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Study of Behavioral Change of Western Corn Rootworm Beetle by Crop and Sex in Maize and Soybean Fields in Northwestern Indiana, USA

GY. BARNA[1], C. R. EDWARDS[2], J. KISS[1], C. GERBER[2] and L. W. BLEDSOE[2]

[1]Department of Plant Protection, Gödöllő University of Agricultural Sciences, Faculty of Agricultural Sciences, H-2103 Gödöllő, Hungary
[2]Department of Entomology, 1158 Entomology Hall, Purdue University, W. Lafayette, Indiana 47907-1158, USA

WCR adults generally lay their eggs in maize and their larvae feed almost exclusively on maize roots (Smith, 1966, Branson and Ortman, 1967, 1971, Branson and Krysan, 1981, Levine and Oloumi-Sadeghi, 1991). For this reason, farmers have accepted growing maize in rotation with soybean to manage WCR larval populations without the use of soil insecticides. Recently, in Northwest Indiana and East Central Illinois in the USA, western corn rootworm has adapted to the above management system (Gerber et al., 1997). A portion of WCR eggs is laid in soybean and in other crops like alfalfa. This behavioral change increases the potential for survival of WCR larvae the following year since most soybean fields are rotated to maize. During the summers of 1996, 1997, and 1998 field studies related to this behavioral shift were conducted in northwestern Indiana. Eleven pairs of maize/soybean fields were selected for the study. During these sampling periods, WCR beetles were present in both maize and soybean. Empirical observations show that there were higher numbers of females in soybean when compared to maize.

Key words: Western corn rootworm, *Diabrotica virgifera virgifera.*

Western corn rootworm (WCR) *Diabrotica virgifera virgifera* LeConte is the most serious insect pest of maize, *Zea mays* L. in the central midwestern states of the USA. The costs of soil insecticides for maize root protection plus yield losses due to failure to apply controls or to poor soil insecticide performance can approach US $ 1 billion annually. In certain regions of the Midwest, WCR larval damage to maize following soybean has recently been observed (Levine and Oloumi-Sadeghi, 1988, Edwards et al., 1996, Barna et al., 1998). Greater WCR oviposition was found in these soybean fields than expected. This behavioral change has not been seen in other areas of the USA, but the area of the infestation of this WCR “variant” is expanding (Sammons et al., 1997). Producing maize in rotation with soybean has been adopted widely by producers in the Midwest USA. One benefit of this crop rotation system has been the control of WCR larval populations without using insecticide, either soil applied for maize root protection or applied as a foliar treatment to control females, thus preventing economic egg laying. Sampling schemes and economic thresholds are available for eggs, larvae, and adult corn rootworms infesting maize planted after maize (continuous maize) (Levine and Oloumi-Sadeghi, 1991). No definitive sampling schemes or economic thresholds are presently available for use in soybean fields to determine if a control is necessary in the following year's maize crop (Boeve et al., 1996). Since western corn rootworms have adapted to the management system of growing maize in rotation with soybean, it is critical to determine the proper sampling technique(s) for WCR in soybean and to develop an economic threshold(s) to determine if WCR larval control is needed in the following year's maize.

Field studies were conducted in Indiana maize fields in 1996, 1997, and 1998 to evaluate the sex ratio and compare the appearance of adult male and female WCR in maize and soybean fields. Our basic hypothesis was that decision to treat for rootworm larvae in maize should be determined based on a critical population defined through monitoring of WCR adults in the previous soybean crop. To do this, the following questions had to be answered and serve as the objectives:

– Do WCR adults search soybean fields for egg laying sites and do larvae develop and damage the following crop, maize?

– Could data on adult numbers in the previous crop, soybean be used as model for prediction (compared to neighboring maize field data)? An additional objective, that being a comparison of male and female numbers in soybean and maize was added as a result of needing additional information to develop an economic threshold(s).

Materials and Methods

Eleven pairs of maize/soybean fields in 6 northwestern Indiana counties (White, Clinton, Newton, Jasper, Fountain, and Benton) were used in this study (Fig. 1). Field size varied from 12 to 45 hectares. Tillage, planting date, and crop inputs were not controlled as a part of this study.

Sampling of western corn rootworm:

Western corn rootworm populations were sampled weekly from 31 July to 3 September 1996, and from 28 July to 2 September 1997, and from 13 July to 7 September 1998 by using Pherocon AM® unbaited yellow sticky traps and a 29-cm diameter sweep net with which at least 30 rootworm beetles were removed from each maize (sticky traps) and soybean (sticky traps and sweep net samples) field weekly, and were preserved in alcohol in a 15 ml glass vial. Vials containing 30 beetles were returned to the laboratory and were sexed.

By using emergence cages, the appearance of WCR adults in maize fields from eggs laid the previous year in soybean could be observed and the numbers of emerging adults recorded. The traps operated from 8 July to 28 August 1996, from 7 July to 25 August 1997, and from 1 July to 13 of August 1998. This study was a part of a larger study referred to as the Indiana Multi-County Study (Barna et al., 1998).

WCR population estimates were made by determining beetle numbers on Pherocon AM® traps and samples in 1996, 1997, and 1998. During the sampling periods, WCR beetles were present in both maize and soybean. Using data of captured insects in emergence cages and Pherocon AM® traps diagrams were made where the incidence levels of western corn rootworm were shown (Figs 2, 3).

Results show that WCR adults were present in soybean fields. Egg laying of WCR in soybean fields was proven by the trapping of WCR beetles in the emergence

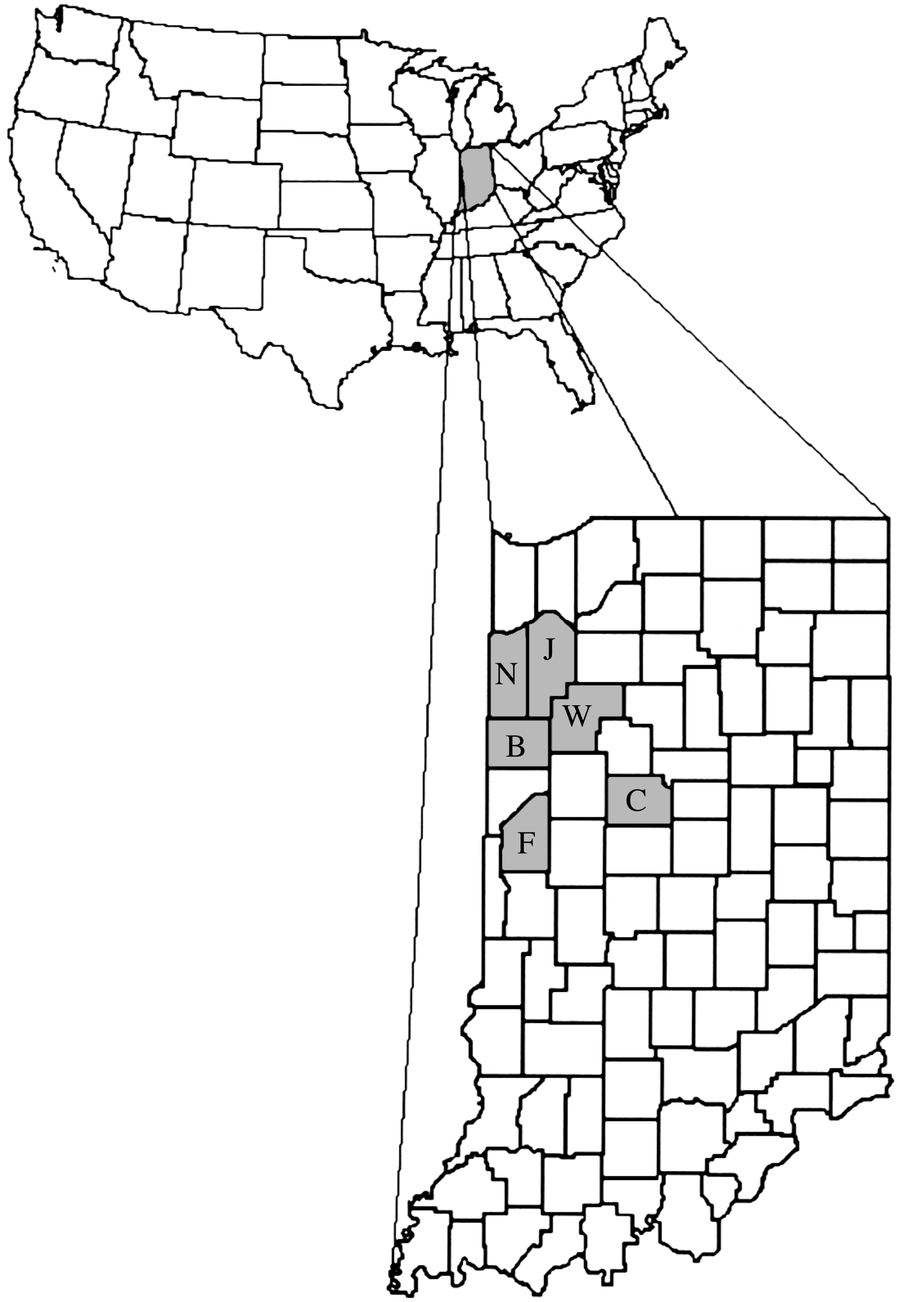

Fig. 1. Location of Indiana counties where sampling was conducted
(W=White, C=Clinton, N=Newton, J=Jasper, F=Fountain, B= Benton)

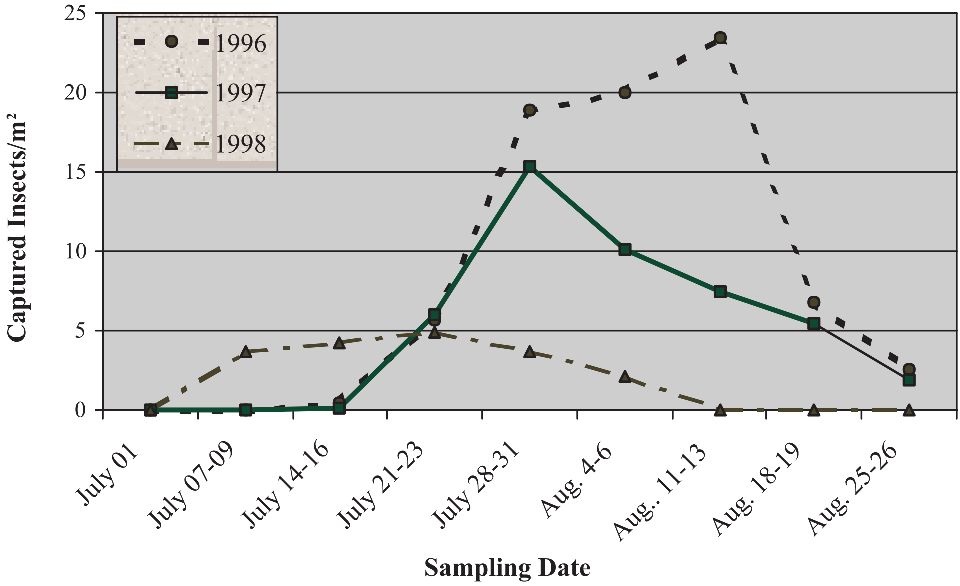

Fig. 2. Number of WCR beetles captured over time in emergence cages in maize fields in Northwest Indiana in 1996, 1997, and 1998
(Data from 1996 and 1997 have been published previously by Barna et al., 1998)

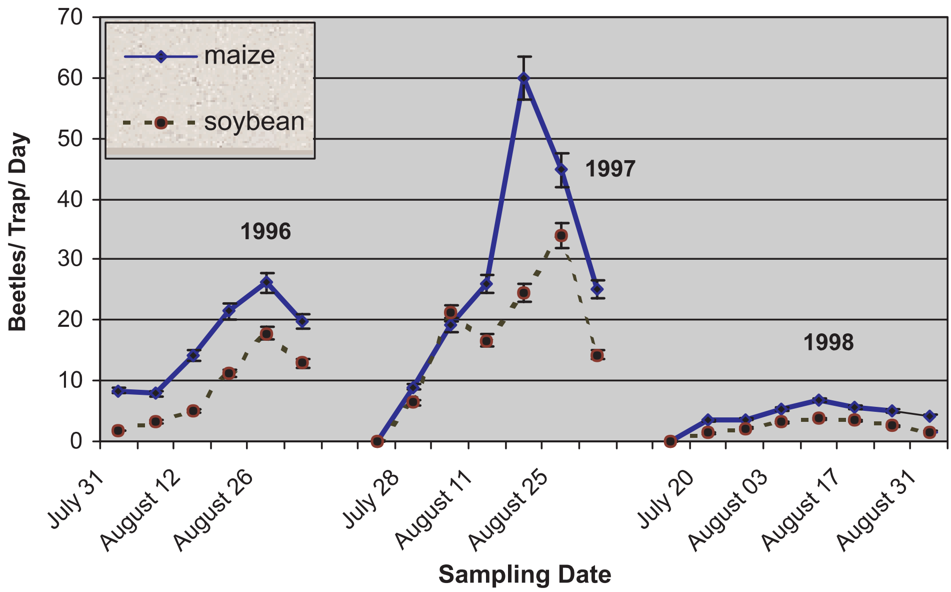

Fig. 3. Number WCR beetles captured on Pherocon AM® traps in 1996, 1997, and 1998
(Data from 1996 and 1997 have been published previously by Barna et al., 1998)

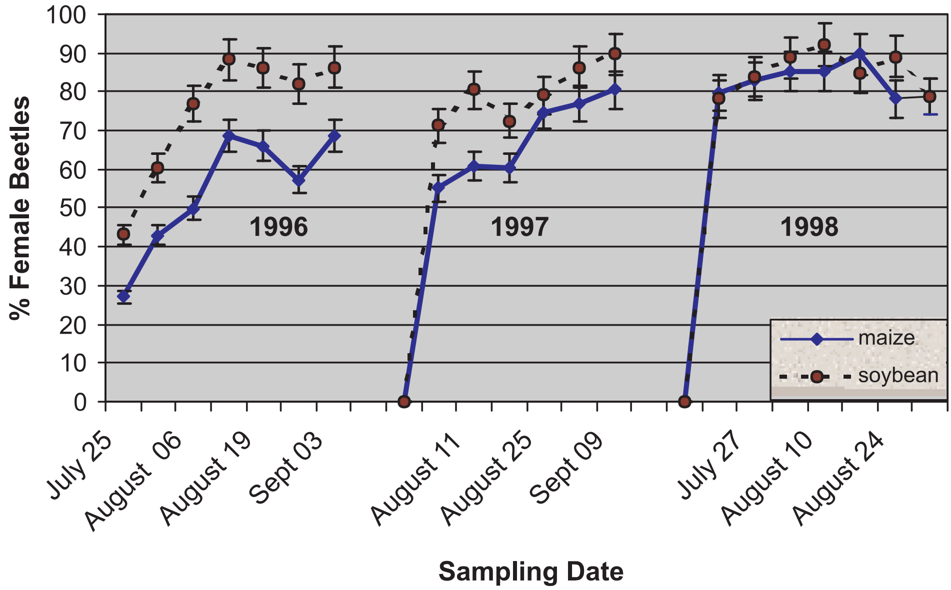

Fig. 4. Numbers of WCR female beetles captured in 1996, 1997, and 1998

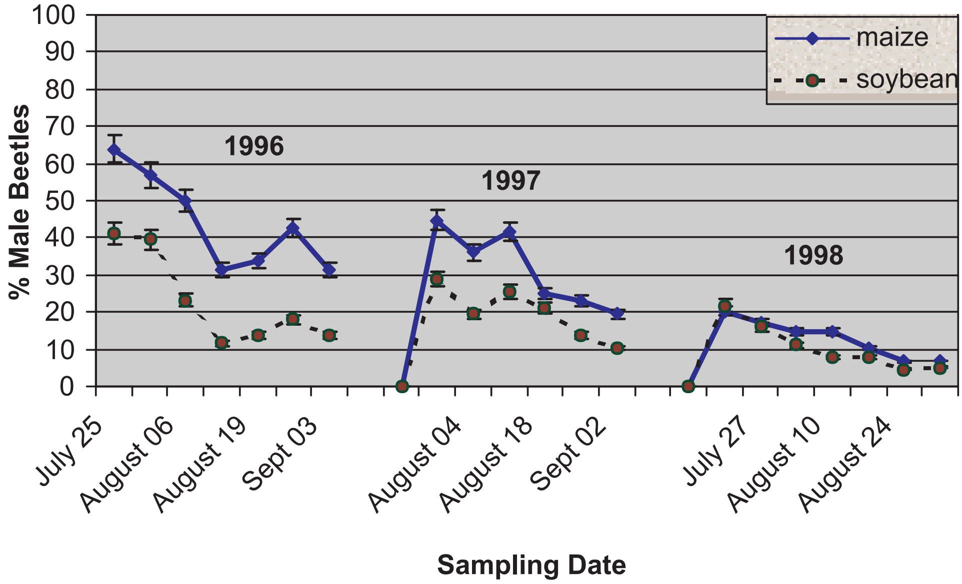

Fig. 5. Number of WCR male beetles captured in 1996, 1997 and 1998

One-Way Analysis of Variance for WCR beetles capture in maize and soybean fields in 1996

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Analysis of Variance
Source    DF       SS       MS        F        p
Factor     1    520111  520111    79.35    0.000
Error    790   5178234    6555
Total    791   5698345
                               Individual 95% CIs for Mean
                               Based on Pooled StDev
Level       N     Mean   StDev      ----+---------+---------+---------+--
in maize  396  112.66   93.46                            (---*---)
in soy    396   61.40   66.14        (---*---)
                                    ----+---------+---------+---------+--
Pooled StDev = 80.96                   60        80       100       120
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One-Way Analysis of Variance for WCR beetles capture in maize and soybean fields in 1997

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Analysis of Variance
Source    DF       SS       MS        F        p
Factor     1    392490   392490   34.36    0.000
Error    790   9024874   11424
Total    791   9417364
                               Individual 95% CIs for Mean
                               Based on Pooled StDev
Level      N      Mean   StDev      ---------+---------+---------+-------
in maize 396     178.7   122.3                        (----*-----)
in soy   396     134.2    88.8      (----*----)
                                   ---------+---------+---------+-------
Pooled StDev =106.9                        140       160       180
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One-Way Analysis of Variance for WCR beetles capture in maize and soybean fields in 1998

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Analysis of Variance
Source    DF       SS       MS        F        p
Factor     1     56870    56870   46.07    0.000
Error    922   1138041    1234
Total    923   1194911
                               Individual 95% CIs for Mean
                               Based on Pooled StDev
Level       N     Mean    StDev     ------+---------+---------+---------+
in maize  462    33.71    46.16                              (----*-----)
in soy    462    18.02    18.39      (----*----)
                                    ------+---------+---------+---------+
Pooled StDev =35.13                    18.0      24.0      30.0      36.0
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Fig. 6. Statistical analysis between WCR beetles capture on Pherocon AM® traps in maize and soybean fields in 1996, 1997 and 1998

cages in maize the following year (Fig. 2). The primary emergence from maize fields occurred during the last week of July and the first two weeks of August in 1996. In 1997, the WCR adult population was lower than in 1996, however the majority of emerged beetles were also the highest in the last week of July and the first two weeks of August. In 1998, weather conditions were not favorable for the larval stage. Excessive precipitation lowered the number of emerging adults when compared to the previous two years.

The results of the captures on Pherocon AM® traps show that the majority of the beetles were present in soybean and maize fields in the last two weeks of August and the first week of September in 1996 (Fig. 3). In 1997 and 1998, the highest numbers occurred also in the last two weeks of August and during the first week of September. In 1996, 1997, and 1998 during the sampling period, the number of WCR beetles was higher in maize than in soybean. Statistical analysis (ANOVA by MINITAB®) was made to prove there is high significant difference between beetles' capture in maize and soybean fields (Fig. 6).

The sex ratio sample data form the basis for Fig. 4. This figure shows the numbers of female beetles in maize and soybean fields.

In 1996, the majority of the beetles in soybean and maize in the last 2 weeks of August and the first week of September were female. During this period, approximately 80–90% of the beetles in soybean was female. Based on statistical analysis of variance, captures of female beetles were significantly higher in soybean fields in 1996 and 1997. Similarly, in 1997 and 1998, 85–90% of beetles in soybean was female. However, caused by the weather conditions in 1998 there was not significant difference between captures of female beetles in maize and soybean fields (Fig. 7). If the percentage of female beetles is fairly consistent this advantageous for developing a sampling plan since producers need only to be concerned about total numbers of beetles present and do not have to sex the beetles.

In 1996, 1997, and 1998 by late summer a majority of female beetles were in soybean. The presence of female WCR beetles in maize and soybean fields was higher at the end of the sampling period than at the beginning (Fig. 4).

In 1996, 1997 and 1998 male WCR beetles were also recorded. The majority of males were in maize fields. In 1996 and 1997 there was significant difference between captures of male WCR beetles in maize and soybean fields. Similarly as at the captures of female beetles, in 1998 there was not significant difference in captures of males in maize and soybean fields (Fig. 8). The number of male WCR beetles diminished at the end of the sampling period (Fig. 5).

Conclusion

Based on this and other studies (Levine and Oloumi-Sadeghi, 1991, Edwards et al., 1996) it is obvious that a portion of the WCR population has changed its preference for maize. Laying eggs in soybean fields increases the likelihood of larval survival the following growing season since a high percentage of soybean fields are rotated to maize. The larvae from eggs laid in maize fields that will be rotated to soybean have little if any

One-Way Analysis of Variance for female WCR beetles in maize and soybean fields in 1996

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	1	616.0	616.0	7.38	0.007
Error	152	12683.9	83.4		
Total	153	13299.9			

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                               Individual 95% CIs for Mean
                               Based on Pooled StDev
Level     N     Mean    StDev    --+---------+---------+---------+----
maize f.  77   14.117   8.069      (-------*--------)
soy f.    77   18.117  10.089                (-------*--------)
                                 --+---------+---------+---------+----
Pooled StDev =9.135               12.5      15.0      17.5      20.0
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One-Way Analysis of Variance for female WCR beetles in maize and soybean fields in 1997

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	1	425.5	425.5	14.65	0.000
Error	130	3777.1	29.1		
Total	131	4202.6			

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                                Individual 95% CIs for Mean
                                Based on Pooled StDev
Level     N     Mean    StDev      -----+---------+---------+---------+-
maize f.  66   20.485   6.636       (-----*------)
soy f.    66   24.076   3.751                       (-----*------)
                                   -----+---------+---------+---------+-
Pooled StDev =5.390                    20.0      22.0      24.0      26.0
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One-Way Analysis of Variance for female WCR beetles in maize and soybean fields in 1998

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	1	20.4	20.4	0.69	0.406
Error	152	4462.1	29.4		
Total	153	4482.5			

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                                Individual 95% CIs for Mean
                                Based on Pooled StDev
Level     N     Mean    StDev      ----+---------+---------+---------+--
maize f.  77   24.857   5.705       (------------*-----------)
soy f.    77   25.584   5.115             (-----------*-----------)
                                   ----+---------+---------+---------+--
Pooled StDev =5.418                    24.0      25.0      26.0      27.0
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Fig. 7. Statistical analysis between female WCR beetles capture in maize and soybean fields in 1996, 1997 and 1998

One-Way Analysis of Variance for male WCR beetles in maize and soybean fields in 1996

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Analysis of Variance
Source     DF      SS       MS       F       p
Factor      1   1776.2   1776.2   52.00   0.000
Error     152   5191.4     34.2
Total     153   6967.6
                              Individual 95% CIs for Mean
                              Based on Pooled StDev
Level       N     Mean     StDev    ---------+---------+---------+-------
maize m.   77   11.545     6.999                        (---*----)
soy m.     77    4.753     4.395   (----*---)
                                    ---------+---------+---------+-------
Pooled StDev =5.844                         6.0       9.0      12.0
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One-Way Analysis of Variance for male WCR beetles in maize and soybean fields in 1997

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Analysis of Variance
Source     DF      SS       MS       F       p
Factor      1    425.5    425.5   14.65   0.000
Error     130   3777.1     29.1
Total     131   4202.6
                              Individual 95% Cis for Mean
                              Based on Pooled StDev
Level       N     Mean     StDev    -------+---------+---------+---------
maize m.   66    9.515     6.636                      (------*-----)
soy m.     66    5.924     3.751     (------*-----)
                                    -------+---------+---------+---------
Pooled StDev =5.390                         6.0       8.0      10.0
```

One-Way Analysis of Variance for male WCR beetles in maize and soybean fields in 1998

```
Analysis of Variance
Source     DF      SS       MS       F       p
Factor      1     16.9     16.9    1.56   0.213
Error     152   1641.4     10.8
Total     153   1658.3
                              Individual 95% Cis for Mean
                              Based on Pooled StDev
Level       N     Mean     StDev    ---------+---------+---------+-------
maize m.   77    3.870     3.193           (------------*-----------)
soy m.     77    3.208     3.377     (-----------*------------)
                                    ---------+---------+---------+-------
Pooled StDev =3.286                         3.00      3.60      4.20
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Fig. 8. Statistical analysis between male WCR beetles capture in maize and soybean fields in 1996, 1997 and 1998

chance of survival due to the lack of maize roots the following season. Also with the fact that soybean is still green at the time that maize fields are drying down, this may have influenced their movement to soybean for oviposition. For fields in soybean/maize rotation, WCR adult sampling conducted in soybean can serve as the basis for determining the need for WCR management in the following maize crop. If WCR females lay their eggs in soybean fields that are in rotation with maize, it means that WCR larvae can impact the next year's maize production. Growing a nonhost crop may be a solution to protecting against WCR larval damage. Otherwise, a soil insecticide may be needed.

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