RESPONSE OF *DENTICHASMIAS BUSSEOLAE* HEINRICH (HYMENOPTERA:ICHNEUMONIDAE) TO *CHILO PARTELLUS* SWINHOE (LEPIDOPTERA: PYRALIDAE) ON SUSCEPTIBLE AND RESISTANT MAIZE GENOTYPES

By

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CHAPTER I

INTRODUCTION

Stem borers constitute one of the major constraints to efficient maize production in the developing world. Yield losses due to stem borers have been observed to vary from 18% in Kenya (Warui and Kuria, 1983), to 44% in Pakistan (Mohyuddin and Attique, 1978), and from 10% in Nigeria to a total crop failure (van Eijnatten, 1965).

Chilo partellus (Swinhoe) is one of the major pests of maize in Africa and Asia. It attacks all stages of the maize plant and contributes to reduced yield. It causes damage by feeding on the leaves, in leaf whorls, and also by boring inside the stem to cause dead hearts and chaffy heads.

The use of insecticides has been the typical control method for stem borer, however this is not practical to subsistence farmers because of their high costs. Integrated pest management methods (resistant cultivars and biological control), which minimize the disruption of the environment, are the most practical approach (Reddy, 1983).

Early studies on maize improvement programs were directed mainly to yield improvement and not towards resistance to stem borers. Furthermore, insecticide applications in the breeding and selection nurseries were common. As a result, most of the high yielding hybrids developed were susceptible to stem borers, particularly to *Chilo partellus* (Omolo, 1983).

Dentichasmias busseolae Heinrich, is an important solitary pupal endoparasitoid of the Pyralid graminaceous stem borer *C. partellus* in East Africa. It is endemic to Africa and is distributed in the Ethiopian region within longitudes 12°N and 25'S. It was referred to as generum near *Chasmias* sp. in a number of publications until recently (Heinrich, 1968).

Mohyuddin (1972) studied several aspects of the biology of *D. busseolae*. He reported studies on the distribution, breeding technique, mating, oviposition behavior, host range, life span, fecundity, and rate of development in relation to temperature.

The compatibility of plant resistance with biological control may provide a cost effective and practical means for the control of stem borers. According to Bergman and Tingey (1979), these two regulatory mechanisms, acting in concert, may provide density-independent mortality in times of low pest density and dynamic density-dependent mortality in times of pest increase.

Although the combined effectiveness of resistant cultivars and biological control has been studied in few instances, the interactions between plant resistance and arthropod predators and parasitoids remain poorly known.

Therefore, the objectives of my studies were to determine the impact of maize genotypes as they affect the performance of the parasitoid *D. busseolae*.

CHAPTER II

REVIEW OF LITERATURE

Host Plant

Maize or corn (Zea mays L.) is a grass and belongs to the large and important family Graminaceae. It is a cross-pollinated, monoecious plant in which the male and female flowers are located in different inflorescences on the same stalk (Inglett, 1970). Its cultivation probably began in Mexico or South America about 7,000 years ago (Mangelsdorf, 1974).

Maize is used for three main purposes: 1) as a staple human food, 2) as feed for livestock and 3) as the raw material for many industrial products. In many parts of the world maize is the most important foodstuff and provides the daily bread for the indigenous population of poorer rural areas. Since 1950, maize has become one of the most important agricultural crops in South Africa. Production now exceeds 10 million tons in favorable years. (van Rensburg et al., 1987).

The development of hybrid corn, modern fertilization practices, and chemical weed control, brought the development of the insect problems on corn and the perfection of modern insect control techniques (Petty and Apple, 1966). With each new development in corn production, whether in plant breeding, fertility, irrigation, or even in insecticides, insects have always adapted to the new environment presented by man.

Stem Borer Complex

The southwestern corn borer, Diatraea grandiosella Dyar, and the European corn borer, Ostrinia nubilalis (Hubner) are major lepidopterous pests of corn (Zea mays L.) in the United States. They attack corn plants in the whorl and tassel stages of growth. Serious yield losses can result from leaf, stalk, and ear damage caused by larvae of these pests (Davis et al., 1989).

The sugarcane borer, Diatraea saccharalis (F.) is the principal insect pest of sugarcane in the United States, but also does serious damage to corn. It is found in a strip along the Gulf Coast from the Southern tip of Texas, through Louisiana, and including the southern edge of Mississippi (Davis et al., 1933). The Lesser cornstalk borer, Elasmopalpus lignosellus is another major pest of maize and sorghum in the Southern U S A and in tropical countries. According to All et al. (1982), the larvae produce damage by tunneling into stalks close to the soil surface.

The African maize stalk borer, Busseola fusca (Fuller), has been recognized as a major pest of maize and sorghum in all African countries south of the Sahara (Jepson, 1954). The degree of infestation of plants varies from practically nil to almost 100%. Smithers (1960) reported an estimated loss of 75% of the crop due to activities of the second generation larvae. Ingram (1958) found B. fusca to be widely distributed in Uganda and most abundant in areas of intensive cultivation, where crop residues abound in which the resting larvae can survive the dry season. Harris (1963) also reported losses due to B. fusca larvae in second-crop maize at Ibadan, Nigeria. In local farms, these generally exceeded 20%. He also observed that the development of a single larva of *B. fusca* in healthy stems could reduce their yield capacity by 28% of the mean cob weight of healthy stems.

The spotted stem borer, *Chilo partellus* (Swinhoe) first appeared in East Africa from Asia in the early 1950s and has now spread as far north as Sudan, Botswana, and Zaire (Ingram, 1983). It has also been recorded as a serious pest of both maize and sorghum from the Indian subcontinent and from a number of African countries (Reddy, 1985). It attacks all stages of maize development and contributes to reduced yield. Alghali (1986) reported 13-45% losses in sorghum grain yield for this insect.

Parasitoids and Biological Control

The term " Biological Control " was first used by Smith (1919) to signify the use of natural enemies to control insect pests. The scope of application in biological control has expanded from the use of a whole range of organisms to control insects, mites, snails,occasional vertebrates, and plants as diverse as algae, fungi, herbs, shrubs and trees (Wilson and Huffaker, 1976).

Askew (1971) described parasitoids as insects that are parasitic only during their immature stages. This would include a large number of species of the so-called parasitic Hymenoptera, the Strepsiptera, and a few Diptera, primarily in the family Tachinidae. Parasitoids make up at least 14% of the more than one million of known insect species. They may be referred to as endoparasitoid or ectoparasitoid, solitary or gregarious, depending on the mode of attack and type of host. The host's future development is of importance only to the parasitoid which is different from that of either the predator or the parasite-host relationship (Vinson, 1975).

The adult female parasitoid after emergence must locate a suitable host to propagate. Although random search has been proposed in some cases (Rogers, 1972), the majority of views seem to support the idea of a preferred habitat and directed search. Laing (1937) divided the host selection process into environmental and host factors and believed that the parasitoid is guided to a host habitat by chemical and physical cues. Once a female has located a host habitat, she then searches intensively for the host.

Flanders (1953) and Doutt (1964) divided the process of successful parasitism into four steps: a) host habitat location, b) host location, c) host acceptance, and d) host suitability. The first three steps are aspects of the host selection process. Chemicals may play a major role at every level of the host selection process. Plant volatiles and odors from the food plants of the host have been shown to be important cues in host habitat location for a number of hymenopterous parasitoids (Arthur, 1962; Camors et al., 1971; Sekhar, 1957).

Compatibility of Resistant Cultivars and Biological Control

Although plant resistance and biological control are generally considered compatible pest management strategies (Schuster and Starks, 1975; Starks et al., 1972), too few studies have been conducted to develop a general model of the interaction of plant resistance and biological control. It has been observed that a low level of resistance can increase the effectiveness of natural enemies where either strategy alone is insufficient to maintain populations below the economic level (van Emden and Wearing, 1965).

Starks et al. (1972) found that the effects of barley and sorghum cultivars resistant to the greenbug are complemented by the activity of the parasite Lysiphlebus testaceipes (Cresson). Isenhour and Wiseman (1987) observed a synergistic interaction between genotypes of maize resistant to the fall armyworm and the armyworm parasite, Campoletis sonorensis (Cameron). The resistance has no adverse affect upon parasite development. Myint et al. (1986) reported that the combination of moderate plant resistance and predation could keep green leaf hopper, Nephotettix viriscens (Distant), population levels below the economic threshold on resistant and moderately resistant rice cultivars.

Studies have also indicated that predator and parasitoid performance may be altered by the host plant of the prey (Flanders, 1942; Smith, 1957). Treacy et al. (1985) observed that although glabrous leaved cotton cultivars reduce bollworm populations, bollworm predators and parasites are adversely affected. High levels of resistance to insects can also be detrimental to parasites. Yanes and Boethel (1983) found that the high level of antibiosis resistance in soybean PI227687 caused high mortality of soybean looper larvae and decreased the parasite Microplitis demolitor's survival in later generations. Also plant growth characteristics have been found to alter the performance of natural enemies. Eikenbary and Fox (1968) reported that the height of the host plant appears to influence parasitism of the Nantucket pine tip moth, Rhyacionia frustrana (Comstock).

CHAPTER III

MATERIALS AND METHODS

The studies were conducted at the Mbita Point Field Station (MPFS) of the International Center of Insect Physiology and Ecology (ICIPE) on the shores of Lake Victoria, Western Kenya. The Station is located 0^{o} 25'S and 34^{o} 10'E with altitude about 1000m above sea level.

Rearing Techniques of the Parasitoid in the Laboratory

A laboratory culture of the parasitoid D. busseolae was first established with adults (both sexes) trapped from the field at MPFS. The parasitoids were kept in rearing cages (25x25x40cm) made of perspex with a window of 6.5cm in diameter having a muslin sleeve for hand insertion. Chilo partellus pupae reared from artificial (Ochieng et al., 1985) and natural diets as obtained from the ICIPE's Insect Mass Rearing Unit were exposed to the parasitoids for 48 hours in 20cm pieces of C. partellus maize infested stems. The stems were split open and 1-5 day old C. partellus pupae were inserted into the tunnel. Fresh frass of Chilo larvae was always added into the slits to induce parasitoid response.

The parasitoids were offered 20% sucrose solution as a diet. Chilo partellus pupae were exposed for 48 hours to the parasitoids and then removed from the cages, placed in separate plastic cups and held in emergence cage until the parasitoids or moths emerged. The emergence cage (30x30x30cm) was made of wooden frames with two sides made of wood, three of wire gauze, and a sliding glass door. All the laboratory experiments were conducted at 25 $\pm$ 2^{o}C, 35-30% RH, and L12 : D12 (fluorescent lamps).

Response of the Parasitoid to the Host on Resistant and Susceptible Host Plants

Field experiments were conducted to evaluate the performance of *D. busseolae* attacking *C. partellus* pupae on susceptible and resistant maize genotypes grown under mosquito net cages. The experiment was designed in a 2x2 Latin Square with 2 replications in a north to south direction with wind movement from east to west. The size of each block was 6x6m with 9 plots of 2x2m. Only 4 plots in each block were planted with the two varieties of maize, "ICZ2-CM" as the resistance source, and "Inbred A" as the susceptible source to *Chilo partellus*. The remaining plots were empty and separated the plots with plants. The position of the varieties in the block were set up so that each variety occupied 2 plots diagonally to each other. The spacing in the plots was 50cm between rows and 30cm within the rows which corresponded to 5 rows having 7 plants per row. This made a total of 35 plants per plot.

The fertilizer Di Ammonium Phosphate (DAP) (18:46:0) was applied at the time of seedbed preparation. Two seeds per hole of each variety of maize were sown by hand and later thinned to 1 seedling per hole after plant emergence. The crop was regularly irrigated to supplement rainfall.

The varieties "ICZ2-CM" (resistant) and "Inbred A" (susceptible) were infested three weeks after plant emergence with ten 2nd instar C. partellus larvae obtained from the Insect Mass Rearing Technology Unit. These were artificially placed in the whorl of each plant. Four weeks after plant infestation, 10 mated females and 5 males of D. busseolae were released in each cage. Another release of 5 females per cage followed five days later. Ten days after the first release, all the plants in each plot were dissected.

The data gathered included the larvae, pupae and pupa cases found on each plant in the plots (See Appendix B). The pupae from each plant were kept in properly labeled vials in the laboratory until the emergence of moths or parasitoids.

An analysis of variance using the Proc Anova procedure (SAS Institute Inc. 1985) including all sources of variation was performed. Testing was for the levels of significance of the Chilo partellus larva establishment and pupa parasitism by Dentichasmias busseolae on the two varieties.

CHAPTER IV

RESULTS AND DISCUSSION

Response of the Parasitoid to the Host on Resistant and Susceptible Host Plants

For decades, studies dealing with resistant plant genotypes were primarily concerned with pest-plant interactions. Only a few studies have been directed at determining the interaction between resistant host plants and biological control agents (Boethel and Eikenbary, 1986). According to Wilson and Huffaker (1976), biological control together with plant resistance are the core around which pest control in crops and forests should be built. Still, little data have been found to support this contention.

The data collected from this experiment showed no significant differences in the larval establishment and development in the two varieties tested. Table I (Appendix A) shows the mean number of *Chilo partellus* per plant found in the larvae and pupae stages on the two varieties for each replication five weeks after 2nd instar larval infestation. The low number of larvae found per plant (average 0.84) is justifiable since the larval period in the field under normal condition varies from 4 to 5 weeks before pupation.

The overall number of insects surviving per plant, including the pupa cases, were not significantly different (P=0.2513, F=5.76, d.f.=1) between the two varieties (Table II). Table III shows the total number of pupae collected from the two varieties, including pupa cases, and the percent parasitism found in each variety. Table IV is the analysis of variance for the number of larvae found in the two varieties of maize in the field. The only significant difference found (P= 0.05) is in the LSRO x Row interaction. It also shows differences in the number of larvae found between plants with a 6% probability. The number found between the two varieties (LSRO x LSCL) were not significant (P=0.0826, F=58.78, d.f.=1).

Table V is the analysis of variance for the number of C. partellus pupae found in the two varieties in the field. Significant differences were found only in the Latin square column with 2% probability. No significant differences were observed on the number of pupae between the two varieties (P=0.7800, F=0.13, d.f.=1). The analysis of variance for the total number of C. partellus including pupa cases found in the two in the field (Table VI), shows a significant difference on the number of C. partellus larvae and pupae found between the plants (P= 0.0002, F=33.35, d.f.=6) and no significance between the two varieties. For the number of pupae parasitized, statistically significant differences were found only in LSCL x Row x Plant interactions (Table VII). The results from this study show that the performance of the parasitoids D. busseolae were not adversely affected by the plant cultivars.

CHAPTER V

SUMMARY AND CONCLUSIONS

The parasitoid D. busseolae Heinrich exhibited attributes of an effective natural enemy. These were: 1) easy to rear in an artificial environment, they were easily reared on Chilo partellus pupae host from both artificial and natural diets, 2) good adaptability to the varying physical conditions, 3) host specificity in the field, the parasitoid has not been reared from hosts other than C. partellus pupae, 4) good life span, Mohyuddin (1972) reported an average life span of 40 days for females and 36 days for males. A release program using D. busseolae should be encouraged since it showed its ability subsequent to being reared in an artificial environment to locate its host in a natural environment soon after release.

For the field experiment, better results could have been obtained if independent trials were conducted. For instance, for the two maize varieties, each variety should be grown separately under mosquito net cages and a third block with both varieties together. Then, the difference in the level of parasitism in each variety grown separately and in the two varieties grown together, if any, would explain better the effect of the two varieties in the performance of the parasitoids. The results obtained from the field experiment showed some sort of compatibility between plant resistance and biological control agent, since no difference in the level of parasitism was observed on pupae from resis tant and susceptible cultivars. So the integrated control method for maize stem borer C. partellus should be encouraged using a variety like ICZ2-CM, which showed good agronomic characteristics including yield, and the parasitoid D. busseolae. As Ortman and Peters (1980) stated, insect resistance will be most optimally employed as an adjunct to other control measures especially biological control.

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APPENDIXES

APPENDIX A

TABLES

TABLE I

MEAN NUMBER OF <u>CHILO</u> <u>PARTELLUS</u> RECOVERED PER PLANT 35 DAYS AFTER LARVAL INFESTATION*

Rep	n**	Larvae	Pupae	Pupa Cases	Total
II	140	0.78	2.60	1.32	4.77
III	140	0.90	2.16	1.63	4.61
Av.	280	0.84	2.38	1.48	4.69

*Average for the two varieties.
**n = number of plants.

TABLE II

MEAN LARVAL ESTABLISHMENT PER PLANT IN THE TWO VARIETIES IN EACH REPLICATION

Variety	Rep	n*	Larvae	Pupae	Pupae Cases	Total
Inbred A	II	70	0.69	2.54	1.30	4.53
	III	70	0.83	2.29	1.46	4.51
ICZ2-CM	II	70	0.87	2.66	1.34	5.01
	III	70	0.97	2.04	1.80	4.71

*n = number of plants per variety in a replicate.

TABLE III

PARASITISM OF _C_. _PARTELLUS_ BY _D_. _BUSSEOLAE_ IN SUSCEPTIBLE AND RESISTANT MAIZE VARIETIES WITHIN THE MOSQUITO NET CAGES

Varieties	No. Pupae collected*	No. Parasitized	% Parasitized
Inbred A	531	134	25.0
ICZ2-CM	549	120	21.5

*Pupae cases were also included.

TABLE IV

ANALYSIS OF VARIANCE FOR THE NUMBER OF *C. PARTELLUS* LARVAE FOUND IN THE TWO VARIETIES OF MAIZE IN THE FIELD

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
TOTAL	279	219.7679			
REP	1	1.0321	1.0321		
LSRO	1	4.3750	4.3750	0.81	0.5344
REP*LSRO[a]	1	5.4321	5.4321		
LSCL	1	1.2893	1.2893	0.68	0.5604
REP*LSCL	1	1.8893	1.8893		
LSRO*LSCL	1	1.8893	1.8893	58.78	0.0826
REP*LSRO*LSCL	1	0.0321	0.0321		
ROW	4	4.6786	1.1696	1.30	0.4021
REP*ROW	4	3.5929	0.8982		
LSRO*ROW	4	3.1786	0.7946	7.81	0.0358*
REP*LSRO*ROW	4	1.0929	0.2732		
LSCL*ROW	4	0.6929	0.1732	0.63	0.6652
REP*LSCL*ROW	4	1.0929	0.2732		
LSRO*LSCL*ROW	4	0.7357	0.1839	0.32	0.8529
REP*LSRO*LSCL*ROW	4	2.3071	0.5768		
PLNT	6	24.0429	4.0071	3.58	0.0629
REP*PLNT	6	6.2429	1.0405		
LSRO*PLNT	6	3.0000	0.5000	1.72	0.2629
REP*LSRO*PLNT	6	1.7429	0.2905		
LSCL*PLNT	6	2.8857	0.4810	0.44	0.8263
REP*LSCL*PLNT	6	6.4857	1.0810		
LSRO*LSCL*PLNT	6	0.7857	0.1310	0.75	0.6301
REP*LSRO*LSCL*PLNT	6	1.0429	0.1738		
ROW*PLNT	24	27.9214	1.1634	1.59	0.1300
REP*ROW*PLNT	24	17.5071	0.7295		
LSRO*ROW*PLNT	24	19.8214	0.8259	1.03	0.4739
REP*LSRO*ROW*PLNT	24	19.2929	0.8039		

TABLE IV (Continued)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
LSCL*ROW*PLNT	24	9.0071	0.3753	0.65	0.8529
REP*LSCL*ROW*PLNT	24	13.9071	0.5795		
LSRO*LSCL*ROW*PLNT	24	14.9643	0.6235	0.81	0.6959
REP*LSRO*LSCL*ROW*PLNT	24	18.4929	0.7705		

[a]Hypothesis tested using the anova MS for REP*LSRO as an error term.
* = Significant at 5% level
LSRO= Latin Square Row LSCL= Latin Square Column PLNT= Plant

TABLE V

ANALYSIS OF VARIANCE FOR THE NUMBER OF C. PARTELLUS PUPAE FOUND IN THE TWO VARIETIES OF MAIZE IN THE FIELD

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
TOTAL	279	836.1107			
REP	1	13.2893	13.2893		
LSRO	1	13.2893	13.2893	1.07	0.4894
REP*LSRO[a]	1	12.4321	12.4321		
LSCL	1	3.4321	3.4321	961.00	0.0205*
REP*LSCL	1	0.0036	0.0036		
LSRO*LSCL	1	0.2893	0.2893	0.13	0.7800
REP*LSRO*LSCL	1	2.2321	2.2321		
ROW	4	15.6643	3.9161	0.56	0.7052
REP*ROW	4	27.9071	6.9768		
LSRO*ROW	4	7.1929	1.7982	0.78	0.5939
REP*LSRO*ROW	4	9.2643	2.3161		
LSCL*ROW	4	12.8357	3.2089	1.09	0.4674
REP*LSCL*ROW	4	11.7643	2.9411		
LSRO*LSCL*ROW	4	12.1929	3.0482	0.63	0.6692
REP*LSRO*LSCL*ROW	4	19.4643	4.8661		
PLNT	6	57.3857	9.5643	2.51	0.1439
REP*PLNT	6	22.8857	3.8143		
LSRO*PLNT	6	15.8857	2.6476	1.34	0.3652
REP*LSRO*PLNT	6	11.8429	1.9738		
LSCL*PLNT	6	3.1429	0.5238	0.14	0.9860
REP*LSCL*PLNT	6	23.2714	3.8786		
LSRO*LSCL*PLNT	6	16.7857	2.7976	1.20	0.4138
REP*LSRO*LSCL*PLNT	6	13.9429	2.3238		
ROW*PLNT	24	78.1857	3.2577	1.17	0.3480
REP*ROW*PLNT	24	66.5429	2.7726		
LSRO*ROW*PLNT	24	48.2571	2.0107	0.64	0.8607
REP*LSRO*ROW*PLNT	24	75.5857	3.1494		

TABLE V (Continued)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
LSCL*ROW*PLNT	24	82.2143	3.4256	1.86	0.0670
REP*LSCL*ROW*PLNT	24	44.0857	1.8369		
LSRO*LSCL*ROW*PLNT	24	45.8571	1.9107	0.66	0.8381
REP*LSRO*LSCL*ROW*PLNT	24	68.9857	2.8744		

[a]Hypothesis tested using the anova MS for REP*LSRO as an error term.
* = Significant at 5% level.
LSRO= Latin Square Row   LSCL= Latin Square Column   PLNT= Plant

TABLE VI

ANALYSIS OF VARIANCE FOR THE TOTAL NUMBER OF CHILO PARTELLUS FOUND IN THE TWO VARIETIES OF MAIZE IN THE FIELD

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
TOTAL	279	1281.5857			
REP	1	1.7286	1.7286		
LSRO	1	27.6571	27.6571	0.62	0.5760
REP*LSRO[a]	1	44.8000	44.8000		
LSCL	1	1.1571	1.1571	0.67	0.5635
REP*LSCL	1	1.7286	1.7286		
LSRO*LSCL	1	8.2286	8.2286	5.76	0.2513
REP*LSRO*LSCL	1	1.4286	1.4286		
ROW	4	11.5143	2.8786	0.29	0.8708
REP*ROW	4	39.6286	9.9072		
LSRO*ROW	4	21.7000	5.4250	0.64	0.6614
REP*LSRO*ROW	4	33.8429	8.4607		
LSCL*ROW	4	5.4143	1.3536	0.70	0.6294
REP*LSCL*ROW	4	7.7000	1.9250		
LSRO*LSCL*ROW	4	26.2000	6.5500	0.67	0.6441
REP*LSRO*LSCL*ROW	4	38.8571	9.7143		
PLNT	6	289.1857	48.1976	33.35	0.0002**
REP*PLNT	6	8.6714	1.4452		
LSRO*PLNT	6	19.8429	3.3072	3.61	0.0718
REP*LSRO*PLNT	6	5.5000	0.9167		
LSCL*PLNT	6	20.8429	3.4738	0.48	0.8036
REP*LSCL*PLNT	6	43.4714	7.2452		
LSRO*LSCL*PLNT	6	4.6714	0.7786	0.37	0.8750
REP*LSRO*LSCL*PLNT	6	12.6714	2.1119		
ROW*PLNT	24	87.3857	3.6411	0.70	0.8011
REP*ROW*PLNT	24	123.9714	5.1655		
LSRO*ROW*PLNT	24	71.8000	2.9917	1.48	0.1698
REP*LSRO*ROW*PLNT	24	48.3571	2.0149		

TABLE VI (Continued)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
LSRO*LSCL*ROW*PLNT	24	66.4000	2.7667	0.83	0.6746
REP*LSRO*LSCL*ROW*PLNT	24	80.0429	3.3351		
LSCL*ROW*PLNT	24	74.5857	3.1077	1.42	0.1992
REP*LSCL*ROW*PLNT	24	52.6000	2.1917		

[a]Hypothesis tested using the anova MS for REP*LSRO as an error term.
** = Significant at 1% level.
LSRO= Latin Square Row   LSCL= Latin Square Columnn   PLNT= Plant

TABLE VII

ANALYSIS OF VARIANCE FOR THE NUMBER OF C. PARTELLUS PUPAE PARASITIZED BY D. BUSSEOLAE IN THE TWO VARIETIES OF MAIZE IN THE FIELD

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
TOTAL	279	259.5857			
REP	1	0.0143	0.0143		
LSRO	1	4.6286	4.6286	9.00	0.2048
REP*LSRO[a]	1	0.5143	0.5143		
LSCL	1	1.4286	1.4286	25.00	0.1257
REP*LSCL	1	0.0571	0.0571		
LSRO*LSCL	1	0.7000	0.7000	5.44	0.2578
REP*LSRO*LSCL	1	0.1286	0.1286		
ROW	4	1.4429	0.3607	0.22	0.9127
REP*ROW	4	6.4286	1.6072		
LSRO*ROW	4	0.8714	0.2179	0.31	0.8557
REP*LSRO*ROW	4	2.7714	0.6929		
LSCL*ROW	4	6.4286	1.6072	2.04	0.2540
REP*LSCL*ROW	4	3.1571	0.7893		
LSRO*LSCL*ROW	4	2.2286	0.5572	0.47	0.7579
REP*LSRO*LSCL*ROW	4	4.7286	1.1822		
PLNT	6	5.7357	0.9560	1.58	0.2968
REP*PLNT	6	3.6357	0.6060		
LSRO*PLNT	6	5.5214	0.9202	1.40	0.3457
REP*LSRO*PLNT	6	3.9357	0.6560		
LSCL*PLNT	6	2.7214	0.4536	0.32	0.9018
REP*LSCL*PLNT	6	8.3929	1.3988		
LSRO*LSCL*PLNT	6	10.0500	1.6750	2.04	0.2031
REP*LSRO*LSCL*PLNT	6	4.9214	0.8202		
ROW*PLNT	24	14.4071	0.6003	0.66	0.8432
REP*ROW*PLNT	24	21.8643	0.9110		
LSRO*ROW*PLNT	24	16.9786	0.7074	0.55	0.9239
REP*LSRO*ROW*PLNT	24	30.7786	1.2824		

TABLE VII (Continued)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
LSCL*ROW*PLNT	24	33.4214	1.3926	2.50	0.0146*
REP*LSCL*ROW*PLNT	24	13.3929	0.5580		
LSRO*LSCL*ROW*PLNT	24	18.0214	0.7509	0.60	0.8937
REP*LSRO*LSCL*ROW*PLNT	24	30.2214	1.2592		

* Significant at 5% level.
[a]Hypothesis tested using the anova MS for REP*LSRO as an erro term.
LSRO= Latin Square Row   LSCL= Latin Square Column   PLNT= Plant

APPENDIX B

RAW DATA OF THE FIELD LAYOUT ON 2X2

LATIN SQUARE DESIGN WITH TWO

VARIETIES OF MAIZE

RAW DATA OF THE FIELD LAYOUT ON 2X2 LATIN SQUARE
DESIGN WITH TWO VARIETIES OF MAIZE

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
1	IA	II	1	1	1	1	0	1	0	1	0
2	IA	II	1	1	1	2	1	2	2	5	0
3	IA	II	1	1	1	3	1	0	1	2	0
4	IA	II	1	1	1	4	1	1	0	2	1
5	IA	II	1	1	1	5	0	1	2	3	0
6	IA	II	1	1	1	6	0	2	2	4	1
7	IA	II	1	1	1	7	0	1	1	2	0
8	IA	II	1	1	2	1	1	1	1	3	1
9	IA	II	1	1	2	2	0	0	2	2	0
10	IA	II	1	1	2	3	1	1	1	3	1
11	IA	II	1	1	2	4	1	1	0	2	1
12	IA	II	1	1	2	5	0	3	2	5	1
13	IA	II	1	1	2	6	0	2	0	2	1
14	IA	II	1	1	2	7	0	4	1	5	1
15	IA	II	1	1	3	1	0	1	2	3	1
16	IA	II	1	1	3	2	1	2	2	5	0
17	IA	II	1	1	3	3	0	1	2	3	0
18	IA	II	1	1	3	4	0	1	0	1	1
19	IA	II	1	1	3	5	1	4	1	6	2
20	IA	II	1	1	3	6	0	5	2	7	3
21	IA	II	1	1	3	7	0	2	1	3	2
22	IA	II	1	1	4	1	0	5	0	5	1
23	IA	II	1	1	4	2	1	3	2	6	1
24	IA	II	1	1	4	3	2	4	1	7	0
25	IA	II	1	1	4	4	0	4	1	5	2
26	IA	II	1	1	4	5	0	4	2	6	1
27	IA	II	1	1	4	6	0	4	3	7	3
28	IA	II	1	1	4	7	1	0	1	2	0
29	IA	II	1	1	5	1	2	0	0	2	0
30	IA	II	1	1	5	2	0	1	3	4	0
31	IA	II	1	1	5	3	3	2	1	6	0
32	IA	II	1	1	5	4	0	2	0	2	1
33	IA	II	1	1	5	5	1	0	3	4	0
34	IA	II	1	1	5	6	1	5	1	7	2
35	IA	II	1	1	5	7	1	0	1	2	0
36	IA	II	2	2	1	1	0	2	0	2	0
37	IA	II	2	2	1	2	1	3	2	6	0
38	IA	II	2	2	1	3	0	5	0	5	1
39	IA	II	2	2	1	4	1	4	1	6	2
40	IA	II	2	2	1	5	1	6	1	8	2
41	IA	II	2	2	1	6	2	1	2	5	1
42	IA	II	2	2	1	7	1	3	1	5	0
43	IA	II	2	2	2	1	1	0	2	3	0
44	IA	II	2	2	2	2	0	3	2	5	2
45	IA	II	2	2	2	3	2	5	1	8	0
46	IA	II	2	2	2	4	0	2	0	2	1
47	IA	II	2	2	2	5	0	5	2	7	2
48	IA	II	2	2	2	6	0	5	1	6	1
49	IA	II	2	2	2	7	2	5	0	7	2
50	IA	II	2	2	3	1	1	4	0	5	2
51	IA	II	2	2	3	2	2	5	2	9	1
52	IA	II	2	2	3	3	0	4	2	6	2
53	IA	II	2	2	3	4	0	2	1	3	0

APPENDIX B (Continued)

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
54	IA	II	2	2	3	5	2	5	1	8	1
55	IA	II	2	2	3	6	0	3	2	5	1
56	IA	II	2	2	3	7	0	1	2	3	0
57	IA	II	2	2	4	1	0	4	1	5	2
58	IA	II	2	2	4	2	2	4	3	9	2
59	IA	II	2	2	4	3	0	4	1	5	1
60	IA	II	2	2	4	4	1	0	0	1	0
61	IA	II	2	2	4	5	3	5	2	10	1
62	IA	II	2	2	4	6	0	1	2	3	0
63	IA	II	2	2	4	7	0	4	1	5	2
64	IA	II	2	2	5	1	0	0	2	2	0
65	IA	II	2	2	5	2	1	2	2	5	2
66	IA	II	2	2	5	3	2	1	0	3	1
67	IA	II	2	2	5	4	1	2	1	4	1
68	IA	II	2	2	5	5	1	2	3	6	1
69	IA	II	2	2	5	6	1	4	2	7	3
70	IA	II	2	2	5	7	0	3	1	4	1
71	IC	II	1	2	1	1	0	1	1	2	0
72	IC	II	1	2	1	2	0	2	2	4	1
73	IC	II	1	2	1	3	2	3	0	5	1
74	IC	II	1	2	1	4	0	4	1	5	2
75	IC	II	1	2	1	5	0	4	3	7	2
76	IC	II	1	2	1	6	0	2	0	2	0
77	IC	II	1	2	1	7	0	6	1	7	3
78	IC	II	1	2	2	1	0	0	1	1	0
79	IC	II	1	2	2	2	2	1	3	6	0
80	IC	II	1	2	2	3	0	3	0	3	1
81	IC	II	1	2	2	4	1	1	1	3	1
82	IC	II	1	2	2	5	0	1	3	4	1
83	IC	II	1	2	2	6	0	3	1	4	2
84	IC	II	1	2	2	7	0	6	2	8	2
85	IC	II	1	2	3	1	0	3	1	4	1
86	IC	II	1	2	3	2	1	2	3	6	0
87	IC	II	1	2	3	3	0	1	3	4	1
88	IC	II	1	2	3	4	1	1	0	2	0
89	IC	II	1	2	3	5	1	2	4	7	0
90	IC	II	1	2	3	6	0	3	2	5	1
91	IC	II	1	2	3	7	0	3	1	4	1
92	IC	II	1	2	4	1	0	2	1	3	0
93	IC	II	1	2	4	2	1	2	2	5	1
94	IC	II	1	2	4	3	0	3	3	6	1
95	IC	II	1	2	4	4	0	1	0	1	0
96	IC	II	1	2	4	5	2	3	1	6	1
97	IC	II	1	2	4	6	0	0	1	1	0
98	IC	II	1	2	4	7	1	3	0	4	0
99	IC	II	1	2	5	1	0	0	3	3	0
100	IC	II	1	2	5	2	1	6	1	8	3
101	IC	II	1	2	5	3	0	0	5	5	0
102	IC	II	1	2	5	4	0	3	0	3	1
103	IC	II	1	2	5	5	2	4	1	7	2
104	IC	II	1	2	5	6	0	3	1	4	1
105	IC	II	1	2	5	7	1	0	0	1	0
106	IC	II	2	1	1	1	1	3	0	4	0
107	IC	II	2	1	1	2	0	6	1	7	2

APPENDIX B (Continued)

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
108	IC	II	2	1	1	3	3	2	1	6	0
109	IC	II	2	1	1	4	0	0	3	3	0
110	IC	II	2	1	1	5	2	4	1	7	1
111	IC	II	2	1	1	6	4	4	1	9	0
112	IC	II	2	1	1	7	0	5	2	7	2
113	IC	II	2	1	2	1	2	2	0	4	0
114	IC	II	2	1	2	2	1	3	2	6	0
115	IC	II	2	1	2	3	2	1	3	6	0
116	IC	II	2	1	2	4	1	0	0	1	0
117	IC	II	2	1	2	5	1	3	2	6	1
118	IC	II	2	1	2	6	0	3	3	6	0
119	IC	II	2	1	2	7	2	5	0	7	2
120	IC	II	2	1	3	1	1	10	0	11	1
121	IC	II	2	1	3	2	2	7	0	9	3
122	IC	II	2	1	3	3	3	3	2	8	1
123	IC	II	2	1	3	4	1	3	0	4	3
124	IC	II	2	1	3	5	0	8	0	8	1
125	IC	II	2	1	3	6	1	2	2	5	1
126	IC	II	2	1	3	7	0	0	3	3	0
127	IC	II	2	1	4	1	0	2	1	3	1
128	IC	II	2	1	4	2	3	3	0	6	0
129	IC	II	2	1	4	3	0	5	2	7	2
130	IC	II	2	1	4	4	1	3	1	5	2
131	IC	II	2	1	4	5	2	0	2	4	0
132	IC	II	2	1	4	6	0	3	0	3	0
133	IC	II	2	1	4	7	2	5	1	8	2
134	IC	II	2	1	5	1	0	4	1	5	4
135	IC	II	2	1	5	2	2	2	1	5	1
136	IC	II	2	1	5	3	2	3	3	8	0
137	IC	II	2	1	5	4	0	3	1	4	1
138	IC	II	2	1	5	5	3	1	1	5	0
139	IC	II	2	1	5	6	3	5	2	10	0
140	IC	II	2	1	5	7	0	1	0	1	0
141	IA	III	1	1	1	1	1	1	2	4	1
142	IA	III	1	1	1	2	2	2	1	5	1
143	IA	III	1	1	1	3	0	3	1	4	0
144	IA	III	1	1	1	4	1	3	0	4	0
145	IA	III	1	1	1	5	0	2	3	5	0
146	IA	III	1	1	1	6	2	0	0	2	0
147	IA	III	1	1	1	7	0	5	1	6	2
148	IA	III	1	1	2	1	1	2	0	3	0
149	IA	III	1	1	2	2	0	3	3	6	2
150	IA	III	1	1	2	3	1	1	2	4	0
151	IA	III	1	1	2	4	1	1	2	4	0
152	IA	III	1	1	2	5	1	2	3	6	2
153	IA	III	1	1	2	6	0	1	2	3	0
154	IA	III	1	1	2	7	1	3	1	5	0
155	IA	III	1	1	3	1	0	0	3	3	0
156	IA	III	1	1	3	2	0	5	1	6	1
157	IA	III	1	1	3	3	2	1	2	5	0
158	IA	III	1	1	3	4	0	5	1	6	4
159	IA	III	1	1	3	5	1	6	1	8	1
160	IA	III	1	1	3	6	2	1	2	5	0
161	IA	III	1	1	3	7	1	0	5	6	0

APPENDIX B (Continued)

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
162	IA	III	1	1	4	1	0	1	1	2	1
163	IA	III	1	1	4	2	2	2	1	5	0
164	IA	III	1	1	4	3	2	3	0	5	1
165	IA	III	1	1	4	4	0	1	0	1	1
166	IA	III	1	1	4	5	2	2	3	7	1
167	IA	III	1	1	4	6	1	4	1	6	1
168	IA	III	1	1	4	7	0	1	2	3	0
169	IA	III	1	1	5	1	0	0	0	0	0
170	IA	III	1	1	5	2	1	3	2	6	2
171	IA	III	1	1	5	3	0	3	2	5	0
172	IA	III	1	1	5	4	0	2	2	4	0
173	IA	III	1	1	5	5	2	1	2	5	1
174	IA	III	1	1	5	6	2	5	1	8	2
175	IA	III	1	1	5	7	0	1	3	4	1
176	IA	III	2	2	1	1	1	4	0	5	1
177	IA	III	2	2	1	2	1	5	0	6	1
178	IA	III	2	2	1	3	3	5	2	10	2
179	IA	III	2	2	1	4	0	2	1	3	1
180	IA	III	2	2	1	5	2	4	1	7	2
181	IA	III	2	2	1	6	2	4	1	7	2
182	IA	III	2	2	1	7	1	1	2	4	1
183	IA	III	2	2	2	1	0	1	2	3	0
184	IA	III	2	2	2	2	0	4	1	5	2
185	IA	III	2	2	2	3	0	2	0	2	0
186	IA	III	2	2	2	4	1	3	0	4	3
187	IA	III	2	2	2	5	2	1	2	5	1
188	IA	III	2	2	2	6	1	2	0	3	1
189	IA	III	2	2	2	7	0	1	2	3	1
190	IA	III	2	2	3	1	0	2	2	4	0
191	IA	III	2	2	3	2	0	2	2	4	2
192	IA	III	2	2	3	3	1	2	1	4	1
193	IA	III	2	2	3	4	0	0	2	2	0
194	IA	III	2	2	3	5	1	1	2	4	0
195	IA	III	2	2	3	6	2	1	0	3	1
196	IA	III	2	2	3	7	1	0	2	3	0
197	IA	III	2	2	4	1	0	5	1	6	2
198	IA	III	2	2	4	2	3	2	1	6	2
199	IA	III	2	2	4	3	0	1	1	2	0
200	IA	III	2	2	4	4	1	1	0	2	1
201	IA	III	2	2	4	5	0	3	2	5	2
202	IA	III	2	2	4	6	0	3	0	3	3
203	IA	III	2	2	4	7	2	2	2	6	0
204	IA	III	2	2	5	1	0	1	2	3	1
205	IA	III	2	2	5	2	0	3	3	6	2
206	IA	III	2	2	5	3	1	3	0	4	2
207	IA	III	2	2	5	4	0	3	1	4	0
208	IA	III	2	2	5	5	1	4	3	8	3
209	IA	III	2	2	5	6	1	4	4	9	2
210	IA	III	2	2	5	7	1	2	1	4	1
211	IC	III	1	2	1	1	0	3	1	4	1
212	IC	III	1	2	1	2	2	4	0	6	0
213	IC	III	1	2	1	3	2	0	4	6	0
214	IC	III	1	2	1	4	0	5	0	5	4
215	IC	III	1	2	1	5	1	4	0	5	0

APPENDIX B (Continued)

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
216	IC	III	1	2	1	6	0	2	5	7	0
217	IC	III	1	2	1	7	1	2	3	6	0
218	IC	III	1	2	2	1	0	2	2	4	2
219	IC	III	1	2	2	2	0	3	3	6	0
220	IC	III	1	2	2	3	1	2	2	5	1
221	IC	III	1	2	2	4	0	1	5	6	0
222	IC	III	1	2	2	5	0	6	1	7	3
223	IC	III	1	2	2	6	1	2	9	12	2
224	IC	III	1	2	2	7	0	0	4	4	0
225	IC	III	1	2	3	1	1	0	2	3	0
226	IC	III	1	2	3	2	1	2	2	5	0
227	IC	III	1	2	3	3	2	1	2	5	1
228	IC	III	1	2	3	4	1	1	2	4	0
229	IC	III	1	2	3	5	1	2	2	5	0
230	IC	III	1	2	3	6	1	0	4	5	0
231	IC	III	1	2	3	7	0	1	2	3	1
232	IC	III	1	2	4	1	1	2	0	3	2
233	IC	III	1	2	4	2	2	5	0	7	1
234	IC	III	1	2	4	3	2	2	1	5	1
235	IC	III	1	2	4	4	1	1	3	5	1
236	IC	III	1	2	4	5	1	4	2	7	0
237	IC	III	1	2	4	6	2	1	1	4	0
238	IC	III	1	2	4	7	2	2	0	4	1
239	IC	III	1	2	5	1	1	2	0	3	1
240	IC	III	1	2	5	2	0	4	1	5	1
241	IC	III	1	2	5	3	2	0	3	5	0
242	IC	III	1	2	5	4	0	4	1	5	1
243	IC	III	1	2	5	5	2	2	0	4	0
244	IC	III	1	2	5	6	2	3	0	5	2
245	IC	III	1	2	5	7	2	0	1	3	0
246	IC	III	2	1	1	1	0	6	2	8	2
247	IC	III	2	1	1	2	1	2	2	5	1
248	IC	III	2	1	1	3	3	1	4	8	0
249	IC	III	2	1	1	4	0	1	0	1	1
250	IC	III	2	1	1	5	2	2	3	7	2
251	IC	III	2	1	1	6	1	1	6	8	0
252	IC	III	2	1	1	7	1	1	2	4	0
253	IC	III	2	1	2	1	1	5	1	7	3
254	IC	III	2	1	2	2	0	3	2	5	2
255	IC	III	2	1	2	3	0	6	2	8	4
256	IC	III	2	1	2	4	1	1	0	2	1
257	IC	III	2	1	2	5	1	6	0	7	1
258	IC	III	2	1	2	6	1	3	4	8	0
259	IC	III	2	1	2	7	1	0	2	3	0
260	IC	III	2	1	3	1	0	0	0	0	0
261	IC	III	2	1	3	2	1	0	3	4	0
262	IC	III	2	1	3	3	0	0	2	2	0
263	IC	III	2	1	3	4	0	0	0	0	0
264	IC	III	2	1	3	5	1	1	2	4	1
265	IC	III	2	1	3	6	2	1	0	3	0
266	IC	III	2	1	3	7	1	2	2	5	1
267	IC	III	2	1	4	1	0	1	1	2	1
268	IC	III	2	1	4	2	2	2	0	4	0
269	IC	III	2	1	4	3	1	0	4	5	0

APPENDIX B (Continued)

OBS	VAR	REP	LSRO	LSCL	ROW	PLNT	LARV	PUPAE	PCASE	TOTL	PPAR
270	IC	III	2	1	4	4	1	3	0	4	2
271	IC	III	2	1	4	5	1	4	2	7	3
272	IC	III	2	1	4	6	3	0	0	3	0
273	IC	III	2	1	4	7	1	1	2	4	0
274	IC	III	2	1	5	1	0	1	0	1	0
275	IC	III	2	1	5	2	2	4	1	7	1
276	IC	III	2	1	5	3	0	1	3	4	1
277	IC	III	2	1	5	4	1	1	0	2	0
278	IC	III	2	1	5	5	1	3	0	4	2
279	IC	III	2	1	5	6	2	0	3	5	0
280	IC	III	2	1	5	7	0	6	2	8	3

VAR= Variety REP= Replication LSRO= Latin Square Row

LSCL= Latin Square Column PLNT= Plant LARV= Larvae

PCASE= Pupa Case TOTL= Total PPAR= Pupa Parasitized

VITA

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