Effects of Maternal Age on Biological Features of *Myzus persicae* (Hemiptera: Aphididae)

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ABSTRACT— ***In living organisms, the effects of parents known as the maternal effect determine many features of the offspring. The phenotype of an organism is determined by its environment and genotype as well as the environment and genotype of its mother. Several reports have indicated that longevity of the offspring of elderly parents are shorter than the lifetime of the offspring of young parents and reproductivity of old parents is lower than the young parents. Aphids as thelytokous parthenogens are one of the ideal organisms for studying the effects of maternal age. Aphids multiply very fast during their parthenogenetic phase of life cycle. Another advantage of working on this pest is that they have a short generation time. Due to the maternal age, some of the offspring die before completion of their development and accordingly, increased mother age reduces the survival rate of the offspring.***

In this study, we aim to determine development time, survival rate, preoviposition, oviposition, postoviposition, and effects of maternal age on the total number of offspring on Green peach aphid, Myzus persicae Sulzer (Hemiptera: Aphididae). Herein, the biology of offspring individuals laid every day by mother was monitored. The trials were conducted at 25 ± 1 °C and 60± 5% relative humidity and 16: 8 hour light: dark conditions in a climate chamber.

At the end, life table of each offspring laid in each day by adults was formed.

So, the study revealed that maternal age effect on fecundity and survival of the green peach aphids reared on pepper plants.

Keywords—Green peach aphid, mother, pepper, life table

1. INTRODUCTION

Genetic structures of parents and changes in their habitat have effects on the biology of individuals formed in subsequent generations (Mousseau and Dingle, 1991a). Mousseau and Dingle (1991b) reported that offsprings born in the early period grew faster, and also females born in the early period laid more eggs, their hatching rate was higher and the lifetime of individuals born was longer. It is known that parental age has various effects on offspring of many insect species (Parsons, 1964; Pianka, 1978; Dixon *et al*., 1993; Fox, 1993; Fox and Dingle, 1994; Dixon, 1998; Mcintyre and Gooding, 2000; Yanagi and Miyatake, 2002; Fox *et al*., 2003; Al-Lawati and Bienefeld, 2009). It has been reported that offspring born from older mothers have a higher mortality rate compared to offsprings born from younger mothers, and they develop later in time and that adults developed from them form smaller individuals or eggs and show lower quality reproductive performance (Jones *et al*., 1982; Wiklund and Persson, 1983; Mcintyre and Gooding, 2000; Al-Lawati and Bienefeld, 2009).

The phenotype of an individual is affected not only by its genes and the environment in which it exists but also by the phenotype of its parents and the environment in which they grow. This pattern of inheritance from parents originates from the factors transferred from parents to offspring rather than simple nuclear DNA sequencing (Priest *et al*., 2002). It has been reported that many researchers investigate the hypothesis concerning the fact that an animal approaching the end of life increases its reproductive efforts in reaction to declining reproductive value (Dixon *et al*., 1993). Dixon *et al*. (1993) emphasized that majority of these studies were related to mammals. Studies carried out on insects were less associated with the life history theory, and that studies were related to the measurement of the size of an offspring rather than the measurement of its reproductive efforts.

In this study, we hypothesized that *M. persicae* life history parameters on pepper will increase/decrease with increasing maternal age and attempt to explain the effect of parental age on the development and fecundity potential of individuals formed in subsequent generations by using the green peach aphids, *Myzus persicae* as an example. For this purpose, life tables of individuals reproduced by the adults of *M. persicae* at different ages were created.

2. MATERIALS AND METHODS

2.1. Capsicum annuum culture

Green pepper plants, Green pepper plants, Capsicum anuum (Var. Lotus), were used to test *M. persicae* in our study. Pepper plants were grown from seed

Lotus green pepper variety was used for the production of the pepper plant. Perlite was added to the sterilized soil at the rate of 1/3, filled in the sterilized pots (25 cm diameter and 17 cm length), and the transfer of pepper seedlings was carried out. The seedlings were carried to climate chambers. The plants were regularly irrigated at 2-3 day intervals. No fertilizer or drug application was performed during the seedling cultivation.

2.2 Myzus persicae Colony

The aphids used during the tests were taken from the stock culture produced in the climate chambers of the Biological Control laboratory at the Plant Protection Department, Faculty of Agriculture, at Süleyman Demirel University. The first contamination was achieved by transferring *M. persicae* individuals taken from the stock culture to the pepper seedlings with 6-8 leaves. In order to maintain the colony, clean plants produced with weekly periods were changed with those that grew old and began to collapse. Plants and aphids were raised in climate chambers adjusted to the temperature of 25±1°C and proportional humidity of 60±5%, 16 hours of illumination, and 8 hours of darkness.

2.3 Experimental procedure

Petri dishes with 12 cm diameter were used for the experiments. 2 cm holes were made in the cover part of the Petri dishes. Afterwards, these parts of the Petri dishes were covered with a veil. Cotton was laid in the base of the Petri dishes, and pepper leaf was placed on it. In order to maintain the vitality of the leaves, cotton pieces placed at the base of the Petri dishes were moistened when necessary. The withered pepper leaves were replaced with the new ones when necessary. For each experiment, first instar nymphs were born live from a female from the stock culture and were transferred to Petri dishes using abrush. These individuals were observed under the stereo microscope until they became adults. The test population was created by transferring the nymphs laid every day by these individuals which completed their development and reached adulthood to new experimental dishes, in such a way that one individual would be placed to each Petri dish separately by taking the days they were born into consideration. Each individual transferred to the new Petri dish environment depending on the day it was born was observed on a daily basis until the day it died, and its development was recorded. During these observations, nymph durations, periods of reaching adulthood and the number of the offspring laid on a daily basis by those which reached adulthood were recorded. Furthermore, the number of the individuals that died during the test period were noted down depending on the day they died. The experiments prepared according to the age groups were set up to ensure at least 100 repetitions. The experiments were carried out in climate chambers where 27.5±1 °C and 60±5% proportional humidity, and 16:8-hour illumination: darkness ambient conditions were provided.

2.4 Data Analysis

The obtained data were evaluated with a life table depending on the age for each population. Data were integrated into an age-dependent life history table based on the Euler-Lotka equation (Birch, 1948) that was evaluated using the RmStat-3 program (Özgökçe and Karaca, 2010).

These parameters:

Net reproduction rate (R_o), were calculated with the aid of the formulas of the Age-specific survivor (l_x) and fecundity rate (m_x) and Intrinsic rate of increase (r_m), Mean generation time (T_o), Gross reproduction rate (*GRR*), Finite rate of increase (□), Doubling time (T_2) were calculated according to Birch (1948) and Carey (1993; 2001).

Age-dependent survival data of different populations used in the study were obtained by the Weibull distribution (Pinder *et al*., 1978):

$$S_p(t) = e^{\left[-\left(\frac{t}{b}\right)^c\right]} \qquad t, b, c > 0$$ (Deevey, 1947)

were $S_p(t)$ represents the survival probability, *b* represents the measurement of inclination, *c* represents the shape of curve, and *t* represents the time. The values that c parameter which explains the form of inclination takes may be $c>1$, $c=1$ and $c<1$, and the survival curve is associated with the similarities with the three types of life curves determined by Holling according to these values (Deevey, 1947; Pinder *et al*., 1978). Parameters in the Weibull distribution were calculated using CurveExpert pro (ver. 1.6.7), MS Excel (ver. 2003) and Delta Graph (ver. 6.0) software packages.

Moreover, Intrinsic rate of increase (rm), obtained for each age group as a result of the study was evaluated with the polynomial regression equation.

3. RESULTS AND DISCUSSION

The lifespan of the mothers used in the experiments, in which the effects of maternal age on the performances of new-born individuals were investigated, is given in Table 1.

In the study carried out by Satar *et al*. (2008) depending on different temperatures (15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 °C), they found out that development time of *M. persicae* before adulthood to be between 5.1 and 11.6 days. While the longest development time (11.6 days) was at 15 °C, the shortest development occurred at 25 °C. It was observed to be 6.1 when it was compared with the 27.5 °C that the researchers worked on, and in this study, it was determined that the harmful one developed much faster. This difference is considered to arise from the difference of pepper species used in both studies.

Table 1: Duration of various biological periods of the mothers used in the experiments (Days ± SE)

Life stages	Number of Individuals (n)	Lifespan (Days)
1 st instar	1661	1,3628 ± 0,00034
2 st instar	1580	1,4604 ± 0,00035
3 st instar	1085	1,2210 ± 0,00036
4 st instar	704	1,4262 ± 0,00057
Development time	704	5,4705 ± 0,00070

Mother individuals examined gave birth for 30 days and the developments of the individuals which were born each day are given in Table 2.

As it is seen in Table 2, the adult lifespan of 100 individuals, which were included in the experiment and reached adulthood, lived a minimum 1 day up to maximum of 30 days, was 14.58 days on average, and they laid 23.97 offspring per individual on average.

Güneyi and Karsavuran (2011) determined the lifespan of *M. persicae* in three different kinds of tobacco (Akhisar 97, Ege 97 and Sarıbağlar 407) to be 18.44, 20.18 and 19.42 days, respectively. The adult lifespan obtained in this study lasted shorter with 14.58 days. When the number of the offspring is compared, the number of the offspring obtained in the present study was found to be less than in the literature. Again, as it is stated above, the difference may result from the host plant.

As it is seen in Table 3, while nymphal instars varied between 1.000 days and 1.833 days on average, they usually took values close to each other. In the study carried out by Karsavuran and Anaç (2014) depending on maternal age (1st day, 7th day, and 15th day), the development periods of *M. persicae* nymphs formed varied between 1.24 and 1.70 days on average, and they showed similarity with this study.

The pre-oviposition, oviposition, post-oviposition, adult lifespan and the number of laid offspring of *Myzus persicae* are given in Table 3.

Table 2: Different biological time periods for each age group (Day) and mortality rate

Days (age)	n	1 Nymph	2 Nymph	3 Nymph	4 Nymph	Preadult	Mortality rate (%)
1	40	1,525	1,282	1,152	1,115	4,846	35,00
2	40	1,400	1,150	1,273	1,143	4,857	30,00
3	60	1,417	1,294	1,262	1,308	4,975	35,00
4	75	1,293	1,281	1,259	1,308	5,051	48,00
5	80	1,288	1,338	1,255	1,256	5,179	51,25
6	116	1,397	1,290	1,269	1,160	5,120	35,34
7	137	1,197	1,563	1,255	1,295	5,270	35,76
8	123	1,114	1,280	1,178	1,231	4,642	36,58
9	109	1,193	1,486	1,144	1,229	4,966	23,85
10	108	1,204	1,450	1,195	1,250	5,081	33,33
11	98	1,306	1,517	1,157	1,186	5,153	39,79
12	99	1,354	1,279	1,260	1,127	5,035	44,44
13	77	1,312	1,276	1,061	1,200	4,659	48,05
14	82	1,305	1,429	1,316	1,104	4,939	41,46
15	70	1,414	1,509	1,149	1,075	4,951	42,85
16	67	1,269	1,367	1,229	1,263	4,949	43,28
17	56	1,393	1,683	1,171	1,161	5,355	44,64
18	51	1,451	1,688	1,458	1,176	5,765	66,66
19	36	1,389	1,393	1,261	1,368	5,421	47,22
20	28	1,464	1,565	1,333	1,100	5,400	64,28
21	12	1,750	1,750	1,167	1,200	5,800	58,33
22	16	1,563	1,818	1,625	1,667	7,000	81,25
23	9	1,778	1,833	1,167	1,200	5,800	44,44
24	12	1,083	1,000	-	-	-	
25	3	1,000	1,000	-	-	-	
26	1	1,000	1,000	-	-	-	
27	1	1,000	1,000	-	-	-	
28	1	1,000	-	-	-	-	
29	1	1,000	-	-	-	-	
30	1	1,000	-	-	-	-	

From the results presented in Table 3, it was observed that while the pre-oviposition, oviposition, post-oviposition, and adult lifespan after the offspring formed reached adulthood vary depending on the age, they do not form a definite pattern. When the maternal age is taken into consideration, the number of the laid offspring was more than that in the first days, and the performances of the offspring laid by old individuals happened to be lower in this respect.

Table 3: Pre-oviposition, oviposition, post-oviposition, adult lifespan and the number of laid offspring of *Myzus persicae* for each age group

Maternal age (day)	Offspring charactaristics				
	Preoviposition (Day)	Oviposition (Day)	Postoviposition (Day)	Adult longevity (Day)	Mean fecundity
1	1,667±0,232	13,400±2,115	0,867±0,435	10,308±0,435	33,600±5,029
2	2,733±0,228	9,067±1,694	0,467±0,291	7,375±1,222	21,133±3,242
3	2,280±0,178	13,200±1,419	1,360±0,331	11,575±1,395	31,800±3,938
4	2,125±0,163	10,042±1,252	1,208±0,301	9,205±1,216	21,708±2,884
5	1,821±0,155	11,000±0,155	1,393±0,437	11,077±1,340	24,607±3,407
6	1,826±0,143	12,783±0,143	2,457±0,510	11,520±1,176	38,109±1,176
7	1,960±0,118	12,173±0,806	1,560±0,236	13,629±0,902	36,360±2,793
8	2,400±0,176	13,720±1,104	1,520±0,280	11852±1,115	40,540±3,482
9	2,246±0,131	10,614±0,817	1,351±0,180	10,068±0,823	28,351±2,342
10	1,894±0,205	11,894±1,123	0,681±0,140	10,230±0,994	31,894±3,158
11	2,167±0,116	10,500±0,971	1,139±0,222	9,458±0,222	30,528±3,015
12	2,389±0,166	11,750±1,295	2,083±0,337	11,228±1,257	27,000±3,440
13	2,462±0,159	10,769±1,280	1,154±0,302	9,545±1,184	25,769±3,657
14	2,273±0,205	10,515±1,092	1,364±0,278	10,469±1,104	25,667±2,724
15	1,906±0,151	8,938±0,866	0,938±0,246	10,049±0,874	27,125±3,184
16	1,870±0,170	10,870±1,178	1,478±0,307	9,333±1,188	24,957±3,240
17	1,864±0,190	9,909±1,530	0,909±0,335	10,258±1,353	24,727±3,386
18	2,250±0,310	4,438±0,826	0,313±0,198	6,706±1,049	9,938±1,743
19	2,000±0,195	9,200±1,918	0,467±0,192	9,895±1,806	22,667±5,624
20	3,000±1,000	7,000±2,646	0,667±0,667	4,700±1,674	12,667±4,177
21	2,000±0,632	6,200±1,800	0,800±0,583	9,000±1,703	11,200±3,967
22	0,667±0,333	7,333±3,180	1,333±0,667	9,333±3,528	11,667±5,207
23	2,000±0,632	6,200±1,800	0,800±0,583	9,000±1,703	9,400±3,059
24	0,000	0,000	0,000	0,000	0,000
25	0,000	0,000	0,000	0,000	0,000
26	0,000	0,000	0,000	0,000	0,000
27	0,000	0,000	0,000	0,000	0,000
28	0,000	0,000	0,000	0,000	0,000
29	0,000	0,000	0,000	0,000	0,000
30	0,000	0,000	0,000	0,000	0,000

In the study carried out on three different kinds of tobacco (Akhisar 97, Ege 97, and Sarıbağlar 407), it was determined that adult individuals of *M. persicae* laid offspring at numbers ranging between 41.36 and 73.41 on average (Güneyi and Karsavuran, 2011). In the study carried out by Karsavuran and Anaç (2014) on three age groups (1st day, 7th day, and 15th day) dependent on the maternal age with the same aphid, the total number of the offspring laid was found to be 51.45, 46.03 and 41.52 respectively.

When this study carried out was compared with the literature study, the number of the offspring in the present study was determined to be less. Moreover, in the study carried out by Karsavuran and Anaç (2014), while the number of the offspring laid decreased depending on the maternal age, the number of the offspring of the first-born individuals in this study showed an increase depending on the age, later decreased and reached the zero value on the 24th day

4.1 Life Tables

The life table parameters of the offspring given by mothers at different ages were created and included in Table 4.

When Table 4 is examined, Net reproduction capacity (R_o) value, which expresses the number of female individuals that *M. persicae* female individuals contributed to the population at the end of a generation under the conditions in which the experiment was conducted, showed a variance depending on the age groups. While this value was seen to be the highest on the 7th day, it reached the zero value starting from the 24th day.

Table 4: Net reproduction capacity (R_o), Intrinsic rate of increase (r_m), average number of offspring (T_o), gross reproduction rate *(GRR)*, time for doubling the population (T_2), increase rate limit (λ) in age groups of *Myzus persicae*

Age	r_m	R_o	T_o	*GRR*	T_2	λ
1	0,197	12,394	12,809	49,097	3,527	1,217
2	0,156	6,746	12,231	40,166	4,441	1,169
3	0,202	12,916	12,658	41,598	3,429	1,224
4	0,163	7,004	11,920	31,264	4,245	1,177
5	0,179	8,488	11,971	41,322	3,880	1,196
6	0,233	15,110	11,661	83,363	2,977	1,262
7	0,257	20,364	11,748	67,158	2,702	1,292
8	0,377	19,765	7,908	60,196	1,837	1,458
9	0,230	14,891	11,742	43,272	3,014	1,259
10	0,298	15,675	9,236	71,562	2,326	1,347
11	0,202	11,101	11,906	40,259	3,428	1,224
12	0,179	9,854	12,748	42,383	3,862	1,197
13	0,169	7,888	12,209	35,079	4,097	1,184
14	0,193	10,252	12,052	38,133	3,589	1,213
15	0,228	11,955	10,897	36,068	3,044	1,256
16	0,182	8,475	11,767	35,389	3,817	1,199
17	0,191	9,247	11,672	37,123	3,637	1,210
18	0,093	2,754	10,937	29,395	7,483	1,097
19	0,166	8,501	12,898	53,167	4,177	1,180
20	0,013	1,188	13,238	20,000	53,393	1,013
21	0,076	2,743	13,229	19,683	9,088	1,079
22	0,069	2,353	12,319	20,333	9,979	1,072
23	0,077	2,700	12,840	16,683	8,960	1,080

Although reproduction capacity has an impact on the development of populations, offspring time makes an important contribution to the population increase in the subsequent offspring. The average offspring time (T_o) examined within this scope varied between 0.000 and 13.238 days depending on the maternal age.

The intrinsic rate of increase (r_m) which gives the number of female offsprings, the most primary parameter that contributes to the development of population on a daily basis and dependent on the genetic structure of the living being, and also shows the population increase, varied depending on the age groups. While this value varied between 0.000 and 0.377, it however showed an increase until the 8th day and afterwards it decreased and reached the zero value on the 24th day.

In the study carried out by Satar *et al*. (2008) depending on different temperatures (15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 °C), the net reproduction capacity (R_o) of *M. persicae* was found to be between 5.00 and 85.33 female/female/generation; the average offspring time (T_o) was found to be between 11.50 and 25.66 days, and the intrinsic rate of increase (r_m) was found to be between 0.143 and 0.412 female/female/day.

When both studies were compared with each other, the intrinsic rate of increase in the test results of Satar *et al*. (2008), showed similarity with those observed in this study, while, the net reproduction capacity and average offspring times obtained by Satar et al. (2008) recorded values that were lower than those obtained in this study.

The Weibull distribution calculated based on the survival rates, and Beta (the form of the inclination, c) and Alpha (the measurement of the inclination, b) values are given in Table 5.

Table 5: Weibull distribution parameters of Myzus *persicae*'s populations in different age groups

Maternal age (Day)	**Beta (or the form of the inclination, *c*)**	**Alpha (or the measurement of the inclination, *b*)**	**R^2**
1	3.62242961718408	3.41654906160733	0.994937766862880
2	1.89009481323180	9.49070054417388	0.974056335474568
3	1.19423412506943	14.0559427151719	0.954584836180289
4	1.41620715449162	10.8605066976958	0.951427444181527
5	1.23550190679903	11.0677534442428	0.964415949550472
6	1.22591804227408	13.4610419421772	0.969486361419785
7	1.45653584474414	16.3754780821073	0.984268137121557
8	1.12471889943626	13.4486119928518	0.960009398449037
9	1.57515028410666	15.2096017260554	0.981580640257058
10	1.35424104822897	13.3100315792873	0.972191365033762
11	1.39695112035784	12.0418946211781	0.958718085017577
12	1.25224394076053	12.3780674012462	0.958745717373463
13	1.17909086614509	10.1533678895680	0.958753222902137
14	1.39578513128927	12.5386591855686	0.975838790022168
15	1.62631486069581	12.3128340856191	0.986493605429483
15	1.38691796586782	11.5101102145542	0.951970633418777
17	1.24548318301623	11.2921137204882	0.974251270482726
18	1.82788332700113	7.87463710301316	0.984517192032907
19	1.28441971013671	10.3029902900134	0.959928807366771
20	2.65011536781776	7.33167642781089	0.967221848552445
21	1.14646993585623	7.09076491163817	0.942416232895131
22	1.65826922509655	8.17835361842803	0.973002713747404
23	0.9920049982058905	7.02288166765826	0.897982429255113

When the Weibull distributions according to the vitality rate in the age group of adults are examined, the Beta (or the form of the inclination, c) value was observed to be higher than 1 in all of them, except the 23th age group (Table 5). This result shows that except the last age group, the population of *M. persicae* has an increasing population. When C parameter is c>1, life curves comply with Holling's 1st type life curve.

A curve was created with the help of the polynomial regression equation based on the values for the intrinsic rate of increase (r_m) of the offspring that *M. persicae* adults laid starting from the first day to the 30th day when they laid their last offspring (Figure 1). When the figure is examined, the reproduction capacity of the offspring that mother aphid gave birth to showed a gradual increase from the beginning. This increase reached its peak point on the 8th day, and the reproduction potential decreased gradually and reached zero value on the 24th day. The correlation coefficient of the curve obtained from the polynomial regression was found to be very high (0.7739). This shows that there is a strong relationship between the maternal age and the reproduction potential of individuals.

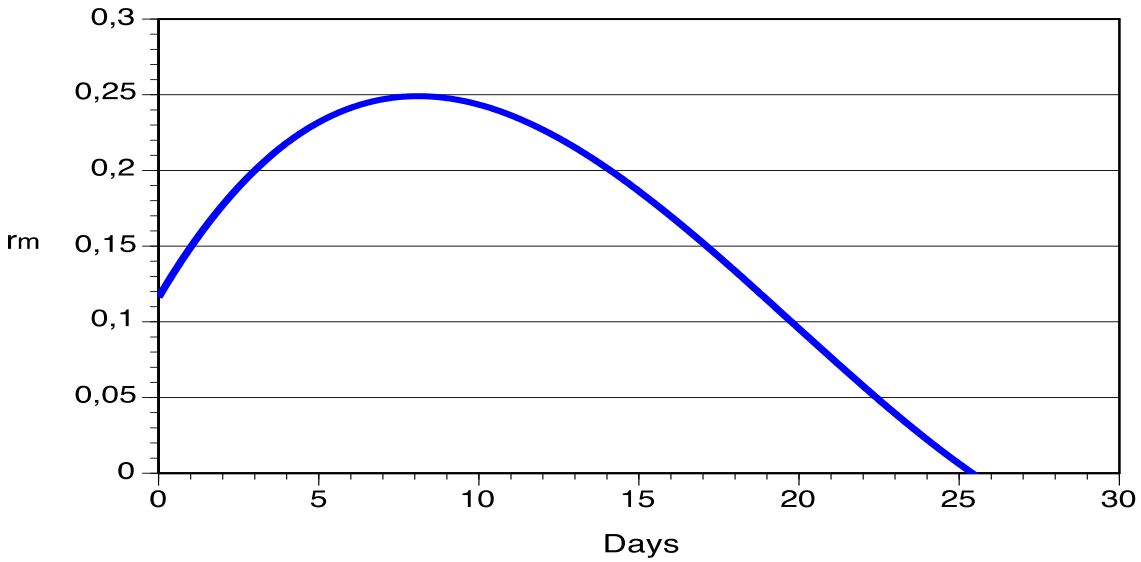

Figure 1: Distribution of intrinsic rate of increase (r_m) values of *Myzus persicae.*

As indicated in the result, during the lifespan of females, as in many insects, the females gave birth to the highest number of the offspring in the first periods, and this number slowly declined towards the end of the oviposition period. It was observed that individuals born from young mothers were much healthier, and their reproduction potentials were higher compared to the offspring of old mothers, and there was a difference between the reproduction potential of the offsprings given by young individuals and old individuals.

Due to the fact that *M. persicae* is preferred by many beneficial insects, it is evident that using young age groups in biological control studies with the production purpose on the basis of the data herein will provide benefits. When it is approached in this way, it will be appropriate to use young parents, especially one-week-olds, in the mass production of the harmful. This choice will lead to improvement in both time and labor savings. When it is approached as harmful, it will provide foresight beforehand for definite subjects. Important numeric data have been obtained in terms of their serving as an example to the studies to be done on this subject.

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