate. Common milkweed was the most tolerant to glufosinate and
common lambsquarters to glyphosate while giant foxtail was the most sensitive species to
both herbicides. Some interactions between AMS or PA and glufosinate or glyphosate
were also observed. Uptake and translocation studies showed that AMS increased the
uptake of $^{14}$C-glufosinate in some weeds, whereas PA had only minimal effects on
absorption and translocation of glufosinate. Metabolism of glufosinate was detected only
in common lambsquarters. A rate dependent loss of chlorophyll in Liberty-Link®
soybeans treated with glufosinate was observed that was greater at 15° C than at 25° or
35° C. Metabolism studies showed a decrease in the rate of glufosinate metabolism 3
hours after treatment in Liberty-Link® soybeans grown at 15° C versus 25° C.
Conversely, chlorophyll loss in glyphosate-treated Roundup-Ready® soybeans was
greater at 35° C than at 15° or 25° C. Translocation studies showed a significantly
greater percentage of absorbed $^{14}$C-glyphosate translocated to developing meristems at
35° C than at 15° C in Roundup-Ready® soybeans. Glufosinate concentrations of 1 mM
and higher significantly inhibited the growth of *Pseudomonas syringae (L-529)* in liquid
media cultures. Typical field use rates of glufosinate also reduced the number of live *P.
syringae* on Liberty-Link® soybean leaves. Overall, the results of this research show that
annual and perennial weeds differ in their sensitivity to glufosinate and glyphosate.
Additives such as AMS and PA may enhance the efficacy of glufosinate on perennial
weed species, and glyphosate in most weeds. Differences in weed sensitivity to
herbicides and effects of additives can in most cases be explained by differences in
absorption or metabolism. Variable temperatures may affect the engineered resistance of
transgenic soybeans to the herbicides glufosinate and glyphosate. The herbicide glufosinate has some bacteriocidal activity on *P. syringae*.

ACKNOWLEDGMENTS

I sincerely thank Dr. Kriton K. Hatzios for the opportunity to study and conduct research at Virginia Tech in the Phytochemistry laboratory. I am very grateful for his advice, guidance, ideas, leadership, and understanding.

I would like to thank my committee members Dr. E. Scott Hagood, and Dr. John Hess for their ideas and suggestions through committee meetings, and one-on-one discussions, and for reading and editing the manuscripts and thesis.

Thank you to the Virginia Tech Graduate School for providing me with a Cunningham fellowship to pursue my M.S. degree, and to the Department of Plant Pathology, Physiology, and Weed Science for providing me with a departmental assistantship.

I extend a very special thank-you to Dr. Jingrui Wu for his daily guidance on laboratory procedures, interpretation of results, editing of manuscripts, and friendship.

Thank you to Dr. George Lacy for hours of advice and patience in teaching a weed scientist how to be a bacteriologist. Thank you Dr. Hagood, Claude Kenely, Kevin Bradley, and Steve King for their help with the planting and spraying of the field study. Thank you to Sue Meredith for help oxidizing, recording data, and friendship, and Verlyn Stromberg for all the expertise on bacteria.

I am in deep gratitude to my fellow graduate students in the PPWS department. Thank you Ivan Morozov and Donna Tuckey for being my daily support system and best friends. Thank you Kevin Bradley, Steve King, and Dan Poston for making work in the lab or the field thoroughly enjoyable, and also to the rest of the 1998 weeds team, Peter Sforza, Rob Richardson, and Greg Armel, for a fun and successful weed contest.

Thank you to Terry Wright and Dr. Donald Penner for encouraging me to go to graduate school in weed science.

A deep and sincere thank you to Goran Srnic’ for his understanding, patience, and love throughout these two years apart.

My deepest gratitude goes to my dad, Bruce, mom, Irene, brother, Kevin, and sister, Melissa who have not always understood what I was doing, but have supported me and loved me through all of it.