10-1-1976

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October 1976

AEc Tech. Pub. No. 15

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A COMPUTER PROGRAM FOR SIMULATING THE THEORETICAL SUPPRESSION OF THE TOBACCO BUDWORM BY GENETIC STERILIZATION

By

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ACKNOWLEDGEMENTS

Special appreciation is extended to Mrs. Nettie Ward for typing the manuscript.

FOREWORD

The purpose of this report is to publish a computer algorithm which simulates the theoretical suppression of the tobacco budworm by genetic sterilization. This report is intended for researchers interested in the details of such a model.

A COMPUTER PROGRAM FOR SIMULATING THE THEORETICAL SUPPRESSION OF THE TOBACCO BUDWORM BY GENETIC STERILIZATION

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INTRODUCTION

Cotton insect control is in a period of transition from almost total reliance on chemical pesticides to a program of integrated pest management. There are several causes for this transition; pesticide residues and subsequent regulations, development of insecticide resistance in target and some previously non-target pests, and the high cost of insecticides.

The key pest of cotton in Mississippi is the boll weevil [13]. This insect is a perennially occurring pest that dominates control practices [13]. This point is argued by some farmers and entomologists in the Delta Area of Mississippi where boll weevils survive in relatively low numbers. From the "current situation only" point of view the tobacco budworm, *Heliothis virescens* (F.), situation is a major problem. A historical point of view and understanding of the ecological upsets caused by pesticides, however, leaves one to realize that the boll weevil was the pest that started the "pesticide syndrome" in cotton [9]. Thus the boll weevil is greatly responsible for release of secondary pests

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and other pesticide related problems [13]. The bollworm, Heliothis zea (Boddie) and the tobacco budworm are the most important secondary pests of cotton in Mississippi. Larvae of these insects are difficult to control, especially in the Mid and Late instars, even when the populations are susceptible to the insecticides being used. In the face of increasing resistance in these Heliothis species, especially the tobacco budworm [13], economic control has frequently been difficult and in a few cases in Mississippi control has not been achieved with high rates of both organochlorine and organophosphate insecticides. This situation dictates the need for alternate methods that will control the tobacco budworm in the face of increasing insecticide resistance.

LITERATURE REVIEW

For numerous reasons (economic, ecological, political, and development of resistance to insecticides) there is general interest in controlling *Heliothis* spp. by use of integrated control methods (biological and cultural) [1, 18, 19]. Simulation or modeling [7, 8, 10, 17] has been shown to be an effective tool for studying insect population dynamics and pest management as an integrated system [3, 4, 5, 6, 7, 11, 16, 20, 21]. Berryman and Plenaar [3] have discussed simulation as a method for investigating the dynamics and management of insect populations. Berryman [2] presented a model which describes the effect of a sterile male release on a wild population. Knipling [4] discussed releasing partially sterile males. Pimentel and Shoemaker [19] developed a model designed to estimate the impact on crop prices and land use of producing cotton and corn with and without insecticides.

A basic problem associated with using modeling as a research tool is that researchers often attempt to model or simulate systems that are too large or complex. A system is too large to model (from scratch) whenever basic technical information concerning the system is such that the system can not be modeled and verified in a reasonable time frame. Additionally, a system is too large to model whenever the researcher can not reasonably predict the time period required to model and verify the system. Naturally as the information base associated with a system becomes more complete, systems that were once too large to model then become suitable areas for modeling.

A THEORETICAL MODEL

Classical integrated pest management concepts <u>require</u> that the boll weevil be controlled before the bollworm can be controlled. However, genetic sterilization does <u>not</u> require that infestations of boll weevils be suppressed before the bollworm can be controlled. The purpose of this paper is to present a computer algorithm which simulates the theoretical suppression of the tobacco budworm by genetic sterilization.

When <u>H. subflexa</u> females are mated with <u>H. virenscens</u> males, fertile eggs are produced. Male progeny resulting from these matings are sterile and the female progeny are fertile. When these females are backcrossed to <u>H. virescens</u> males, sterile male and fertile female progeny are produced [15]. The algorithm presented in this paper allows the modeling of the release of these backcrosses (BC) progeny into the wild population and provides the user with mappings of population characteristics.

The assumptions underlying the model are: 1) The natural population exists with an equal sex ratio; 2) BC and normal females are equally competitive for mating with normal males; 3) BC males and females are released in equal numbers but there is no direct influence of BC males on the natural population; 4) Normal males mate only with females that have not had a normal mating; 5) Females mate only one time with normal males; 6) BC moths are released with an equal sex ratio. The assumptions concerning mateing were made to add conservatism to the model and are not intended to infer a normal situation.

The computer algorithm allows user control of five parameters. The total natural population may be varied. The number of hybrids re= leased may be varied. The increase per generation is under user con= trol. The number of generations to be examined may be either ten or twenty. The number of matings per normal male may vary from one to five.

THE COMPUTER MODEL

Table 1 lists the computer program and Table 2 lists the first 37 data cards which may be considered as part of the program since they are used to label the output. These 37 cards are required. The information presented in Table 2 must reside in the first 48 card columns. One additional data card is required for each model to be examined. This card has the format as presented in Table 3.

Additional models can be examined by stacking general data cards (see format described in Table 3). The first 37 data cards should not be repeated if models are to be stacked. Table 4 lists example output for a 9:1 release. Table 5 lists example output for a 19:1 release. Table 6 reports example output for a 29:1 release. The information at the top of the table describes the general data card which was used as input. The comment which says "DIVISOR = 0, GENERATION = 7" (Table 6) indicates that the computer program attempted to calculate a probability in the 7th generation for which the divisor would have been zero. This indicates that the population would have gone to near zero (less than one insect) in the 7th generation. Generation to generation increase in the normal population is reported in the next to the last line of Tables 4, 5 and 6.

TABLE 1. SOURCE LISTING OF GENETIC STERILIZATION PROGRAM

```
C     LASTER RELEASE MODEL
C     WRITTEN BY D.W. PARVIN JR.
C                    DEPT. OF AG. ECON.
C                    MISS. STATE UNIV.
      DIMENSION A(45,8),X(20,45),L(20,45),ID(20)
      DO 70 I = 1, 20
   70 ID(I) = I
    1 DO 2 I = 1,37
    2 READ (5, 101) (A(I,J), J = 1, 8)
 6442 DO 3 I = 1, 20
      DO 3 J = 1, 45
      X(I,J) = 0.0
    3 L(I,J) = 0
      READ (5, 102) TNP,THR,XIPG,NG,NM
      WRITE (6, 901) TNP
      WRITE (6, 902) THR
      WRITE (6, 903) XIPG
      WRITE (6, 904) NG
      WRITE (6, 905) NM
  901 FORMAT (1H1,T2,'TOTAL NATURAL POPULATION =        ',F10.0)
  902 FORMAT (1H ,T2,'TOTAL HYBRIDS RELEASED =          ',F10.0)
  903 FORMAT (1H ,T2,'INCREASE PER GENERATION =         ',F10.0)
  904 FORMAT (1H ,T2,'NO OF GENERATIONS =               ',I10)
  905 FORMAT (1H ,T2,'NO OF MATINGS PER NORMAL MALE =   ',I10)
C     TNP = TOTAL NATURAL POPULATION (MALES + FEMALES)
C     THR = TOTAL HYBRIDS RELEASED (MALES + FEMALES)
C     XIPG = INCREASE PER GENERATION
C     NG = NO. OF GENERATIONS
C     NM = NO. OF MATINGS PER MALE
  101 FORMAT (8A6)
  102 FORMAT (2F10.0, F5.0, 2I5)
  103 FORMAT (1H0, T2,'DESCRIPTION',T38,'GENERATION=',T50, 10I7)
  104 FORMAT (1H , T2, 8A6, 10I7)
      I = 0
      DO 44 J = 1, NG
      I = I + 1
      X(I, 3) = TNP
      X(I,6) = THR
      IF (J-1) 53, 54, 53
54    X(I,1) = X(I,3) / 2.0
      X(I,2) = X(I,3) / 2.0
      X(I,4) = X(I,6) / 2.0
      X(I,5) = X(I,6) / 2.0
```

Table 1. CONTINUED

```
      GO TO 56
53    X(I,1) = X(I,3)
      X(I,2) = X(I,3)
      X(I,4) = X(I,6)
      X(I,5) = X(I,6)
56    CONTINUE
      X(I,7) = X(I,1) + X(I,4)
      X(I,8) = X(I,2) + X(I,5)
      IF ( X(I,8 ) .EQ. 0.0 ) GO TO 444
      X(I,9) =(X(I,2) / X(I,8))* X(I,1)
      M = X(I,9) + .5
      X(I,9) = M
      X(I,10) = X(I,1) - X(I,9)
      X(I,11) = X(I, 2) - X(I, 9)
      X(I,12) = X(I, 5)
      X(I,13) = X(I,11) + X(I, 12)
      IF ( X(I,13) .EQ. 0.0 ) GO TO 444
      IF ( NM. EQ. 1) GO TO 66
      X(I, 14) = X(I, 11) / X(I, 13) * X(I, 1)
      M = X(I, 14) + .5
      X(I, 14) = M
      X(I, 15) = X(I,1) - X(I, 14)
      X(I, 16) = X(I, 11) - X(I, 14)
      X(I, 17) = X(I, 5)
      X(I, 18) = X(I, 16) + X(I, 17)
      IF ( X(I,18) .EQ. 0.0 ) GO TO 444
      IF ( NM. EQ. 2) GO TO 66
      X(I, 19) = X(I, 16) / X(I, 18) * X(I, 1)
      M = X(I, 19) + .5
      X(I, 19) = M
      X(I, 20) = X(I, 1) - X(I, 19)
      X(I, 21) = X(I, 16) - X(I, 19)
      X(I, 22) = X(I, 5)
      X(I, 23) = X(I, 21) + X(I, 22)
      IF ( X(I,23) .EQ. 0.0 ) GO TO 444
      IF ( NM. EQ. 3) GO TO 66
      X(I, 24) = X(I, 21) / X(I, 23) * X(I, 1)
      M = X(I, 24) + .5
      X(I, 24) = M
      X(I, 25) = X(I, 1) - X(I, 24)
      X(I, 26) = X(I, 21) - X(I, 24)
      X(I, 27) = X(I, 5)
      X(I, 28) = X(I, 26) + X(I, 27)
      IF ( X(I,28) .EQ. 0.0 ) GO TO 444
      IF ( NM. EQ. 4) GO TO 66
      X(I, 29) = X(I, 26) / X(I, 28) * X(I, 1)
```

Table 1. CONTINUED

```
      M = X(I, 29) + .5
      X(I, 29) = M
      X(I, 30) = X(I, 1) - X(I, 29)
      X(I, 31) = X(I, 26) - X(I, 29)
      X(I, 32) = X(I, 5)
      X(I, 33) = X(I, 31) + X(I, 32)
   66 CONTINUE
      X(I, 34) = X(I,9)+X(I,14)+X(I,19)+X(I,24)+X(I,29)
      X(I, 35) = X(I,10)+X(I,15)+X(I,20)+X(I,25)+X(I,30)
      X(I, 36) = X(I, 34) * XIPG
      X(I, 37) = X(I, 35) * XIPG
      IF ( X(I, 36). GT. 125000.0 )  X(I, 36) = 125000.0
      IF ( X(I, 37). GT. 125000.0 )  X(I, 37) = 125000.0
      TNP = X(I, 36)
      TWR = X(I, 37)
  927 FORMAT (1H0, I5)
   44 CONTINUE
      GO TO 448
  444 CONTINUE
      WRITE (6,449) J
  449 FORMAT (1H ,T2,'DIVISOR = 0 , GENERATION = ',I3)
  448 CONTINUE
      DO 55 I = 1, 20
      DO 55 J = 1, 45
   55 L(I, J) = X(I, J)
      WRITE (6, 103) (ID(J), J = 1, 10 )
      DO 77 I = 1, 37
   77 WRITE (6, 104) (A(I, J),J=1, 8), (L(K, I), K= 1, 10 )
      IF ( NG. GT. 10 ) GO TO 88
      GO TO 99
   88 WRITE (6, 103) (ID(J), J= 11, 20)
      DO 79 I = 1, 37
   79 WRITE (6, 104) (A(I, J) ,J=1,8), (L(K,I),K = 11,20)
   99 CONTINUE
      GO TO 6442
      END
```

TABLE 2. 80 X 80 LISTING OF FIRST 37 DATA CARDS

```
NORMAL MALES
NORMAL FEMALES
TOTAL NORMAL
HYBRID MALES
HYBRID FEMALES
TOTAL HYBRID
TOTAL MALES
TOTAL FEMALES
NORMAL FIRST MATINGS
HYBRID FIRST MATINGS
NORMAL FEMALES SEARCHING AFTER FIRST MATING
HYBRID FEMALES SEARCHING AFTER FIRST MATING
TOTAL  FEMALES SEARCHING AFTER FIRST MATING
NORMAL SECOND MATINGS
HYBRID SECOND MATINGS
NORMAL FEMALES SEARCHING AFTER SECOND MATING
HYBRID FEMALES SEARCHING AFTER SECOND MATING
TOTAL  FEMALES SEARCHING AFTER SECOND MATING
NORMAL THIRD MATINGS
HYBRID THIRD MATINGS
NORMAL FEMALES SEARCHING AFTER THIRD MATING
HYBRID FEMALES SEARCHING AFTER THIRD MATING
TOTAL  FEMALES SEARCHING AFTER THIRD MATING
NORMAL FOURTH MATINGS
HYBRID FOURTH MATINGS
NORMAL FEMALES SEARCHING AFTER FOURTH MATING
HYBRID FEMALES SEARCHING AFTER FOURTH MATING
TOTAL  FEMALES SEARCHING AFTER FOURTH MATING
NORMAL FIFTH MATINGS
HYBRID FIFTH MATINGS
NORMAL FEMALES SEARCHING AFTER FIFTH MATING
HYBRID FEMALES SEARCHING AFTER FIFTH MATING
TOTAL  FEMALES SEARCHING AFTER FIFTH MATING
TOTAL NORMAL MATINGS
TOTAL HYBRID MATINGS
NORMAL INCREASE
HYBRID INCREASE
```

TABLE 3. FORMAT FOR GENERAL DATA CARD(S).

Card Column	Variable Description	Program Mnemonic
1 - 10	Total Natural Population	TNP
11 - 20	Total Hybrid Population	THP
21 - 25	Increase Per Generation	XIPG
26 - 30	Number of Generations	NG
31 - 35	Number of Matings Per Normal Male	NM

Table 4. Example Output, 9:1 Release

```
TOTAL NATURAL POPULATION =            1000.
TOTAL HYBRIDS RELEASED =              9000.
INCREASE PER GENERATION =                5.
NO OF GENERATIONS =                     20
NO OF MATINGS PER NORMAL MALE =          3
```

DESCRIPTION GENERATION=	1	2	3	4	5	6	7	8	9	10
NORMAL MALES	500	680	850	980	1050	1050	985	875	735	585
NORMAL FEMALES	500	680	850	980	1050	1050	985	875	735	585
TOTAL NORMAL	1000	680	850	980	1050	1050	985	875	735	585
HYBRID MALES	4500	6820	9350	11770	13650	14700	14765	13900	12390	10440
HYBRID FEMALES	4500	6820	9350	11770	13650	14700	14765	13900	12390	10440
TOTAL HYBRID	9000	6820	9350	11770	13650	14700	14765	13900	12390	10440
TOTAL MALES	5000	7500	10200	12750	14700	15750	15750	14775	13125	11025
TOTAL FEMALES	5000	7500	10200	12750	14700	15750	15750	14775	13125	11025
NORMAL FIRST MATINGS	50	62	71	75	75	70	62	52	41	31
HYBRID FIRST MATINGS	450	618	779	905	975	980	923	823	694	554
NORMAL FEMALES SEARCHING AFTER FIRST MATING	450	618	779	905	975	980	923	823	694	554
HYBRID FEMALES SEARCHING AFTER FIRST MATING	4500	6820	9350	11770	13650	14700	14765	13900	12390	10440
TOTAL FEMALES SEARCHING AFTER FIRST MATING	4950	7438	10129	12675	14625	15680	15688	14723	13084	10994
NORMAL SECOND MATINGS	45	56	65	70	70	66	58	49	39	29
HYBRID SECOND MATINGS	455	624	785	910	980	984	927	826	696	556
NORMAL FEMALES SEARCHING AFTER SECOND MATING	405	562	714	835	905	914	865	774	655	525
HYBRID FEMALES SEARCHING AFTER SECOND MATING	4500	6820	9350	11770	13650	14700	14765	13900	12390	10440
TOTAL FEMALES SEARCHING AFTER SECOND MATING	4905	7382	10064	12605	14555	15614	15630	14674	13045	10965
NORMAL THIRD MATINGS	41	52	60	65	65	61	55	46	37	28
HYBRID THIRD MATINGS	459	628	790	915	985	989	930	829	698	557
NORMAL FEMALES SEARCHING AFTER THIRD MATING	364	510	654	770	840	853	810	728	618	497
HYBRID FEMALES SEARCHING AFTER THIRD MATING	4500	6820	9350	11770	13650	14700	14765	13900	12390	10440
TOTAL FEMALES SEARCHING AFTER THIRD MATING	4864	7330	10004	12540	14490	15553	15575	14628	13008	10937
NORMAL FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
NORMAL FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL NORMAL MATINGS	136	170	196	210	210	197	175	147	117	88
TOTAL HYBRID MATINGS	1364	1870	2354	2730	2940	2953	2780	2478	2088	1667
NORMAL INCREASE	680	850	980	1050	1050	985	875	735	585	440
HYBRID INCREASE	6820	9350	11770	13650	14700	14765	13900	12390	10440	8335

Table 4. CONTINUED

DESCRIPTION	GENERATION= 11	12	13	14	15	16	17	18	19	20
NORMAL MALES	440	315	215	140	90	60	40	30	15	0
NORMAL FEMALES	440	315	215	140	90	60	40	30	15	0
TOTAL NORMAL	440	315	215	140	90	60	40	30	15	0
HYBRID MALES	8335	6285	4510	3085	2010	1290	860	570	435	225
HYBRID FEMALES	8335	6285	4510	3085	2010	1290	860	570	435	225
TOTAL HYBRID	8335	6285	4510	3085	2010	1290	860	570	435	225
TOTAL MALES	8775	6600	4725	3225	2100	1350	900	600	450	225
TOTAL FEMALES	8775	6600	4725	3225	2100	1350	900	600	450	225
NORMAL FIRST MATINGS	22	15	10	6	4	3	2	1	0	0
HYBRID FIRST MATINGS	418	300	205	134	86	57	38	29	15	0
NORMAL FEMALES SEARCHING AFTER FIRST MATING	418	300	205	134	86	57	38	29	15	0
HYBRID FEMALES SEARCHING AFTER FIRST MATING	8335	6285	4510	3085	2010	1290	860	570	435	225
TOTAL FEMALES SEARCHING AFTER FIRST MATING	8753	6585	4715	3219	2096	1347	898	599	450	225
NORMAL SECOND MATINGS	21	14	9	6	4	3	2	1	0	0
HYBRID SECOND MATINGS	419	301	206	134	86	57	38	29	15	0
NORMAL FEMALES SEARCHING AFTER SECOND MATING	397	286	196	128	82	54	36	28	15	0
HYBRID FEMALES SEARCHING AFTER SECOND MATING	8335	6285	4510	3085	2010	1290	860	570	435	225
TOTAL FEMALES SEARCHING AFTER SECOND MATING	8732	6571	4706	3213	2092	1344	896	598	450	225
NORMAL THIRD MATINGS	20	14	9	6	4	2	2	1	0	0
HYBRID THIRD MATINGS	420	301	206	134	86	58	38	29	15	0
NORMAL FEMALES SEARCHING AFTER THIRD MATING	377	272	187	122	78	52	34	27	15	0
HYBRID FEMALES SEARCHING AFTER THIRD MATING	8335	6285	4510	3085	2010	1290	860	570	435	225
TOTAL FEMALES SEARCHING AFTER THIRD MATING	8712	6557	4697	3207	2088	1342	894	597	450	225
NORMAL FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
NORMAL FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL NORMAL MATINGS	63	43	28	18	12	8	6	3	0	0
TOTAL HYBRID MATINGS	1257	902	617	402	258	172	114	87	45	0
NORMAL INCREASE	315	215	140	90	60	40	30	15	0	0
HYBRID INCREASE	6285	4510	3085	2010	1290	860	570	435	225	0

Table 5. Example Output, 19:1 Release

```
TOTAL NATURAL POPULATION =              1000.
TOTAL HYBRIDS RELEASED =               19000.
INCREASE PER GENERATION =                  5.
NO OF GENERATIONS =                       10
NO OF MATINGS PER NORMAL MALE =            3
```

DESCRIPTION GENERATION=	1	2	3	4	5	6	7	8	9	10
NORMAL MALES	500	360	250	170	110	70	45	30	15	0
NORMAL FEMALES	500	360	250	170	110	70	45	30	15	0
TOTAL NORMAL	1000	360	250	170	110	70	45	30	15	0
HYBRID MALES	9500	7140	5150	3580	2440	1580	1005	645	435	225
HYBRID FEMALES	9500	7140	5150	3580	2440	1580	1005	645	435	225
TOTAL HYBRID	19000	7140	5150	3580	2440	1580	1005	645	435	225
TOTAL MALES	10000	7500	5400	3750	2550	1650	1050	675	450	225
TOTAL FEMALES	10000	7500	5400	3750	2550	1650	1050	675	450	225
NORMAL FIRST MATINGS	25	17	12	8	5	3	2	1	0	0
HYBRID FIRST MATINGS	475	343	238	162	105	67	43	29	15	0
NORMAL FEMALES SEARCHING AFTER FIRST MATING	475	343	238	162	105	67	43	29	15	0
HYBRID FEMALES SEARCHING AFTER FIRST MATING	9500	7140	5150	3580	2440	1580	1005	645	435	225
TOTAL FEMALES SEARCHING AFTER FIRST MATING	9975	7483	5388	3742	2545	1647	1048	674	450	225
NORMAL SECOND MATINGS	24	17	11	7	5	3	2	1	0	0
HYBRID SECOND MATINGS	476	343	239	163	105	67	43	29	15	0
NORMAL FEMALES SEARCHING AFTER SECOND MATING	451	326	227	155	100	64	41	28	15	0
HYBRID FEMALES SEARCHING AFTER SECOND MATING	9500	7140	5150	3580	2440	1580	1005	645	435	225
TOTAL FEMALES SEARCHING AFTER SECOND MATING	9951	7466	5377	3735	2540	1644	1046	673	450	225
NORMAL THIRD MATINGS	23	16	11	7	4	3	2	1	0	0
HYBRID THIRD MATINGS	477	344	239	163	106	67	43	29	15	0
NORMAL FEMALES SEARCHING AFTER THIRD MATING	428	310	216	148	96	61	39	27	15	0
HYBRID FEMALES SEARCHING AFTER THIRD MATING	9500	7140	5150	3580	2440	1580	1005	645	435	225
TOTAL FEMALES SEARCHING AFTER THIRD MATING	9928	7450	5366	3728	2536	1641	1044	672	450	225
NORMAL FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
NORMAL FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL NORMAL MATINGS	72	50	34	22	14	9	6	3	0	0
TOTAL HYBRID MATINGS	1428	1030	716	488	316	201	129	87	45	0
NORMAL INCREASE	360	250	170	110	70	45	30	15	0	0
HYBRID INCREASE	7140	5150	3580	2440	1580	1005	645	435	225	0

Table 6. Example Output, 29:1 Release

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TOTAL NATURAL POPULATION =          1000.
TOTAL HYBRIDS RELEASED =           29000.
INCREASE PER GENERATION =              5.
NO OF GENERATIONS =                   10
NO OF MATINGS PER NORMAL MALE =        3
DIVISOR = 0 , GENERATION =    7
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DESCRIPTION GENERATION=	1	2	3	4	5	6	7	8	9	10
NORMAL MALES	500	245	115	50	15	0	0	0	0	0
NORMAL FEMALES	500	245	115	50	15	0	0	0	0	0
TOTAL NORMAL	1000	245	115	50	15	0	0	0	0	0
HYBRID MALES	14500	7255	3560	1675	735	225	0	0	0	0
HYBRID FEMALES	14500	7255	3560	1675	735	225	0	0	0	0
TOTAL HYBRID	29000	7255	3560	1675	735	225	0	0	0	0
TOTAL MALES	15000	7500	3675	1725	750	225	0	0	0	0
TOTAL FEMALES	15000	7500	3675	1725	750	225	0	0	0	0
NORMAL FIRST MATINGS	17	8	4	1	0	0	0	0	0	0
HYBRID FIRST MATINGS	483	237	111	49	15	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FIRST MATING	483	237	111	49	15	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FIRST MATING	14500	7255	3560	1675	735	225	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FIRST MATING	14983	7492	3671	1724	750	225	0	0	0	0
NORMAL SECOND MATINGS	16	8	3	1	0	0	0	0	0	0
HYBRID SECOND MATINGS	484	237	112	49	15	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER SECOND MATING	467	229	108	48	15	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER SECOND MATING	14500	7255	3560	1675	735	225	0	0	0	0
TOTAL FEMALES SEARCHING AFTER SECOND MATING	14967	7484	3668	1723	750	225	0	0	0	0
NORMAL THIRD MATINGS	16	7	3	1	0	0	0	0	0	0
HYBRID THIRD MATINGS	484	238	112	49	15	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER THIRD MATING	451	222	105	47	15	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER THIRD MATING	14500	7255	3560	1675	735	225	0	0	0	0
TOTAL FEMALES SEARCHING AFTER THIRD MATING	14951	7477	3665	1722	750	225	0	0	0	0
NORMAL FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FOURTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FOURTH MATING	0	0	0	0	0	0	0	0	0	0
NORMAL FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
HYBRID FIFTH MATINGS	0	0	0	0	0	0	0	0	0	0
NORMAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
HYBRID FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL FEMALES SEARCHING AFTER FIFTH MATING	0	0	0	0	0	0	0	0	0	0
TOTAL NORMAL MATINGS	49	23	10	3	0	0	0	0	0	0
TOTAL HYBRID MATINGS	1451	712	335	147	45	0	0	0	0	0
NORMAL INCREASE	245	115	50	15	0	0	0	0	0	0
HYBRID INCREASE	7255	3560	1675	735	225	0	0	0	0	0

SUMMARY

There are generally four or more generations of tobacco budworms each season. The information prescribed in Table 6 indicates that there is a theoretical probability that a hybrid release of a 29:1 ratio might suppress the tobacco budworm population.

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