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INSECT STERILITY PROGRAM

TECHNICAL REPORT 6

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Insect Sterility Program

(Formerly Potential for Gamma-Induced Sterility in Control of the Sugarcane Borer *D. saccharalis* (Fab.) in Puerto Rico)

Research supported by the USAEC Division of Biology and Medicine and the US Department of Agriculture under contract No. AT(40-1)-1833

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I. Introduction

This is the sixth technical report to be published for the project (1965, 6, 7, 8, and '70). The Project was begun under the title of Potential for Gamma-induced Sterility in Control of the Sugarcane Borer (Diatraea saccharalis), and the program as now called the Insect Sterility Program. The original motive was to determine if the sugarcane borer could be sterilized by gamma radiation and to develop rearing methods suitable for adapting to a factory rearing method with the objective of releasing fully sterilized borer males into a natural population as a mass sterile release program. Subsequent work has demonstrated that adult males and females can be sterilized by ^{60}Co gamma exposures and field tests showed that it might be practicable as a means of eradication of this species. Several problems prevent a high degree of efficiency for the use of this method for this particular species however. Among these are the short life span of the adults (whether sterilized or normal), necessitating the frequent overflooding to maintain the necessary sterile to normal ratios; the high cost of production of sterile adults for release; the difficulty of adapting to factory rearing methods to produce millions of individuals of this species to sterilize; the long larval developmental period; multiple mating; and the necessity for sterilizing the individuals for release in the adult stage.

To solve the problem of eradicating this species we explored the possibility of giving sub-sterilizing dosages of gamma radiation. This was found to have some important advantages over the release of individuals that are fully sterile-i.e. resulting semi-sterile offspring as contrasted to dominant lethals in embryonic development. Originally we called this effect Delayed Sterility, but later we have coined the phrase Inherited Partial Sterility. In addition to the sugarcane borer we have observed the IPS effect in other lepidoptera Lamprosema indicata, Prodenia ornithogalla, Heliothis zea, and in one hemiptera (Nezara viridula). Some of this work is discussed in this report. In addition North (1968), La Chance (1969), Proshold (1970) and others have observed the same effect in other lepidoptera, in hemiptera and in homoptera. The original observations of this effect were reported by Proverbs (1962) and by Husseiny (1964), but no practical significance was attributed to it. Walker and Pederson (1969), Knipling (1969), North (1970) and others have shown how IPS might be used to suppress or to eradicate a pest population from a theoretical standpoint.

Therefore the original thrust of the program (study of the sugarcane borer intensively with the motive of eradication) has been changed to concentrating upon general means of suppression and eradication of pest species that have holokinetic chromosomes. Our present objectives are in the direction of determining the mechanisms that cause the delay in mortality, and particularly how this mechanism(s) can be used most effectively within the reference of integrated pest management systems. The application of the method to pest population control is still the most important aspect of the program, but in addition the converse concept of how a strain can maintain itself while carrying a heavy gene load is of considerable significance as well. We suspect that the long-term effect over many successive generations is due primarily to point mutations, eliminations and breaks. We believe this to be the case for several reasons. Translocations commonly occur at dosages of one-half to three-fourths of the dose needed to cause complete dominant lethality (25 kr), however we encounter the IPS effect when there are no observable translocations in meotic divisions. This of course does not mean that the translocations are not present. Since individual fragments operate as separate and distinct chromosomes we suspect that the code is nearly complete in IPS lines from low doses, but that the code is in a scrambled version. Some indirect evidence can be used to support this view, although the evidence is not sufficient to prove the point.

Subsequent sections of this report discuss the work of the previous year, and evaluate the significance of the work and its relation to other related work particularly in relation to pest management systems, future plans and a narrative report are also included.

At present the program is funded by a grant from the US Atomic Energy Commission Division of Biology and Medicine and a grant from the US Department of Agriculture. In addition to these we are working cooperatively with the Experiment Stations of both the Commonwealth of Puerto Rico and with the USDA Federal Experiment Station, and with the Entomological Laboratory of the Biology Department of the UPR in Mayaguez. These cooperative programs do not entail the interchange of funds.

Among the many individuals deserving acknowledgement for their cooperation and advice I would like to mention Dr. Murray Blum (Univ. of Georgia), Dr. R. C. Von Borstel (Univ. of Manitoba), Drs. Robert Rabson and Charles Edington (DBM of AEC), Drs. Frank Koo, Shreekant Deshpande, Jose Ferrer-Monge and Mr. Jose Cuevas-Ruiz, Mrs. Dolores Ayguabibas de Ruiz and Mr. Samuel de la Rosa, of PRNC, and Drs. Goru Kuno, Chester Moore, and Flavio Padovani and Mr. Ruben Restrepo of the Biology Department, UPR Mayaguez, Dr. Nader Vakili of the USDA Experiment Station and Dr. Niilo Virkki of the UPR Experiment Station, Rio Piedras.

II. Accomplishments

For convenience of presentation results is under general subject headings with sub-divisions by species.

A. Laboratory

Lepidoptera

1. Diatraea saccharalis Fab. (sugarcane borer)

We are maintaining one strain of this species in the laboratory on a modification of the Shorey Bean Diet (Walker, Tech. Rept. 6, 1970) in a ten inch plastic dish with a cover. Larval is good except for the first stage. This method was recommended by Dr. A. N. Sparks, USDA Southern Grain Insects Laboratory at Tifton, Georgia (personal communication) and is a modification of the method used for the European Corn Borer. Theoretically the mature larvae leave the food before pupating, migrate to a wax-covered ring made of corrugated paper and pupated in the food itself. Two generations have been tested with this method and survival was approximately 70 percent in the first generation (700 larvae) and about 60 percent in the second (using

1,200 larvae). Transfer to the container was made by shaking larvae from oviposition cups directly. There was considerable bacterial and mold contamination in both tests. Containers can be washed, sterilized with calcium hypochlorite solution and re-used. Similar tests in smaller rectangular plastic containers have yielded comparable results. Future sugarcane borer rearing will be in these plastic containers. The advantages are fairly high production capacity with minimum handling and attention. The major disadvantage is that larva to larva disease transmission is facilitated.

Since the diet is nutritionally adequate there is a minimum of cannabalism except for accidental feeding of larvae upon pupae. It may be possible to devise an easy method for harvesting adults directly from these containers by using a light source for attracting the adults.

Less than 10 percent of the adults have manifested physical deformities caused by overcrowding or by inadequate diet. Dr. Kuno has isolated material from diseased borer larvae and is testing the inoculum prepared from these into healthy larvae in an attempt to isolate and identify the pathogen(s). Microscopic examinations have not shown fungi nor bacteria so that a virus infection is suspected.

Rearing capacity for this species is apparently limited only by the labor force available. The strain selected and the laboratory regime and diet appear to be adequate for producing several thousands of adults weekly under the proper conditions and with adequate facilities. Production cost is still high. approximately 0.2 cents each, this includes labor costs.

2. Prodenia ornithogalli Gn. (yellow striped armyworm, subfamily Amphipyrinae, Phalaenidae)

This species is a large-size larva that attacks vegetable and other succulent crops, it has a wide host range, including (beans, tobacco, weeds, practically all vegetable crops). Mating is nocturnal, and adult lifespan is fairly long in the laboratory. It is rarely encountered during the day on plants since the larvae pass the day in soil and feed at night. The species is particularly damaging to young plants.

This species develops well in the bean diet for sugarcane borer. Two generations were passed in the laboratory and preliminary radiation/sterility tests were made. The strain selected underwent an arrested development after the second generation and the adults produced emerged over such a long period of time that it was not possible to obtain viable offspring for a third generation. This species will be available early next year and we will continue our work with it at that time. Only a single larva can be grown in each cup. Fairly large mating and oviposition chambers are needed to culture this species. Because of the large size of the larvae haemolymph is available in considerable quantity, a decided advantage in the protein electrophoresis work.

3. Lamprosema indicata (Fab.) (pega pega, Pyralidae)

We were able to develop a satisfactory combination of diet and container for rearing larvae of this species (bean diet) however we had great difficulty in providing the proper conditions for mating. Mating frequency was higher when adults were able to fly horizontally over a considerable distance at bean plant height. Mating was better in cages when plants were provided. Even though reproductive rate in nature is very high we were not able to havest more than 15 to 20 fertile eggs per mated female. Due to these difficulties we have temporarily suspended work with this species.

Hemiptera

4. Nezara viridula (L.) (southern green stink bug, Pentatomidae)

Mr. Ruben Restrepo has performed most of the rearing work on this species. He is working on a volunteer basis. We have cultured this species through 6 generations using a combination of diets. Attractant tests and nutrition tests were mentioned in the previous report (Walker 6, 1970). A meridic (defined) diet has been adequate for supporting 3 generations of this species by Mullet and Rodriguez at UPR Mayaguez. Mr. Restrepo is capable of maintaining it on a combination of guava and acerola nectar (available as a canned juice), bean pods (wild bean) and cabbage leaf. Although the rearing methods tested need considerable refinement it is apparent that we will be able to make evaluations of IPS with the rearing procedure that we have. IPS tests with this species are discussed in a later section of this report. Since the previous report we have changed to one gallon containers for enclosing adults and nymphs of this species: survival and lifespan has been increased as a result. Providing a constant air stream through the net covering over the top has also helped to maintain the laboratory colony. Current production in the laboratory is 20 to 30 adults per week, but under these conditions and with adequate labor this can be increased to 400 to 500 adults per week.

Adult lifespan has exceeded 3 and one-half months in some of the tests. Mating has been observed and egg development has been studied so that fertile eggs can be distinguished from haploid eggs as shown in table 1.

The only serious problems encountered rearing this species is keeping sufficient food available and separating nymphal stages so that predation is prevented. This commonly occurs at the time of molting, mature individuals feeding on younger nymphs while the integument of the younger individual is still soft.

5. Other species cultivated

In addition to the above we have tested artificially rearing the following: Prodenia eridenia (Phalaenidae Lepidoptera); Acrosternum marginatum (Pentatomidae Hemiptera); Leptoglossus gonagra (Coreidae Hemiptera); Diaprepes abbreviata (Curculionidae, Coleoptera); Trichoplusia ni (Noctuidae, Lepidoptera); Phyllophaga vandinei (maybeetle, Scarabaeidae, Coleoptera); Cosmopolites sordida, Metamasius hemiptera, Cylas formicaria, and an Anthonomus species (Curculionidae, Coleoptera).

We will be capable of rearing P. eridenia and T. ni without too much difficulty, however there is no great advantage in rearing the former when we are rearing P. ornithogalli and T. ni is being investigated by USDA scientists.

We had considerable difficulty rearing all of the Coleoptera for a variety of reasons. The food was not acceptable to larvae in some cases, and there was considerable migration from the cups in the root inhabiting species, as well as a very long larval lifespan, for these reasons they were not suitable test insects for laboratory studies.

All of the above species are of some economic importance to commercial crops in Puerto Rico.

B. Inherited Partial Sterility

Lepidoptera

1. Diatraea saccharalis

Tables 2 to 25 and figures 1 to 25 show the mating lineages and reproductive potential of lines at various P generation doseages. Comparable Control lines do not show decrease in fecundity over subsequent generations as the IPS lines do. By itself this data is difficult to interpret with any degree of meaning. It is important to note that there have been no lines that have shown a high degree of chromosome fragmenting (Virkki). This is the case whether the particular line has demonstrated IPS or not. Originally we suspected that the IPS was caused mainly from translocations. This hypothesis appears to have been a valid one, and indeed there may be translocations which we have not observed, however none have been observed upon cytological examination of male meiotic divisions (metaphase). This is in itself an interesting phenomenon, and it raises the point that translocations themselves may not be the sole cause of the late manifestation of lethal factors in subsequent generations.

The fact that we did not observe cytological aberrations while there was still IPS effect indicates that there are other genetic mechanisms that might explain the carrying capacity of these lethal factors.

The preliminary conclusions that can be drawn from these tests include the following:

1. Although the survival rate in the first and second generations of the egg stage is considerably reduced at higher doses the survival rate of ensuing generations is not, i.e. P and F_1 generation produced embryos show a dose-dependent relationship, whereas ensuing generations do not.

2. In non-afflicted lines there is very little embryonic death and larval mortality is highest in the first stage with less in the fifth stage and the pupal stage and virtually no death in the other larval stages. In afflicted lines the proportion of death in embryonic stages is considerably higher and the death rate is uniformly high in all larval stages.

3. Female lines are capable of transmitting, or conversely surviving IPS factors, but to a slightly less extent than male lines. Earlier tests showed that female lines were incapable of transmitting IPS more that two successive generations through the female side only.

4. Development rate in afflicted larvae was considerably longer than in normal larvae, regardless of the generation number.

5. IPS factors are apparently not selected against, even by outbreeding as far as the seventh or eighth generation.

6. No phenotypic abnormalities were observed. Mating frequency was less in afflicted lines, but mating behavior was normal.

7. Preliminary gel electrophoresis work with hemolymph proteins from normal and afflicted lines of larvae are similar in profile, but there is such variation in profiles of larvae of different ages that it would be difficult to make a statement about the similarity between afflicted and normal lines.

One of the most difficult problems encountered in studying the hemolymph proteins has been to develop a method for concentrating the proteins sufficiently to get distinct bands in the gel. Related to this is the labile nature of the proteins, apparently they are of fairly low molecular weight. A graduate student will be working on this problem for her dissertation in the near future.

2. Prodenia ornithogalli

In the preliminary tests at low dosages (4, 6, 8 and 10 Krads) to P generation adults larvae hatched but did not survive to pupate. Further tests are planned in the future. The sterilizing dosage has not been determined.

Hemiptera

3. Nezara viridula

One series of adults was treated with 1.5, 7.5, or 15.0 Krads, mated and observed for egg development as shown in Table at the two higher cases. None of the eggs from treated females survived the nymphal stages to become adults so that it was not possible to observe F_1 egg hatch. At 1.5 Krads we are rearing inbred lines of F_2 nympho from the F_1 generation.

In a previous series F_1 adults had produced offspring that had survived to the second nymphal stage at the 2 K_{rad} treatment. This line was lost at the F_2 egg stage.

Egg development was slower from irradiated parents than from normals, but nymphal development was almost as fast as normals. Lifespan was reduced by irradiation, and in these tests mating frequency was less than in the normals. Dissection after death showed no morphological differences between irradiated and normal females, however egg production was lower in irradiated females. Unfortunately it is difficult to ascertain the number of times that a female has mated since the sperm are not in spermatophores. The courtship behavior is distinctive but not particularly elaborate in this species as is described in Table 1. Development of eggs from irradiated and normal adults is also described in the same table.

C. Fractionated Dose Observations

Sub-sterilizing doses have been given to adults of both the sugarcane borer and the armyworm as fractionated doses in preliminary tests. Exposures were given four hours apart in 2 or 4 K_{rad} increments. The data obtained has not been sufficiently consistent to demonstrate a difference between a total dose of 4 Krads as a fractionated dose or as a single exposure. Likewise there has been no observable difference between 8 Krads as a fractionated or as a single exposure dose.

D. Hormone Treatment

Previous work has shown that some of the juvenile hormones cause chromosome puffing in addition to their main effect on developmental retardation. Because of this observation we have initiated work with the objective of measuring the combined effect of hormone treatment and irradiation.

The effects of Juvenile Hormone B (Cal Biochem) and Ecdysterone (Mann) have been evaluated with larval sugarcane borers. No males survived treatment of 1.0, 10.0, nor 100.0 micrograms of injected juvenile hormone to the fourth stage larvae, however females were able to complete their life cycle and were subsequently irradiated with 4.2 K_{rads} of gamma irradiation. Offspring have been harvested from the 100.0 microgram treated females after breeding them with normal males.

None of the male fourth or fifth instar larvae treated with 1.0, 2.0 or 5.0 micrograms of moulting hormone, Ecdysterone, survived to become adults. The female larvae that emerged as adults and were subsequently irradiated with 4.2 Krads failed to produce viable offspring when mated with normal males.

These data are shown in Table 26.

III. Narrative Report

The change in the program funding structure resulting in a complete shift of the financial support of the Senior Investigator to the grant funds in December 1968 resulted in a staff reduction from the equivalence of three and one-half employees to one and one-half employees. Prior to this the Senior Investigator was receiving one-half of his salary from the ABS Division of PRNC. This funding structure has reduced program operations considerably, particulary in the capability for performing field tests (of dominant lethality and IPS), host preference tests and pheromone field tests.

In addition the degree of participation by the two cooperating Scientists Dr. Flavio Padovani and Dr. Niilo Virkki (both on ad honorem appointments) has been reduced due to the direct obligations in their own branches of UPR. To correct this problem a proposal was submitted in 1970 to the National Institutes of Health for additional support, and an additional proposal is pending approval by the National Science Foundation. The latter will be presented to the Reviewing Panel of NSF in February of 1972.

Dr. Padovani continues his interest in related aspects of the program mainly through the work of graduate students working with nutritional requirements of hemiptera. Dr. Virkki continues his chromosome observations with preserved material from previous tests as time allows.

The cooperative program with Dr. Nader Vakili (Plant Geneticist) of the USDA Experiment Station has mutually benefitted our program as well as his own bean selection program, because his extensive plots are available to us for collecting a variety of lepidoptera and hemiptera for preliminary rearing tests in the laboratory.

Two species of lepidoptera from bean tests have shown particular promise for sterility tests: Prodenia ornithogalli and Lamprosema indicata. Future tests to evaluate the mechanism of host preference will be possible when time and facilities become available. Dr. Vakili is evaluating several hundreds of species of beans and cowpeas in Puerto Rico and in Central America. In addition to the species tested in the second section of this report (Accomplishments) we have also completed preliminary rearing trials with Acrosternum marginatum and Thyanta perdida (Pentatomidae, Hemiptera), Systena basalis, Ceratoma ruficornis, and Epitrix cucumeris (flea beetles, Chrysomelidae, Coleoptera); Maruca testulalis, Fundella pelluscens, Etiella zinkinella (Lepidoptera): Diaprepes abbreviatus, Metamasius hemipterus, Cosmopolites sordida (Curculionidae, Coleoptera) and Elasmopalpus lignosellus and Protoparce sexta Trichoplusia ni, Prodenia eridenia (Lepidoptera).

Nearly all of these tests were related to the bean resistance program.

Dr. Goru Kuno (Entomological Laboratory, UPR Mayaguez) is collecting and isolating pathogens from our laboratory colony of the sugarcane borer and in addition he has assisted in the maintenance of our insect culture.

Mr. Ruben Restrepo (graduate student in Biology, UPR Mayaguez) has developed rearing methods for Nezara viridula on a voluntary basis during the past year and one half. We are attempting to provide him a short term paid appointment during the spring and early summer of 1972 for Nezara work prior to his return to his appointment at the Universidad Nacional de Columbia (Bogota). Mr. Restrepo has worked diligently in the laboratory and much of the Nezara work in this report has been the result of his efforts. His thesis research is in the taxonomy of the Membracidae (Homoptera).

IPS tests have not been made for all of these species mentioned since a reliable artificial rearing method is a prerequisite for evaluating IPS. Nonetheless from the limited evidence that is available it is apparent that the IPS phenomenon is related to the holokinetic chromosome.

Mrs. Dolores Ayguabibas de Ruiz will terminate her appointment as Research Assistant on the program at an early date at the request of her husband. During the interim period Dr. Lowman has loaned Mr. Sam de la Rosa to the Program until we can find a replacement for Dolores.

In addition to his program activity at PRNC Dr. Walker has given seminars at the Pioneering Entomological Laboratory of UPR Mayaguez, to the Institute of Marine Sciences and to the Sigma Xi Club of the UPR. He served as an advisor to the Environmental Quality Review Board (Office of the Governor of P.R.) for the pending Pesticide Law of the Commonwealth of P.R. The San Juan Star prepared a two page article on the Insect Sterility Program and this was included in the Sunday Supplement, Sept. 19, 1971.

IV. Future Work Planned

Future efforts will concentrate on aspects of Inherited Partial Sterility. We will continue to explore the utility of IPS in population suppression on a laboratory population study basis using the sugarcane borer, the armyworm (Prodenia) and perhaps another moth if rearing methods can be developed with facility, the stinkbug (Nezara) and possibly a scale insect if rearing methods can be developed.

Dr. Kuno has shown an interest in a tissue culture of insect tissues and of this can fit into our chromosome study provided that Dr. Virkki will have sufficient time to give to the program. We are studying haemolymph proteins of Nezara and the sugarcane borer using the disc electrophoresis method and will be combining this with molecular sieve techniques at a later date.

The combination treatment of juvenile hormone and ecdysterone with low radiation dose shows sufficient promise to warrant further consideration. Our early data from fractionated doses is not clear enough to give a forthright interpretation, however this area should be given further study.

Staff size is too small to consider further field testing because the amount of labor needed to maintain the laboratory colony to the size needed for field tests is greater than the help that we have available.

V. Publications

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Publications in preparation.

Genetic Collapse. 2. Dose-effect on subsequent generations of sugarcane borers.

Mechanism of Inherited Partial Sterility.

Short distance perception of female sex pherome by male sugarcane borers.

Chromosome abnormalities in IPS lines of the sugarcane borer.

VI. Relation to Other Work and Conclusions

The intense interest in environmental quality in conjunction with the need for high production quotas of agricultural products has stimulated interest in pest management concepts and particularly an integrated systems approach to crop protection. Pesticide pollution has become recognized as a serious threat to the environment yet we do not have satisfactory alternative methods for pest prevention and pest control sufficiently adequate to ensure high yields. This whole problem is further complicated by the mono-cultural practice. The solution to this general problem appears to lie in a combination of practices: more effective and sophisticated pesticide use, particularly the choice of specific insecticides for specific pest species (those available that have short residual half-life and that are least damaging to warm blooded animals); the use of pheromones; judicious use of released parasites and predators of specific pest species such as egg parasites, larval parasites, predatory bugs and orthoptera, etc; use of insect pathogens for creating epizootic among pest populations; crop timing to avoid having the most susceptible growth stage synchronized with the maximum pest population; the use of pest resistant plants; and overflooding the natural population with sterile individuals.

I have mentioned the overflooding technique last since it is most efficiently used when the target pest species is in small numbers. Overflooding can be used in two ways: either for eradication or for suppression. As a consequence our work relates directly with the current concepts of future pest control. This area of technology is developing rapidly as a consequence of the impetus for a clean environment.

The thrust of this new thinking is to develop a number of specific solutions to the specific pest problem and to use these specific methods in such a way that each one will yield a maximum effect. For example a sugarcane borer program in the tropics would probably begin with the use of Endrin[R] granules applied to cane that is not developed beyond the stool stage this could be followed by the release of Trichograma minutum adults (which are egg parasites) and also Lixophaga diatraea (a larval parasite), as well as by setting pheromone traps. If the combination of these methods succeeded in reducing the natural population sufficiently, semi-sterile adults could be released after which time the parasites and pheromone traps would be temporarily removed.

In addition to raising the insects for release it would be necessary to constantly monitor the natural population in order to evaluate the effectiveness of each control measure and to provide the information for timing the sterile release. The overhead for such a program in terms of technological input would be large to begin with, but the overal cost probably would be less than an intensive program if amortized over the period of time that it is effective - for example a two or three year cycle. The obvious dangers of such a method is that an alternate species might take the same ecologic niche from which the pest species is being eliminated. In this example Elasmopalpus lignosellus might occupy this niche. This particular problem could be avoided by including pheromone traps that attract both the sugarcane borer and Elasmopalpus, i.e. traps that have two sex pheromones. The other control measures mentioned are equally effective against both pests. Management techniques are best adapted to permanent crops such as deciduous fruits (apples, pears, peaches, cherries, oranges, etc.), alfalfa, sugarcane, mango, etc.

VII. References

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Table 1. Nezara viridula (L.)

A. Description of Embryonic Development in non-Fertile, Normal, and Eggs from an Irradiated Female Parent

non-Fertile Eggs	from Irradiated Female	Normal Eggs
	I. 14 to 16 hours	
cluster regular but with a small number of eggs in each cluster, often laid singly; bright yellow	cluster irregular, eggs not in neat rows; individual eggs are turgid.	turgid, barrel shaped; apical margin spines directed into margin toward the apex; not elongated; white ring around 1mm. or less in diameter, uniform yellow throughout except margin, egg contents milk, and turbid, homogeneous; and egg cluster convex because of swelling of individual eggs; upper cap light reflective, waxy sheen, egg capsule light yellow, eggs tightly packed together in cluster.
	II. 24 hours	
bright yellow, spines pointed inward.	eggs with milky turbid contents clear area not distinct.	center of egg with a clear area inside of marginal ring; spines pointing out from argin to outer surface; interior of egg becoming turbid above base.
	III. 36 hours	
no clear area, no murky flocculations develop.	clear area does not develop.	clear area in center of egg apex with a ring inside egg margin that is milky white color.
	IV. 48 hours	
eggs turn dark and become flaccid.	stylets do not form as discrete	red color at egg apex from developing stylets and forelegs appear like an "eagle" with wings spread.

	V. <u>120 hours</u> (5 days)	
dark colored eggs, flaccid.	eggs turn dark yellow and are turbid with clumps of fatty appearing bodies.	body outline distinct, legs visible, embryo surrounded by a clear fluid.
	VI. <u>144 hours or longer</u> (6 days)	
same as above.	no further embryo development, eggs become dark brown after 7 to 8 days, and eventually become flaccid.	eggs hatch, lymph leaves from circular hole of egg apex.

B. Description of Courtship Behavior and Egg Laying (Restrepo)

Male moves parallel with female performing a trembling motion, then he moves in front of female and stimulates the female by touching her with his antennae on the frons and on her antennae, they are face to face in this position. Male continues his trembling motion while repeatedly touching his antennae on her frons and her antennae and the anterior dorsum of her thorax, when female stops moving and is quiet he continues palpitating her with his antennae until she raises her abdominal tip. The male moves rapidly to the raised abdominal tip and inserts the aedegus. There is no spermatophore transferred.

Males will attempt to mate with females at random or with other males. If there is no response from the female or from the other male he will not persist. After coupling the male and female will remain in tandem for as long as an hour or more. This usually takes place on the upper surface of a leaf. Mating takes place at any time of day and has not been observed in the dark.

Females lay fertile eggs in clusters with from 12 to 120 eggs per clusters. Eggs are usually laid during the morning hours, but may be laid as late as 1400 hours.

C. Life Table of Nymphs

Embryonic development 7 to 8 days
First nymphal stage - 5 days
Second - 7 days
Third - 6 days
Fourth - 6 days
Fifth - 8 days
Adult lifespan to and beyond 120 days, average probably 90 days or less.

LEGEND FOR SYMBOLS USED IN COLUMNS ON TABLES 2 THROUGH 25

TITLE	is the code number of a specific mating. It has a letter designation (A,B, etc. to H), followed by a number that is code for the dose, followed by the parent's code number, and terminated by the specific number of that mating.
B	the number of fertile eggs laid
F	the number of fertile eggs that hatched
F/B	percent of the fertile eggs that hatched into larvae
G	is the number of newly emerged larvae that were harvested and placed into artificial diet
M	is the number of adults harvested
M/G	percent survival, first instars to adults

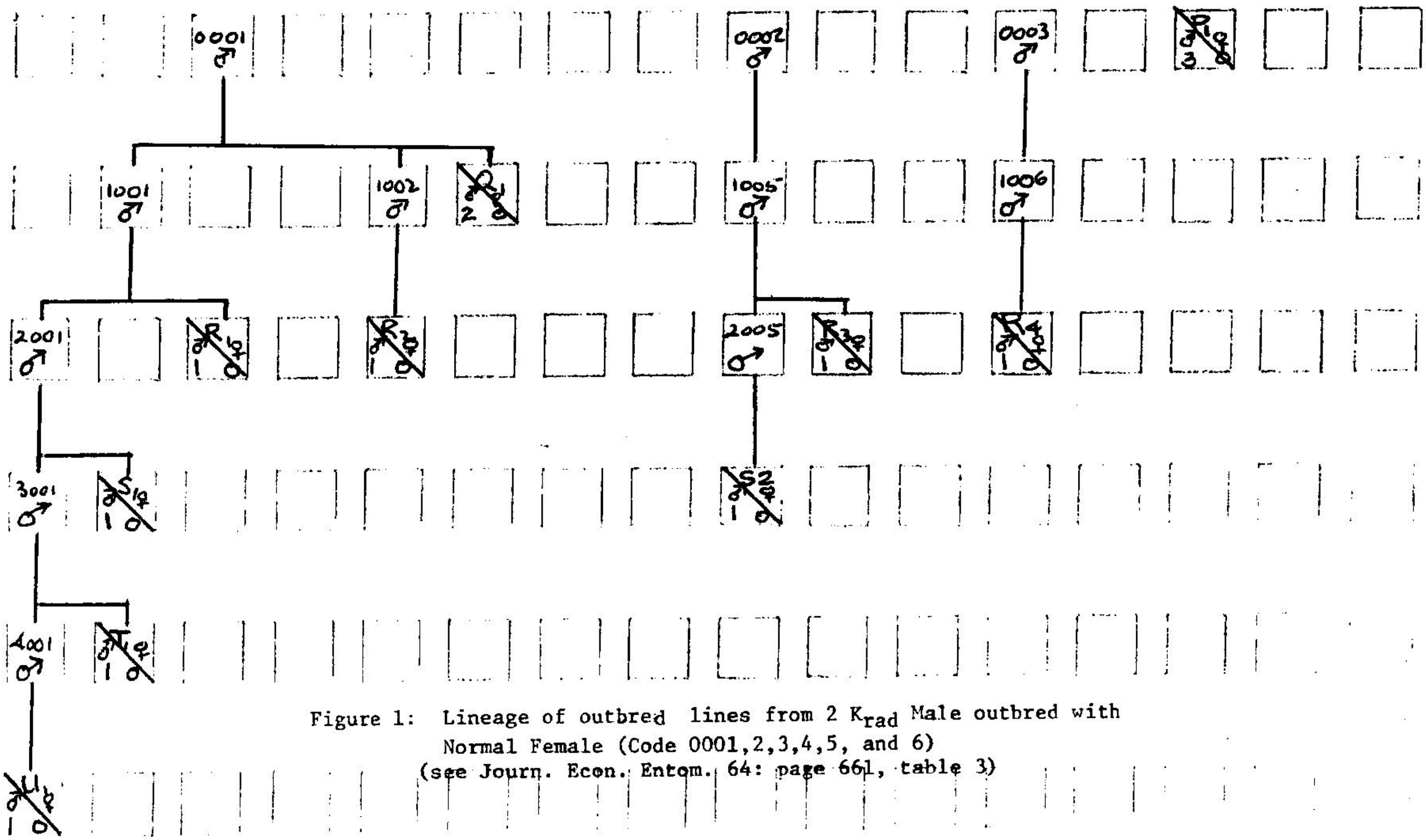


Figure 1: Lineage of outbred lines from 2 K_{rad} Male outbred with Normal Female (Code 0001,2,3,4,5, and 6) (see Journ. Econ. Entom. 64: page 661, table 3)

Table 2

Outbred Offspring from 2 K_{rad} Male Mated to Female Normal (Code A1-0001)

TITLE=A1 ANCESTOR IS 1

TITLE		B	F	F/B	G	M	M/G		B	F	F/B	G	M	M/G
A1	1	805	527	0.6547	521	40	0.0768	A120553024	649	135	0.2080	86	40	0.4651
A1	11001	1293	378	0.2923	378	65	0.1720	A120553031	449	140	0.3118	140	62	0.4429
A1	11006	473	111	0.2347	0	0	0.0000	A120553032	325	22	0.0677	0	0	0.0000
A1	11007	437	237	0.5423	215	65	0.3023	A120553050	509	145	0.2849	145	40	0.2759
A1	11009	426	55	0.1291	0	0	0.0000	A120553051	353	45	0.1275	45	11	0.2444
A1	11011	0	0	0.0000	0	0	0.0000	A120553057	439	110	0.2506	110	8	0.0727
A1	11016	663	262	0.3952	80	38	0.4750	A120303030	15	8	0.5333	0	0	0.0000
A1	11017	1015	278	0.2739	150	9	0.0600	A130514012	544	270	0.4963	270	10	0.0370
A1	11027	455	221	0.4857	180	12	0.0667	A130234027	456	180	0.3947	180	3	0.0167
A1	11030	60	0	0.0000	0	0	0.0000	A130244029	395	240	0.6076	240	50	0.2083
A1	11034	151	1	0.0066	0	0	0.0000	A140125009	395	0	0.0000	0	0	0.0000
A1	11035	809	335	0.4141	200	17	0.0850	A140295013	547	370	0.6764	370	27	0.0730
A1	11036	33	0	0.0000	0	0	0.0000	A140295014	442	45	0.1018	45	0	0.0000
A1	11037	320	255	0.7969	185	41	0.2216	A140295015	610	365	0.5984	365	12	0.0329
A1	11044	10	6	0.6000	0	0	0.0000	A140295016	686	380	0.5539	380	22	0.0579
A1	11047	953	193	0.2025	125	30	0.2400	A140295017	611	145	0.2373	145	11	0.0759
A1	11049	121	28	0.2314	0	0	0.0000	A140295018	510	300	0.5882	300	46	0.1533
A1	11054	515	145	0.2816	0	0	0.0000	A140295020	95	0	0.0000	0	0	0.0000
A1	11055	37	0	0.0000	0	0	0.0000	A140295021	631	190	0.3011	190	0	0.0000
A1	11056	485	185	0.3814	0	0	0.0000	A140295022	100	0	0.0000	0	0	0.0000
A1	11057	62	0	0.0000	0	0	0.0000	A140295023	362	0	0.0000	0	0	0.0000
A1	11069	45	0	0.0000	0	0	0.0000	A140295024	412	145	0.3519	145	2	0.0138
A1	11076	465	180	0.3871	95	34	0.3579	A140295025	512	195	0.3809	180	21	0.1167
A1	11077	230	0	0.0000	0	0	0.0000	A140295026	291	0	0.0000	0	0	0.0000
A1	11078	255	45	0.1765	0	0	0.0000	A140295027	156	110	0.7051	0	0	0.0000
A1	11082	410	275	0.6707	0	0	0.0000	A140295028	563	246	0.4369	246	17	0.0691
A1	11083	267	27	0.1011	0	0	0.0000	A140295029	432	173	0.4005	161	11	0.0683
A1	11085	170	6	0.0353	0	0	0.0000	A140295030	415	140	0.3373	140	7	0.0500
A1	11105	670	240	0.3582	135	22	0.1630	A140295031	515	234	0.4544	105	0	0.0000
A1	11114	230	30	0.1304	0	0	0.0000	A150286029	525	62	0.1181	10	0	0.0000
A1	11121	628	419	0.6672	327	10	0.0306	A150296032	719	417	0.5800	370	0	0.0000
A110012005		435	25	0.0575	0	0	0.0000	A150186006	756	366	0.4841	175	3	0.0171
A110012008		330	19	0.0576	0	0	0.0000	A150186008	555	309	0.5568	3	0	0.0000
A110012011		393	75	0.1908	0	0	0.0000	A150186009	621	0	0.0000	0	0	0.0000
A110012012		186	18	0.0968	0	0	0.0000	A150186010	740	370	0.5000	205	1	0.0049
A110012030		417	95	0.2278	60	6	0.1000	A150186011	303	0	0.0000	0	0	0.0000
A110012031		27	0	0.0000	0	0	0.0000	A150186012	361	118	0.3269	56	2	0.0357
A110012032		543	275	0.5064	175	73	0.4171	A150186023	538	178	0.3309	150	8	0.0533
A110012037		373	260	0.6971	200	17	0.0850	A150176013	513	273	0.5322	273	0	0.0000
A110012044		328	185	0.5640	120	53	0.4417	A150176019	235	13	0.0553	13	0	0.0000
A110072055		527	348	0.6603	290	66	0.2276	A150156014	899	370	0.4116	230	31	0.1348
A110072056		150	46	0.3067	37	3	0.0811	A150136021	0	0	0.0000	0	0	0.0000
A110352070		185	41	0.2216	0	0	0.0000	A150256025	733	174	0.2374	168	0	0.0000
A120443016		139	60	0.4317	60	4	0.0667	A150256026	692	229	0.3309	60	0	0.0000
A120443018		605	90	0.1488	90	1	0.0111	A150256030	229	0	0.0000	0	0	0.0000
A120443020		358	156	0.4358	0	0	0.0000	A150256031	91	68	0.7473	55	0	0.0000
A120443021		193	179	0.9223	0	0	0.0000	A150256033	105	0	0.0000	0	0	0.0000
A120553023		669	291	0.4350	0	0	0.0000	A160147014	559	204	0.3649	200	0	0.0000

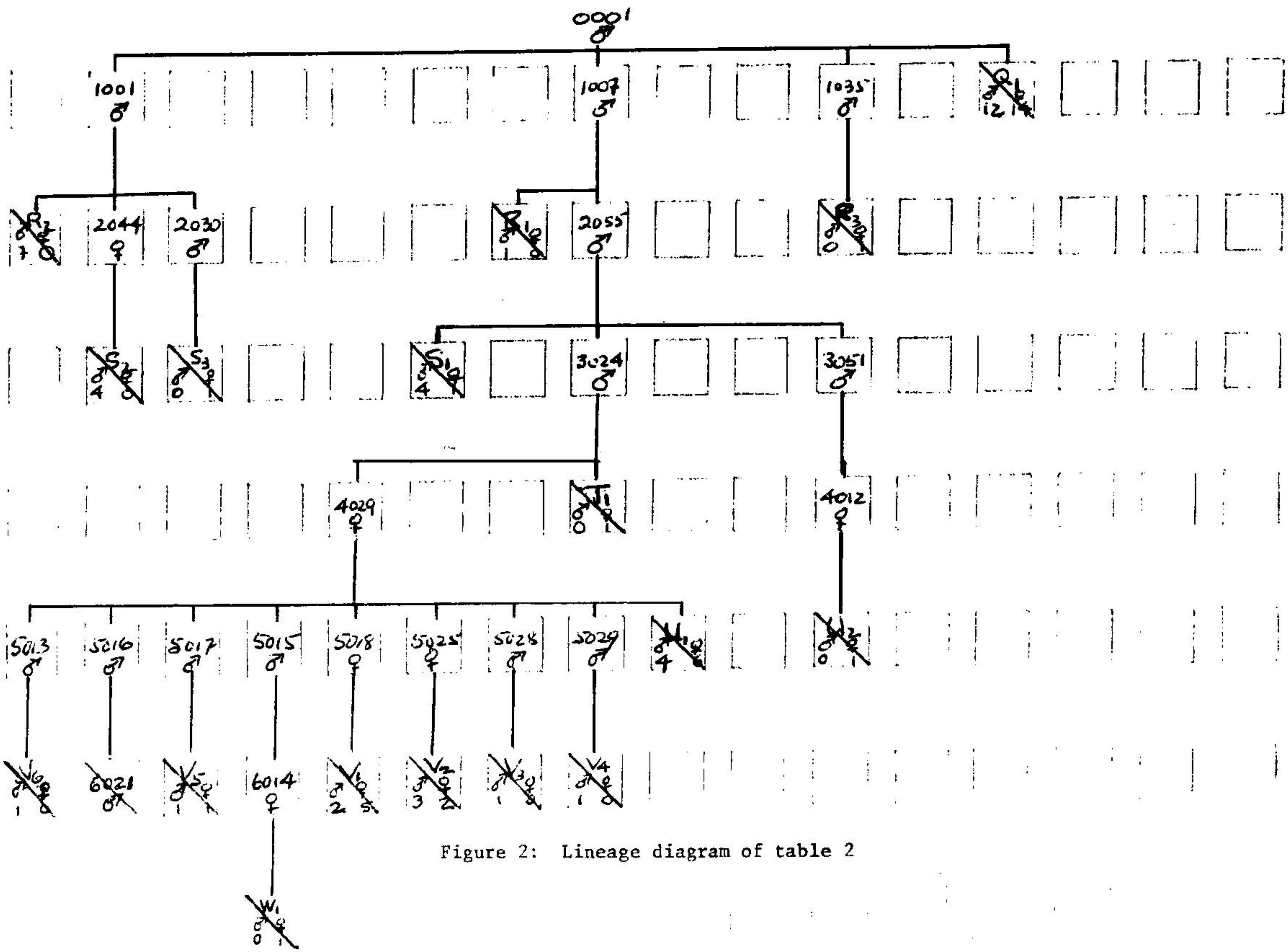


Figure 2: Lineage diagram of table 2

Table 3

Outbred Offspring from 2 K_{rad} Male Mated to Female Normal (Code A1-0003, 4)

TITLE=A1 ANCESTOR IS 3

	TITLE	B	F	F/B	G	M	M/G
A1	3 3	351	244	0.6952	210	16	0.0762
A1	31018	685	486	0.7095	365	11	0.0301
A1	31019	592	142	0.2399	121	7	0.0165
A1	31046	64	39	0.6094	30	0	0.0000
A1	31068	295	15	0.0508	0	0	0.0000
A1	31084	468	38	0.0812	0	0	0.0000
A1	31096	535	160	0.2991	130	18	0.1385
A1	10962067	546	265	0.4853	265	10	0.0377

TITLE=A1 ANCESTOR IS 4

	TITLE	B	F	F/B	G	M	M/G
A1	4 4	435	368	0.8460	352	46	0.1307
A1	41003	761	154	0.2024	50	17	0.3400
A1	41012	681	85	0.1248	0	0	0.0000
A1	41013	961	266	0.2768	200	23	0.1150
A1	41015	564	282	0.5000	200	24	0.1200
A1	41020	332	2	0.0060	0	0	0.0000
A1	41021	861	468	0.5436	85	36	0.4235
A1	41040	615	395	0.6423	200	10	0.0500
A1	41045	308	13	0.0422	0	0	0.0000
A1	41052	74	28	0.3784	0	0	0.0000
A1	41053	473	323	0.6829	200	2	0.0100
A1	41058	660	395	0.5985	70	4	0.0571
A1	41059	645	265	0.4109	0	0	0.0000
A1	41062	715	105	0.1469	0	0	0.0000
A1	41063	330	0	0.0000	0	0	0.0000
A1	41064	410	65	0.1585	0	0	0.0000
A1	41065	500	105	0.2100	0	0	0.0000
A1	41070	86	0	0.0000	0	0	0.0000
A1	41081	210	3	0.0143	0	0	0.0000
A1	41090	383	143	0.3734	110	25	0.2273
A1	41093	565	265	0.4690	110	7	0.0636
A1	41101	595	130	0.2185	105	0	0.0000
A1	41107	311	65	0.2090	0	0	0.0000
A1	41112	150	45	0.3000	0	0	0.0000
A1	41116	448	33	0.0737	0	0	0.0000
A1	41119	618	118	0.1909	60	6	0.1000
A1	10212009	543	10	0.0184	0	0	0.0000
A1	10212035	345	293	0.8493	200	47	0.2350
A1	10212057	269	110	0.4089	80	17	0.2125
A1	10212058	667	231	0.3463	125	26	0.2080
A1	10932065	235	95	0.4043	95	17	0.1789
A1	10932066	141	40	0.2837	40	13	0.3250
A1	20583022	250	33	0.1320	0	0	0.0000
A1	20583025	533	75	0.1407	75	47	0.6267
A1	20583060	406	129	0.3177	0	0	0.0000
A1	20353044	80	14	0.1750	0	0	0.0000
A1	20353045	173	90	0.5202	90	17	0.1889
A1	20353047	737	292	0.3962	0	0	0.0000
A1	20353048	370	20	0.0541	20	7	0.3500

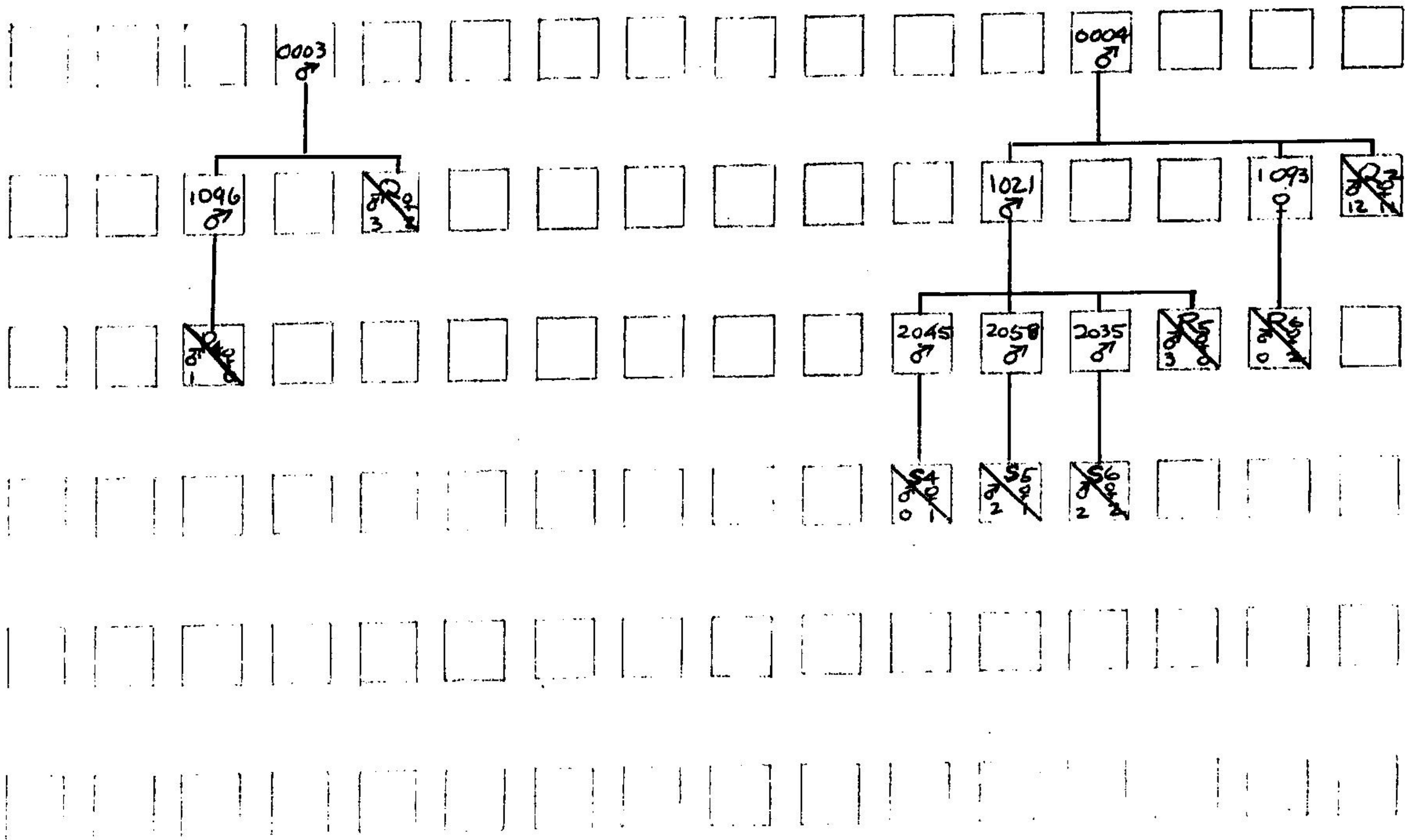


Figure 3: Lineage diagram of table 3

Table 4

Outbred Offspring from 6 K_{rad} Male Mated to Female Normal (Code A2-0001,2,3,4,5)

TITLE=A2 ANCESTOR IS 1

	TITLE	B	F	F/B	G	M	M/G
A2	1 1	370	112	0.3027	106	16	0.1509
A2	11053	553	201	0.3635	185	12	0.0649

TITLE=A2 ANCESTOR IS 2

	TITLE	B	F	F/B	G	M	M/G
A2	2 2	438	196	0.4475	189	90	0.4762
A2	21009	124	3	0.0242	3	1	0.3333
A2	21011	18	18	1.0000	18	4	0.2222
A2	21071	287	56	0.1951	25	7	0.2800
A2	21242	185	100	0.5405	50	4	0.0800
A2	21106	397	167	0.4207	135	20	0.1481
A2	21127	551	81	0.1470	35	11	0.3143
A2	21128	762	200	0.2625	75	1	0.0133
A2	21140	337	122	0.3620	100	43	0.4300
A2	21144	280	115	0.4107	100	4	0.0400
A2	21156	570	225	0.3947	175	0	0.0000
A2	21235	323	123	0.3808	65	13	0.2000
A2	21040	422	149	0.3531	137	22	0.1606
A210112049		453	147	0.3245	85	36	0.4235

TITLE=A2 ANCESTOR IS 3

	TITLE	B	F	F/B	G	M	M/G
A2	3 3	521	318	0.6104	284	42	0.1479
A2	31114	379	31	0.0818	20	1	0.0500
A2	31136	550	250	0.4545	150	1	0.0067
A2	31146	505	330	0.6535	225	46	0.2044
A2	31170	365	115	0.3151	100	0	0.0000
A2	31228	342	280	0.8187	195	22	0.1128
A2	31229	963	43	0.0447	35	8	0.2286
A2	31247	270	15	0.0556	0	0	0.0000
A212292165		436	185	0.4243	160	6	0.0375

TITLE=A2 ANCESTOR IS 4

	TITLE	B	F	F/B	G	M	M/G
A2	4 4	175	139	0.7943	136	54	0.3971
A2	41005	78	48	0.6154	15	4	0.2667
A2	41024	494	119	0.2409	119	32	0.2689
A2	41032	643	12	0.0187	12	1	0.0833
A2	41036	575	147	0.2557	101	11	0.1089
A2	41248	651	138	0.2120	0	0	0.0000
A2	41051	173	110	0.6358	65	2	0.0308
A2	41079	405	255	0.6296	110	18	0.1636
A2	41107	582	42	0.0722	30	7	0.2333
A2	41126	490	125	0.2551	110	3	0.0273
A2	41132	309	174	0.5631	165	6	0.0364
A2	41152	335	130	0.3881	85	4	0.0471
A2	41236	400	80	0.2000	40	1	0.0250
A210242001		617	95	0.1540	55	4	0.0727
A210242035		423	33	0.0780	0	0	0.0000
A210242128		298	29	0.0973	0	0	0.0000

TITLE=A2 ANCESTOR IS 5

	TITLE	B	F	F/B	G	M	M/G
A2	5 5	563	221	0.3925	200	18	0.0900
A2	51054	548	108	0.1971	70	1	0.0143
A2	51056	828	137	0.1655	40	11	0.2750
A2	51147	468	255	0.5449	200	2	0.0100
A2	51165	415	355	0.8554	205	8	0.0390
A2	51111	405	165	0.4074	0	0	0.0000

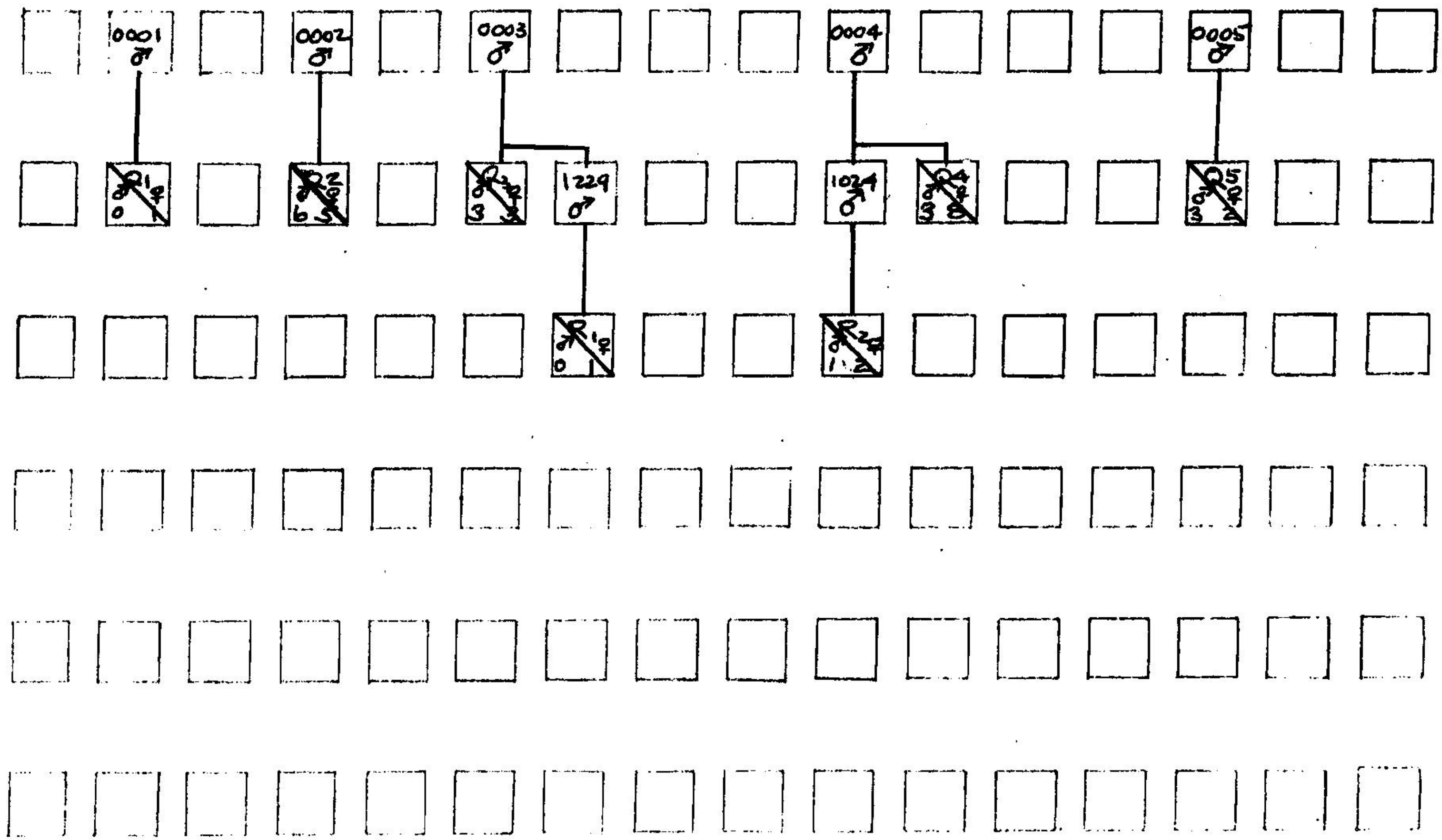


Figure 4: Lineage diagram of table 4

Table 5

Outbred Offspring from 12 K_{rad} Male Mated to Female Normal (Code A3-0001,2,3,4,6)

TITLE=A3 ANCESTOR IS 1

TITLE		B	F	F/B	G	M	M/G
A3	1 1	580	82	0.1414	58	2	0.0345

TITLE=A3 ANCESTOR IS 2

TITLE		B	F	F/B	G	M	M/G
A3	2 2	425	137	0.3224	128	17	0.1328
A3	21009	231	3	0.0130	0	0	0.0000
A3	21012	620	25	0.0403	0	0	0.0000
A3	21014	127	1	0.0079	0	0	0.0000
A3	21040	40	0	0.0000	0	0	0.0000
A3	21051	400	0	0.0000	0	0	0.0000
A3	21037	275	0	0.0000	0	0	0.0000
A3	21060	94	0	0.0000	0	0	0.0000
A3	21065	123	0	0.0000	0	0	0.0000
A3	21066	300	0	0.0000	0	0	0.0000

TITLE=A3 ANCESTOR IS 3

TITLE		B	F	F/B	G	M	M/G
A3	3 3	792	218	0.2753	208	22	0.1058
A3	31005	300	17	0.0567	17	0	0.0000
A3	31008	584	14	0.0240	14	0	0.0000
A3	31010	248	2	0.0081	2	0	0.0000
A3	31013	213	7	0.0329	7	0	0.0000
A3	31023	307	2	0.0065	2	0	0.0000
A3	31032	13	5	0.3846	5	0	0.0000
A3	31036	325	0	0.0000	0	0	0.0000
A3	31050	380	0	0.0000	0	0	0.0000
A3	31054	250	0	0.0000	0	0	0.0000
A3	31064	430	0	0.0000	0	0	0.0000
A3	31067	471	201	0.4268	66	0	0.0000
A3	31068	21	12	0.5714	12	0	0.0000
A3	31069	188	0	0.0000	0	0	0.0000
A3	31070	227	112	0.4934	0	0	0.0000
A3	31075	493	0	0.0000	0	0	0.0000

TITLE=A3 ANCESTOR IS 4

TITLE		B	F	F/B	G	M	M/G
A3	4 4	343	101	0.2945	95	2	0.0211
A3	41073	423	22	0.0520	0	0	0.0000
A3	41041	43	0	0.0000	0	0	0.0000

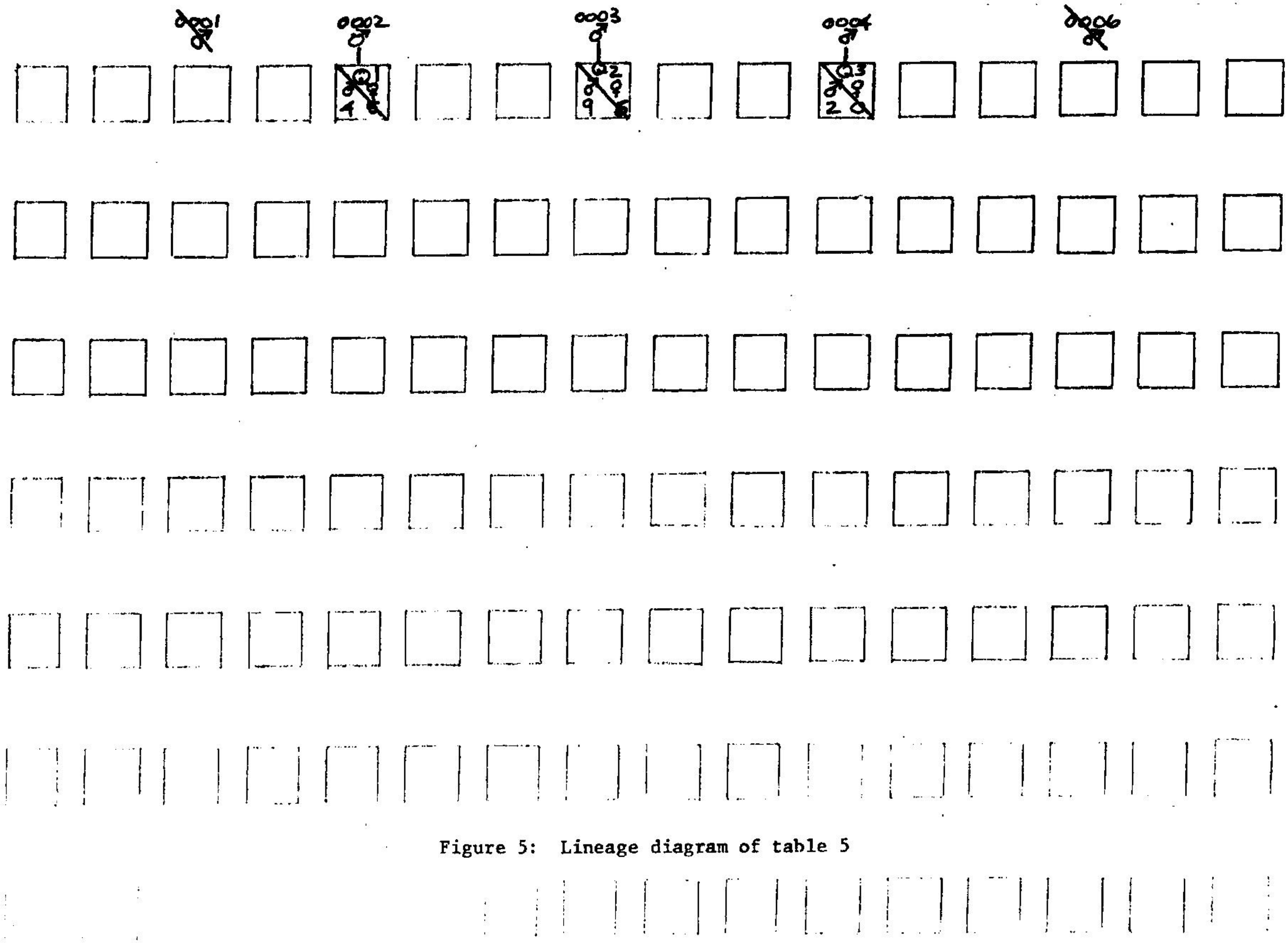


Figure 5: Lineage diagram of table 5

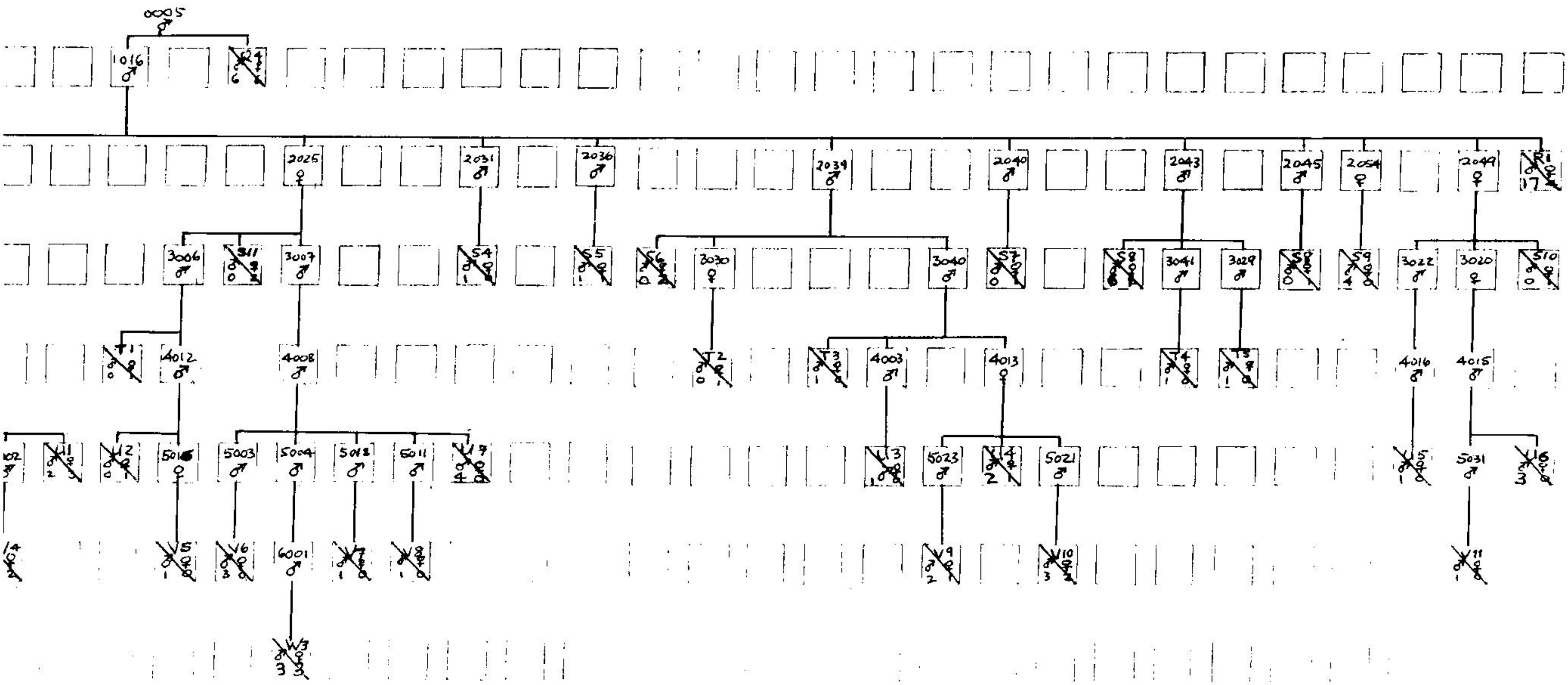
Table 6

Outbred Offspring from 12 K_{rad} Male Mated to Female Normal (Code A3-0005)

TITLE=A3 ANCESTOR IS 5

TITLE	B	F	F/B	G	M	M/G
A3 5 5	548	221	0.4033	207	24	0.1159
A3 51004	1	0	0.0000	0	0	0.0000
A3 51007	100	45	0.4500	0	0	0.0000
A3 51015	98	2	0.0204	0	0	0.0000
A3 51016	668	325	0.4865	290	151	0.5207
A3 51021	465	5	0.0108	0	0	0.0000
A3 51029	210	0	0.0000	0	0	0.0000
A3 51033	315	0	0.0000	0	0	0.0000
A3 51034	521	8	0.0154	0	0	0.0000
A3 51035	75	0	0.0000	0	0	0.0000
A3 51038	370	0	0.0000	0	0	0.0000
A3 51045	80	0	0.0000	0	0	0.0000
A3 51046	57	0	0.0000	0	0	0.0000
A3 51048	270	0	0.0000	0	0	0.0000
A3 51015	98	2	0.0204	0	0	0.0000
A3 51016	668	325	0.4865	290	151	0.5207
A310162001	230	115	0.5000	75	0	0.0000
A310162002	119	22	0.1864	0	0	0.0000
A310162003	256	123	0.4805	100	8	0.0800
A310162004	478	355	0.7427	0	0	0.0000
A310162003	256	123	0.4905	100	8	0.0800
A310162005	371	290	0.7917	245	0	0.0000
A310162006	437	309	0.7071	309	40	0.1294
A310162008	446	342	0.7668	320	31	0.0969
A310162016	547	305	0.5576	290	36	0.1241
A310162015	348	108	0.3103	93	1	0.0108
A310162024	629	88	0.1399	70	40	0.5714
A310162025	507	123	0.2426	75	25	0.3333
A310162029	445	43	0.0966	25	9	0.3600
A310162031	291	43	0.1478	30	9	0.3000
A310162032	376	130	0.3457	121	13	0.1074
A310162035	528	213	0.4034	65	16	0.2462
A310162036	506	142	0.2806	128	25	0.1953
A310162039	328	314	0.9573	311	84	0.2701
A310162040	506	293	0.5791	284	89	0.3134
A310162043	392	256	0.6531	238	144	0.6050
A310162045	193	97	0.5026	80	15	0.1875
A310162049	519	189	0.3642	176	104	0.5909
A310162050	485	55	0.1134	46	14	0.3043
A310162054	461	263	0.5705	155	37	0.2387
A320033048	563	212	0.3766	120	3	0.0250
A320243038	267	252	0.9439	135	77	0.5704
A320243049	369	196	0.5312	92	1	0.0109
A320253006	446	145	0.3251	50	6	0.1200
A310162007	310	145	0.4677	100	2	0.0200
A310162009	289	153	0.5294	135	0	0.0000
A310162010	133	56	0.4211	0	0	0.0000
A310162012	354	48	0.1356	22	0	0.0000
A310162013	239	55	0.2301	20	0	0.0000
A320393017	397	83	0.2091	60	2	0.0333
A320393030	467	178	0.3812	70	19	0.2714
A320393040	620	226	0.3645	210	72	0.3429
A320033048	563	212	0.3766	120	3	0.0250
A310162017	499	95	0.1904	0	0	0.0000
A310162034	344	0	0.0000	0	0	0.0000
A320243039	267	252	0.9438	135	77	0.5704
A320243049	369	196	0.5312	92	1	0.0109
A310162037	534	39	0.0730	23	0	0.0000
A310162038	309	156	0.5049	139	0	0.0000
A320253006	446	145	0.3251	50	6	0.1200
A320253007	468	154	0.3291	81	4	0.0494
A310162053	180	0	0.0000	0	0	0.0000
A320393017	397	83	0.2091	60	2	0.0333
A320393030	467	178	0.3812	70	19	0.2714
A320393040	620	226	0.3645	210	72	0.3429
A320433002	382	118	0.3089	45	17	0.3778
A320433009	558	251	0.4498	100	17	0.1700
A320433029	507	267	0.5266	109	20	0.1835
A320433041	475	113	0.2379	86	9	0.1047
A320453037	261	91	0.3487	46	3	0.0652
A320313001	298	150	0.5034	150	0	0.0000
A320253006	455	95	0.2089	95	2	0.0211
A320493018	518	221	0.4266	90	5	0.0556
A320493020	311	177	0.5691	95	33	0.3474
A320493022	426	98	0.2300	30	1	0.0333
A320493045	140	1	0.0071	0	0	0.0000
A320493046	541	75	0.1386	75	8	0.1067
A320543004	258	64	0.2481	35	7	0.2000
A320543015	309	69	0.2233	69	0	0.0000
A320393050	486	2	0.0041	2	0	0.0000
A320393051	259	0	0.0000	0	0	0.0000
A320393053	635	80	0.1260	80	0	0.0000
A320433008	595	148	0.2487	80	3	0.0375
A320433010	0	0	0.0000	0	0	0.0000
A320433011	26	22	0.8462	22	3	0.1364
A320433013	271	7	0.0258	7	0	0.0000
A320433025	276	68	0.2464	68	0	0.0000
A330074008	682	390	0.5718	390	53	0.1359
A330064012	264	100	0.3788	100	2	0.0200

TITLE	B	F	F/B	G	M	M/G
A330064004	96	0	0.0000	0	0	0.0000
A330204015	241	150	0.6130	150	17	0.0750
A330404003	338	208	0.6154	100	17	0.1700
A330404013	624	316	0.5064	240	34	0.1417
A330224016	654	155	0.2370	155	4	0.0258
A330304010	456	215	0.4715	210	4	0.0190
A330404002	293	118	0.4027	118	0	0.0000
A330404003	338	208	0.6154	100	17	0.1700
A330404013	624	316	0.5064	240	34	0.1417
A330414005	635	169	0.2661	50	2	0.0400
A330494009	723	219	0.3029	139	51	0.3636
A330414011	230	177	0.7696	177	0	0.0000
A330294014	0	0	0.0000	0	0	0.0000
A340085003	969	448	0.4623	375	15	0.0427
A340085004	411	143	0.3479	70	25	0.3571
A340085010	395	88	0.2228	60	0	0.0000
A340085011	750	311	0.4147	240	7	0.0292
A340085018	625	340	0.5440	340	11	0.0324
A340085024	720	430	0.5972	375	20	0.0533
A340085025	803	425	0.5293	425	7	0.0165
A340095001	490	164	0.3347	135	38	0.2815
A340095002	501	245	0.4890	245	28	0.1143
A340095005	792	394	0.4975	320	31	0.0969
A340095012	384	370	0.9635	370	59	0.1595
A340085014	532	0	0.0000	0	0	0.0000
A340085019	136	0	0.0000	0	0	0.0000
A340085020	47	0	0.0000	0	0	0.0000
A340085025	803	425	0.5293	425	7	0.0165
A340125016	258	127	0.4922	120	5	0.0417
A340125015	304	0	0.0000	0	0	0.0000
A340135021	399	302	0.7569	290	30	0.1034
A340135022	456	60	0.1316	60	0	0.0000
A340135023	678	541	0.7979	504	21	0.0417
A340155029	95	0	0.0000	0	0	0.0000
A340155030	396	130	0.3283	130	20	0.1539
A340155031	313	165	0.5272	165	43	0.2606
A340155032	726	704	0.9697	80	10	0.1250
A340035006	82	0	0.0000	0	0	0.0000
A340135017	347	30	0.0865	30	1	0.0333
A340165033	408	0	0.0000	0	0	0.0000
A350056003	622	209	0.3360	120	14	0.1167
A350056008	550	90	0.1636	90	5	0.0556
A350056002	0	0	0.0000	0	0	0.0000
A350056005	31	0	0.0000	0	0	0.0000
A350056006	0	0	0.0000	0	0	0.0000
A350056008	550	90	0.1636	90	5	0.0555
A350056011	451	30	0.0665	30	1	0.0333
A350056020	1061	303	0.2856	190	2	0.0105
A350056030	614	271	0.4414	235	1	0.0043
A350026004	480	106	0.2208	65	1	0.0154
A350026019	268	24	0.0896	15	0	0.0000
A350036012	1021	298	0.2919	180	5	0.0278
A350036013	920	262	0.2848	230	0	0.0000
A350036028	688	235	0.3416	235	1	0.0043
A350056027	376	0	0.0000	0	0	0.0000
A350126018	292	0	0.0000	0	0	0.0000
A350126023	274	0	0.0000	0	0	0.0000
A350126031	79	0	0.0000	0	0	0.0000
A350126017	858	594	0.6923	355	15	0.0423
A350126021	543	188	0.3462	15	2	0.1333
A350126016	774	373	0.4817	90	2	0.0222
A350126014	632	190	0.3016	115	0	0.0000
A350046001	717	321	0.4477	185	26	0.1405
A350116015	271	25	0.0923	10	1	0.1000
A350126022	885	188	0.2124	55	1	0.0182
A350126024	840	276	0.3286	155	1	0.0065
A350126025	702	321	0.4573	75	1	0.0133
A350126026	777	269	0.3462	195	0	0.0000
A350126035	517	140	0.2708	35	0	0.0000
A350126036	105	0	0.0000	0	0	0.0000
A350216034	201	0	0.0000	0	0	0.0000
A350126039	624	259	0.4151	200	4	0.0200
A350186029	476	30	0.0630	30	0	0.0000
A350216033	473	20	0.0423	20	1	0.0500
A350216037	819	367	0.4481	291	11	0.0378
A350216042	259	85	0.3282	85	3	0.0353
A350216040	130	0	0.0000	0	0	0.0000
A350216043	332	32	0.0964	32	0	0.0000
A350236032	960	213	0.2219	156	0	0.0000
A350316038	398	31	0.0779	18	0	0.0000
A360017001	512	194	0.3789	139	2	0.1144
A360017002	983	429	0.4364	155	11	0.0710
A360017003	785	322	0.4102	90	1	0.1000
A360017005	830	334	0.4024	270	0	0.0000
A360017012	550	329	0.5962	95	0	0.0000
A360037008	751	478	0.6365	392	0	0.0000
A360037009	671	342	0.5097	330	0	0.0000
A360037011	472	232	0.4915	190	0	0.0000
A360017007	107	0	0.0000	0	0	0.0000
A360037004	63	0	0.0000	0	0	0.0000
A360087010	747	352	0.4712	310	0	0.0000



igure 5: Lineage diagram of table 6

Table 7

Outbred Offspring from 14 K_{rad} Male Mated to Female Normal (Code A4-0001,2,3,4)

TITLE=A4 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
A4 2 2	425	137	0.3224	128	17	0.1328
A4 21032	196	0	0.0000	0	0	0.0000

TITLE=A4 ANCESTOR IS 4

TITLE	B	F	F/B	G	M	M/G
A4 4 4	422	147	0.3483	136	8	0.0588
A4 41014	753	510	0.6773	308	87	0.2825
A4 41015	430	35	0.0814	0	0	0.0000
A4 41020	788	3	0.0038	0	0	0.0000
A4 41031	607	7	0.0115	0	0	0.0000
A4 41025	710	250	0.3521	0	0	0.0000
A4 41030	333	3	0.0090	0	0	0.0000
A4 41024	420	0	0.0000	0	0	0.0000
A410142006	278	78	0.2806	60	29	0.4833
A410142002	326	140	0.4294	0	0	0.0000
A410142001	200	18	0.0900	0	0	0.0000
A410142004	311	123	0.3955	0	0	0.0000
A410142005	98	12	0.1224	0	0	0.0000
A410142007	201	105	0.5224	25	0	0.0000
A410142009	229	68	0.2969	55	0	0.0000
A410142010	91	0	0.0000	0	0	0.0000
A410142011	90	7	0.0778	0	0	0.0000
A410142012	211	37	0.1754	35	12	0.3429
A410142014	65	9	0.1385	0	0	0.0000
A410142015	469	289	0.6162	175	41	0.2343
A410142017	252	107	0.4246	85	10	0.1176
A410142020	499	238	0.4770	110	4	0.0364
A410142021	104	93	0.8942	70	28	0.4000
A410142018	76	18	0.2368	13	0	0.0000
A420153021	337	125	0.3709	125	14	0.1120
A420153022	371	34	0.0916	20	1	0.0500
A420153023	5	0	0.0000	0	0	0.0000
A420153029	200	70	0.3500	70	3	0.0429
A420213003	284	67	0.2359	30	1	0.0333
A420063010	526	149	0.2833	80	0	0.0000
A420213014	0	0	0.0000	0	0	0.0000
A420213026	15	0	0.0000	0	0	0.0000
A420063006	24	14	0.5833	0	0	0.0000
A420063015	180	45	0.2500	3	0	0.0000
A420063019	577	175	0.3033	95	24	0.2526
A420063021	337	125	0.3709	125	14	0.1120
A420053030	723	288	0.3983	90	33	0.3667
A420063022	371	34	0.0916	20	0	0.0000
A420063020	60	0	0.0000	0	0	0.0000
A420063031	629	67	0.1065	0	0	0.0000
A420173001	0	0	0.0000	0	0	0.0000
A420173002	99	48	0.4848	48	0	0.0000
A420203011	0	0	0.0000	0	0	0.0000
A420203017	64	14	0.2188	0	0	0.0000
A430304005	297	119	0.3980	119	4	0.0336
A430194013	0	0	0.0000	0	0	0.0000
A430214001	494	280	0.5668	180	5	0.0278
A430214009	31	0	0.0000	0	0	0.0000
A430214011	91	77	0.8462	66	0	0.0000
A430214012	197	82	0.4162	78	1	0.0128
A430194013	0	0	0.0000	0	0	0.0000
A430214007	1034	590	0.5706	590	1	0.0017
A430304010	663	298	0.4461	260	10	0.0385
A430304016	907	467	0.5149	290	1	[illegible]
A430304017	945	569	0.6011	470	67	0.1426
A440015006	[illegible]	132	[illegible]	15	1	0.1284
A440105005	596	0	0.0000	0	0	0.0000
A440175010	557	308	0.5530	75	5	0.0667
A440175011	718	266	0.3705	200	47	0.2350
A440175012	756	179	0.2368	125	17	0.1360
A440175013	710	184	0.2592	60	8	0.1333
A440175015	865	553	0.6393	235	30	0.1277
A440175014	516	165	0.3198	165	18	0.1091
A440175016	321	256	0.7975	256	5	0.0195
A440175017	170	0	0.0000	0	0	0.0000
A440175018	199	0	0.0000	0	0	0.0000
A440175019	109	0	0.0000	0	0	0.0000
A440175020	715	159	0.2224	110	11	0.1000
A440165007	731	242	0.3311	210	14	0.0667
A440015003	490	235	0.4796	195	25	0.1282
A440015006	591	130	0.2200	35	1	0.0286
A440105001	991	421	0.4248	340	57	0.1676
A440105002	897	500	0.5574	500	9	0.0180
A440105004	656	350	0.5335	285	166	0.5825
A450016020	770	70	0.0909	50	0	0.0000
A450026006	112	20	0.1786	20	4	0.2000
A450076019	521	183	0.3512	89	0	0.0000
A450136033	618	315	0.5097	225	14	0.0622
A450126026	80	62	0.7750	50	13	0.2600
A450126031	276	120	0.4348	120	11	0.0917
A450126040	350	51	0.1457	51	5	0.0980
A450066014	65	4	0.0615	2	0	0.0000
A450036001	649	209	0.3220	155	10	0.0645
A450036003	665	172	0.2586	70	12	0.1714
A450026007	298	220	0.7383	120	3	0.0250
A450026013	618	380	0.6149	270	3	0.0111
A450046009	963	680	0.7061	345	6	0.0174
A450046015	624	206	0.3301	109	8	0.0734
A450046022	626	105	0.1677	100	0	0.0000
A450156034	812	344	0.4236	320	4	0.0125
A450156035	522	300	0.5747	240	47	0.1958
A450156037	937	512	0.5464	420	22	0.0524
A450156038	867	465	0.5363	465	39	0.0839
A450156042	740	256	0.3459	205	0	0.0000
A450116025	423	20	0.0473	20	0	0.0000
A450116028	1429	722	0.5052	260	0	0.0000
A450116029	667	205	0.3073	200	0	0.0000
A450116032	658	467	0.7097	405	52	0.1284
A450116036	706	381	0.5397	325	38	0.1169
A450116039	634	58	0.0915	40	0	0.0000
A450046008	170	0	0.0000	0	0	0.0000
A450046021	506	244	0.4822	100	0	0.0000
A450076017	131	0	0.0000	0	0	0.0000
A450116024	280	0	0.0000	0	0	0.0000
A450116027	190	0	0.0000	0	0	0.0000
A450156041	593	0	0.0000	0	0	0.0000
A450066011	320	310	0.9689	20	0	0.0000
A450066016	6	0	0.0000	0	0	0.0000
A460077007	628	285	0.4538	0	0	0.0000
A460157005	159	0	0.0000	0	0	0.0000
A450016005	0	0	0.0000	0	0	0.0000
A440125008	135	0	0.0000	0	0	0.0000
A460017004	931	553	0.6655	553	0	0.0000
A450017006	269	126	0.4684	114	0	0.0000
A460037001	38	9	0.2368	0	0	0.0000
A460037002	637	200	0.3140	200	0	0.0000
A460037003	377	330	0.3763	176	0	0.0000
A460157005	151	0	0.0000	0	0	0.0000

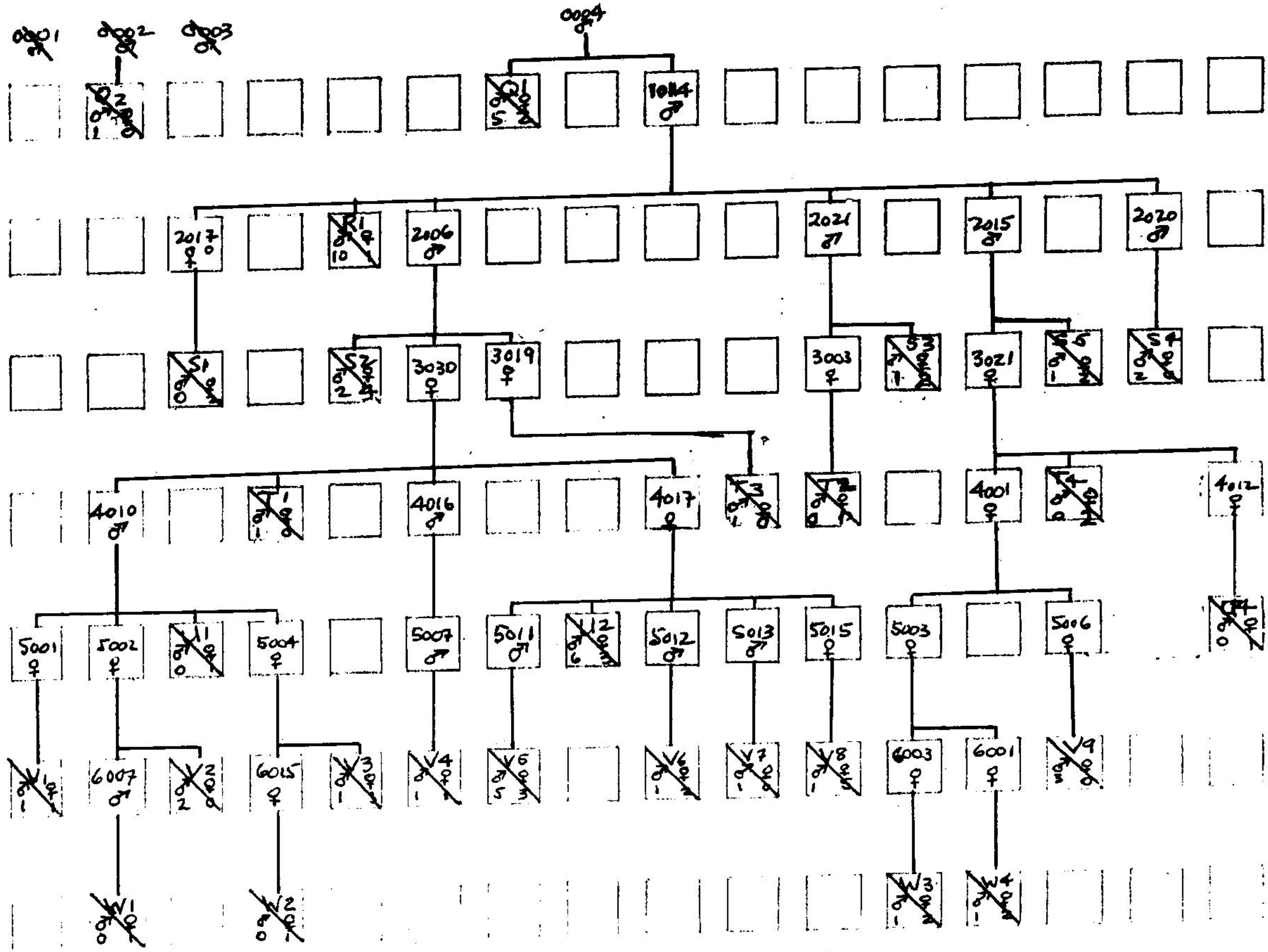


Figure 7: Lineage diagram of table 7

Table 8

Outbred Offspring from 2 K_{rad} Female Mated to Male Normal (Code B1-0001,2)

TITLE=B1 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
B1 2 2	593	103	0.1737	89	7	0.0787
B1 21033	115	45	0.3913	10	2	0.2000
B1 21051	750	315	0.4200	70	0	0.0000
B1 21118	859	644	0.7497	514	85	0.1654
B1 21120	39	18	0.4615	0	0	0.0000
B111182071	458	137	0.2991	40	10	0.2500

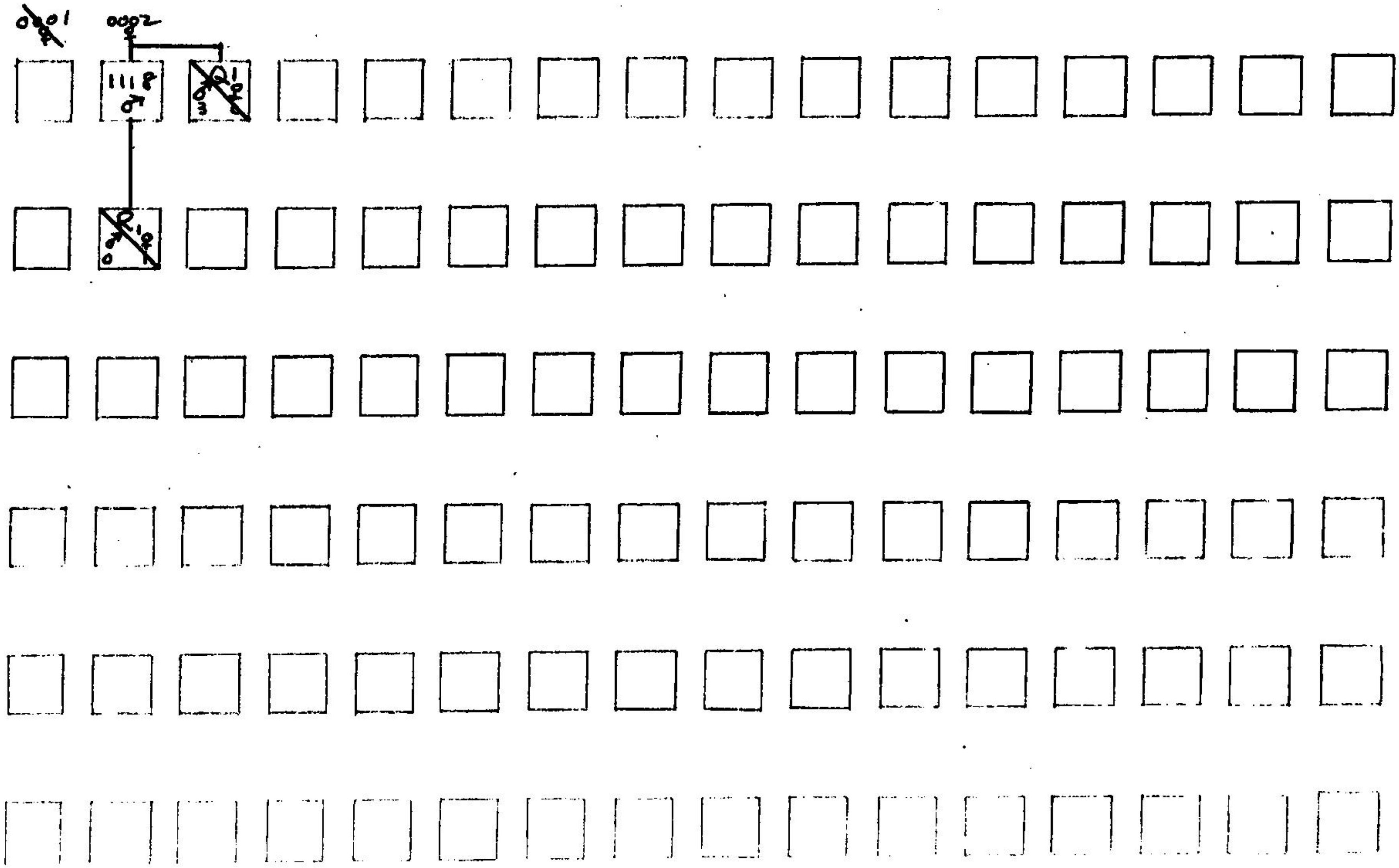


Figure 8: Lineage diagram of table 8

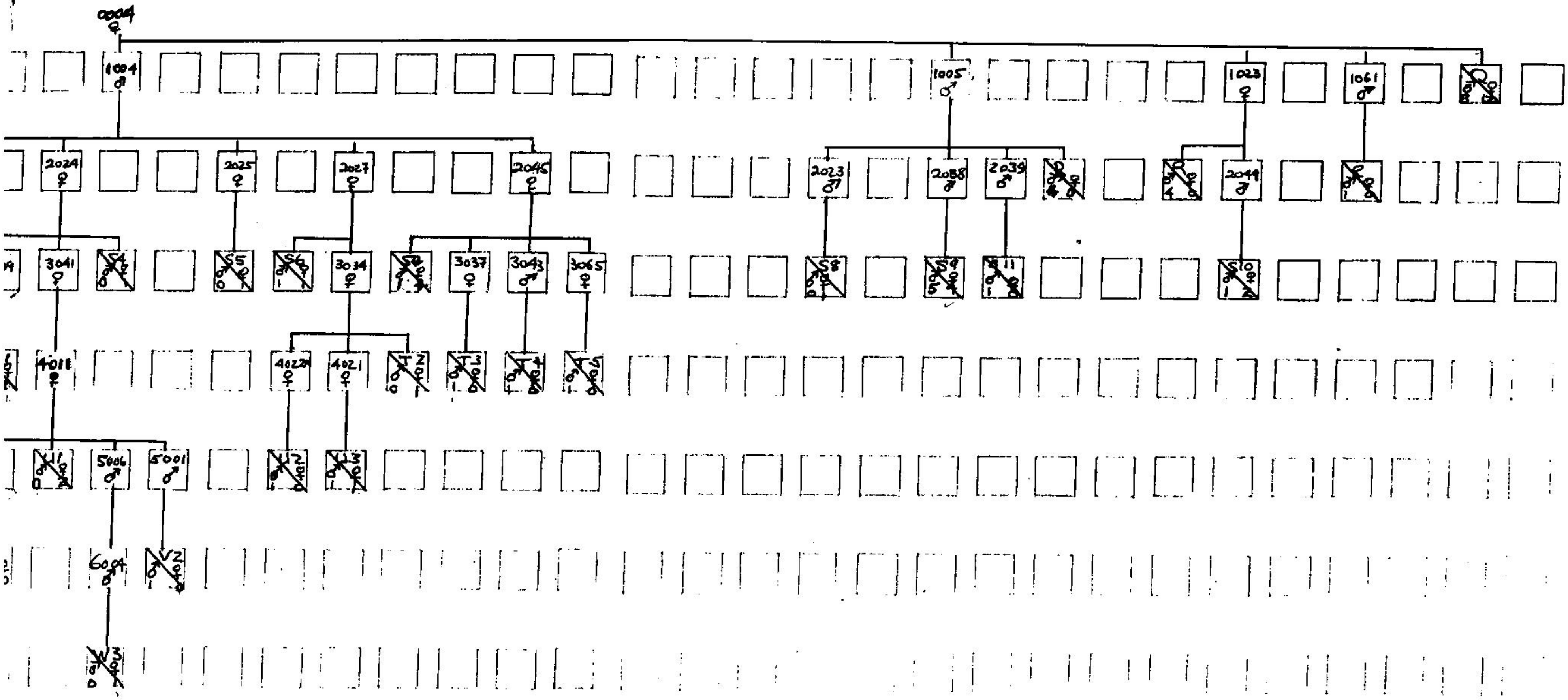
Table 9

Outbred Offspring from 2 K_{rad} Female Mated to Male Normal (Code B1-0004)

LITTER=B1 ANCESTOR IS 4

	LITTER	N	F	F/N	G	M	M/G
B1	4 4	929	430	0.4629	429	31	0.0733
B1	41004	822	400	0.4976	315	115	0.3651
B1	41005	900	650	0.7222	406	122	0.3012
B1	41023	679	337	0.4963	300	75	0.2500
B1	41026	158	0	0.0000	0	0	0.0000
B1	41029	938	707	0.7537	290	46	0.1586
B1	41041	63	3	0.0476	0	0	0.0000
B1	41042	281	205	0.7295	205	57	0.2780
B1	41043	483	63	0.1304	25	0	0.0000
B1	41050	21	4	0.1905	0	0	0.0000
B1	41060	450	0	0.0000	0	0	0.0000
B1	41061	656	303	0.4619	200	15	0.0750
B1	41066	420	0	0.0000	0	0	0.0000
B1	41067	649	113	0.1744	48	12	0.2500
B1	41071	510	165	0.3235	0	0	0.0000
B1	41072	503	260	0.5169	175	90	0.5143
B1	41074	757	172	0.2272	150	70	0.4667
B1	41075	643	203	0.3157	185	34	0.1838
B1	41079	370	80	0.2162	80	0	0.0000
B1	41080	536	76	0.1418	0	0	0.0000
B1	41086	134	3	0.0224	0	0	0.0000
B1	41098	420	200	0.4762	130	13	0.1000
B1	41099	144	0	0.0000	0	0	0.0000
B1	41104	446	0	0.0000	0	0	0.0000
B1	41106	435	280	0.6437	35	0	0.0000
B110042048		192	24	0.1250	18	0	0.0000
B110042002		492	242	0.4919	0	0	0.0000
B110042003		650	450	0.6923	200	68	0.3400
B110042007		299	149	0.4983	100	7	0.0700
B110042014		248	217	0.8750	0	0	0.0000
B110042017		264	78	0.2955	0	0	0.0000
B110042019		415	205	0.4940	45	20	0.4444
B110042022		320	160	0.5000	0	0	0.0000
B110042024		346	230	0.6647	200	103	0.5150
B110042025		476	51	0.1071	45	30	0.6667
B110042027		331	225	0.6798	150	22	0.1467
B110042045		298	76	0.2493	70	13	0.1857
B110042060		316	188	0.5949	120	55	0.4583
B110052006		542	200	0.3690	0	0	0.0000
B110052010		756	185	0.2447	0	0	0.0000
B110052020		340	90	0.2647	25	3	0.1200
B110052023		424	229	0.5401	50	27	0.5400
B110052038		680	568	0.8353	400	61	0.1525
B110052039		364	306	0.8407	190	41	0.2158
B110052042		422	146	0.3460	75	7	0.0933
B110052048		192	24	0.1250	0	0	0.0000
B110232049		218	118	0.5413	50	24	0.4800
B110232050		423	0	0.0000	0	0	0.0000
B110232051		170	20	0.1176	0	0	0.0000
B110232053		63	0	0.0000	0	0	1.0000
B110232054		90	0	0.0000	0	0	0.0000
B110612063		1113	878	0.7883	557	85	0.1545
B120493002		241	125	0.5187	125	26	0.2080
B120493005		534	433	0.6001	200	101	0.5450
B120493006		147	30	0.2041	0	0	0.0000
B120033004		21	0	0.0000	0	0	0.0000
B120033042		714	228	0.3193	228	23	0.1000
B120233004		235	20	0.0851	20	0	0.0000
B120293002		413	31	0.2172	15	0	0.0000
B120383010		155	[illegible]	[illegible]	[illegible]	0	1.0000
B120383012		125	50	0.4000	0	0	0.0000
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		410	[illegible]	[illegible]	[illegible]	3	[illegible]

LITTER	N	F	F/N	G	M	M/G
B120383056	239	149	0.6234	142	21	0.1400
B120383066	8	0	0.0000	0	0	0.0000
B120383068	193	73	0.3782	73	8	0.1096
B120073014	346	60	0.1734	0	0	0.0000
B120073026	48	2	0.0417	0	0	0.0000
B120073027	423	20	0.0473	20	6	0.3000
B120073046	411	140	0.3406	140	18	0.1286
B120453015	411	75	0.1825	0	0	0.0000
B120453037	452	160	0.3540	160	18	0.1125
B120453043	494	140	0.2834	140	56	0.4000
B120453064	275	95	0.3455	95	0	0.0000
B120453065	375	178	0.4747	178	2	0.0112
B120253029	372	45	0.1210	45	3	0.0667
B120273033	402	116	0.2886	0	0	0.0000
B120273034	458	235	0.5131	235	40	0.1702
B120273036	502	135	0.2689	65	8	0.1231
B120243039	578	165	0.2855	165	70	0.4242
B120243040	533	234	0.4390	140	8	0.0571
B120243041	361	270	0.7479	270	16	0.0593
B120233059	150	32	0.2133	0	0	0.0000
B120193063	322	61	0.1894	61	3	0.0492
B120393049	685	103	0.1504	103	0	0.0000
B120453061	202	67	0.3317	67	8	0.1194
B120383008	235	20	0.0851	20	0	0.0000
B120383009	419	91	0.2172	15	0	0.0000
B120383010	246	0	0.0000	0	0	0.0000
B120383012	198	50	0.2525	0	0	0.0000
B120383052	0	0	0.0000	0	0	0.0000
B120383053	418	98	0.2344	98	3	0.0306
B120383056	0	0	0.0000	0	0	0.0000
B120383066	8	0	0.0000	0	0	0.0000
B120383068	193	73	0.3782	73	8	0.1096
B130434003	239	100	0.4184	100	3	0.0300
B130414011	207	140	0.6763	140	22	0.1571
B130374013	0	0	0.0000	0	0	0.0000
B130344016	132	30	0.2273	10	0	0.0000
B130344021	211	100	0.4739	100	6	0.0600
B130344022	167	160	0.9581	160	13	0.0812
B130654022	377	186	0.4934	0	0	0.0000
B130394023	220	220	1.0000	150	0	0.0000
B140115001	380	80	0.0200	80	2	0.0250
B140115002	274	155	0.5657	155	14	0.0903
B140115003	640	420	0.6563	420	2	0.0048
B140115006	893	120	0.1344	120	7	0.0583
B140115008	532	171	0.3214	90	1	0.0111
B140225011	843	410	0.4864	410	11	0.0268
B140215012	29	0	0.0000	0	0	0.0000
B140215019	85	0	0.0000	0	0	0.0000
B150026001	340	262	0.7706	220	28	0.1273
B150026002	582	261	0.4485	200	30	0.1500
B150026003	110	23	0.2091	0	0	0.0000
B150026005	357	355	0.9944	0	0	0.0000
B150026007	233	0	0.0000	0	0	0.0000
B150064004	594	256	0.5079	126	10	0.0794
B150036003	665	172	0.2586	70	12	0.1714
B160027002	618	140	0.2265	140	7	0.0500
B160027003	667	248	0.3718	210	15	0.0714
B160027006	472	92	0.1949	65	0	0.0000
B160027007	616	393	0.6380	325	11	0.0338
B160027008	285	121	0.4246	90	0	0.0000
B160027012	448	195	0.4353	190	0	0.0000
B160017004	729	155	0.2130	155	5	0.0258
B160017005	633	532	0.7326	460	144	0.3130
B160047011	277	77	0.2780	70	0	0.0000



gure 9: Lineage diagram of figure 9

Table 10

Outbred Offspring from 6 K_{rad} Female Mated to Male Normal (Code B2-0001,2)

TITLE=B2 ANCESTOR IS 1

TITLE	B	F	F/B	G	M	M/G
B2 1 1	653	86	0.1317	72	7	0.0972
B2 11069	163	23	0.1411	0	0	0.0000
B2 11093	335	300	0.8955	160	28	0.1750
B2 11110	345	210	0.6087	175	7	0.0400
B2 11130	200	0	0.0000	0	0	0.0000
B2 11182	320	206	0.6437	190	28	0.1474
B2 11183	405	85	0.2099	0	0	0.0000
B2 11193	200	0	0.0000	0	0	0.0000
B211102166	597	263	0.4405	190	31	0.1632
B210932157	13	7	0.5385	0	0	0.0000

TITLE=B2 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
B2 2 2	679	155	0.2283	133	37	0.2782
B2 21001	449	262	0.5835	230	72	0.3130
B2 21027	19	0	0.0000	0	0	0.0000
B2 21028	692	64	0.0925	0	0	0.0000
B2 21029	464	101	0.2177	89	10	0.1124
B2 21042	402	0	0.0000	0	0	0.0000
B2 21046	675	413	0.6119	325	49	0.1508
B2 21048	653	101	0.1547	65	20	0.3077
B2 21061	429	25	0.0583	20	2	0.1000
B2 21085	578	58	0.1003	0	0	0.0000
B2 21118	440	280	0.6364	230	20	0.0870
B2 21143	420	272	0.6476	245	25	0.1020
B2 21194	406	6	0.0148	0	0	0.0000
B2 21249	354	26	0.0734	0	0	0.0000
B210462077	591	280	0.4738	200	89	0.4450
B210462099	588	365	0.6207	150	51	0.3400
B210282008	513	39	0.0760	30	9	0.3000
B210282009	390	165	0.4342	105	3	0.0286
B210282050	429	189	0.4406	149	16	0.1074
B210282056	442	22	0.0498	0	0	0.0000
B210282057	554	4	0.0072	0	0	0.0000
B210282070	371	43	0.1159	0	0	0.0000
B210282071	389	18	0.0463	0	0	0.0000
B210282072	286	63	0.2203	0	0	0.0000
B210012003	249	57	0.2289	30	5	0.1667
B210012004	576	236	0.4097	115	8	0.0696
B210012018	222	13	0.0586	0	0	0.0000
B210012021	699	381	0.5451	156	4	0.0256
B210012022	173	28	0.1618	0	0	0.0000
B210012036	340	19	0.0559	0	0	0.0000
B210012053	232	24	0.1034	0	0	0.0000
B210012054	198	88	0.4444	40	16	0.4000
B210012055	291	7	0.0241	0	0	0.0000
B210012017	485	95	0.1959	0	0	0.0000
B210012020	96	30	0.3125	30	2	0.0667
B210012060	310	15	0.0484	0	0	0.0000
B210012068	340	52	0.1529	35	13	0.3714
B210012079	294	203	0.6905	200	0	0.0000
B210012090	266	5	0.0188	0	0	0.0000
B210012096	299	35	0.1171	20	0	0.0000
B210012122	335	65	0.1940	0	0	0.0000
B210012123	585	300	0.5128	55	7	0.1273
B210012124	303	50	0.1650	0	0	0.0000
B210282047	299	271	0.9064	271	14	0.0517
B210282048	215	0	0.0000	0	0	0.0000
B210012039	1	0	0.0000	0	0	0.0000
B210012062	366	0	0.0000	0	0	0.0000
B210012063	137	0	0.0000	0	0	0.0000
B210012067	5	0	0.0000	0	0	0.0000
B210012081	230	0	0.0000	0	0	0.0000
B210012092	153	0	0.0000	0	0	0.0000
B210012115	145	0	0.0000	0	0	0.0000
B210012116	0	0	0.0000	0	0	0.0000
B210012125	530	367	0.6925	165	64	0.3879
B210012138	235	0	0.0000	0	0	0.0000
B210282047	299	271	0.9064	155	15	0.0968
B220993037	602	191	0.3173	0	0	0.0000

B220993038	778	194	0.2494	194	6	0.0309
B220543027	963	241	0.2503	50	18	0.3600
B220683024	243	78	0.3210	52	23	0.4423
B220773028	458	321	0.7009	80	13	0.1625
B220773029	615	196	0.3187	160	10	0.0625
B220543070	640	188	0.2937	144	15	0.1042
B220993016	674	519	0.7700	240	44	0.1833
B220993011	552	209	0.3786	185	37	0.2000
B220503073	651	280	0.4301	50	7	0.1400
B220473043	513	139	0.2710	120	19	0.1583
B210462077	591	280	0.4738	200	86	0.4300
B210012068	340	52	0.1529	35	12	0.3429
B220993013	653	252	0.3859	90	27	0.3000
B230134050	135	0	0.0000	0	0	0.0000
B230434002	437	183	0.4188	180	17	0.0944
B230434026	311	100	0.3215	100	4	0.0400
B230434027	403	192	0.4764	180	24	0.1333
B230114009	322	113	0.3509	75	0	0.0000
B230734011	391	183	0.4680	7	0	0.0000
B230704014	0	0	0.0000	0	0	0.0000
B230704016	816	465	0.5699	465	25	0.0538
B230294017	694	122	0.1758	110	5	0.0455
B230244031	117	0	0.0000	0	0	0.0000
B230274034	202	12	0.0594	0	0	0.0000
B230164037	105	40	0.3810	40	0	0.0000
B230164039	257	94	0.3658	10	1	0.1000
B230164041	24	7	0.2917	0	0	0.0000
B230164043	575	137	0.2383	0	0	0.0000
B240165021	696	526	0.7557	479	89	0.1862
B240165026	476	298	0.6261	297	6	0.0202
B240165032	64	0	0.0000	0	0	0.0000
B230284038	75	0	0.0000	0	0	0.0000
B240175006	733	0	0.0000	0	0	0.0000
B240175024	814	575	0.7064	410	60	0.1463
B240025007	239	34	0.1423	0	0	0.0000
B240025012	465	116	0.2495	80	2	0.0250
B240025017	446	189	0.4238	104	29	0.2788
B240275008	583	245	0.4202	200	11	0.0550
B240275025	126	0	0.0000	0	0	0.0000
B240275011	364	0	0.0000	0	0	0.0000
B240275014	463	200	0.4320	200	14	0.0700
B240275018	0	0	0.0000	0	0	0.0000
B240435022	528	105	0.1989	95	3	0.0316
B240435031	664	163	0.2455	65	9	0.1385
B250216006	672	256	0.3810	130	0	0.0000
B250216010	839	339	0.4041	275	3	0.0109
B250216011	878	237	0.2699	200	9	0.0450
B250216013	186	0	0.0000	0	0	0.0000
B250216014	564	327	0.5798	170	0	0.0000
B250216015	817	464	0.5679	125	1	0.0080
B250216017	600	66	0.1100	60	10	0.1667
B250216021	1085	394	0.3631	335	23	0.0687
B250216024	248	0	0.0000	0	0	0.0000
B250216025	555	130	0.2342	100	3	0.0300
B250216026	572	56	0.0979	56	1	0.0179
B250216028	751	323	0.4301	255	2	0.0078
B250216030	186	48	0.2581	45	0	0.0000
B250216032	714	440	0.6162	350	13	0.0371
B250216034	343	11	0.0321	0	0	0.0000
B250216035	670	0	0.0000	0	0	0.0000
B250216036	527	0	0.0000	0	0	0.0000
B250216037	381	3	0.0079	0	0	0.0000
B250216038	364	0	0.0000	0	0	0.0000
B250086007	457	227	0.4957	115	0	0.0000
B250176008	569	85	0.1494	85	8	0.0941
B250176012	534	154	0.2884	90	1	0.0111
B250176023	280	0	0.0000	0	0	0.0000
B250176027	378	297	0.7593	200	7	0.0350
B250316039	350	88	0.2514	0	0	0.0000
B250327017	766	388	0.5065	84	0	0.0000

D

C

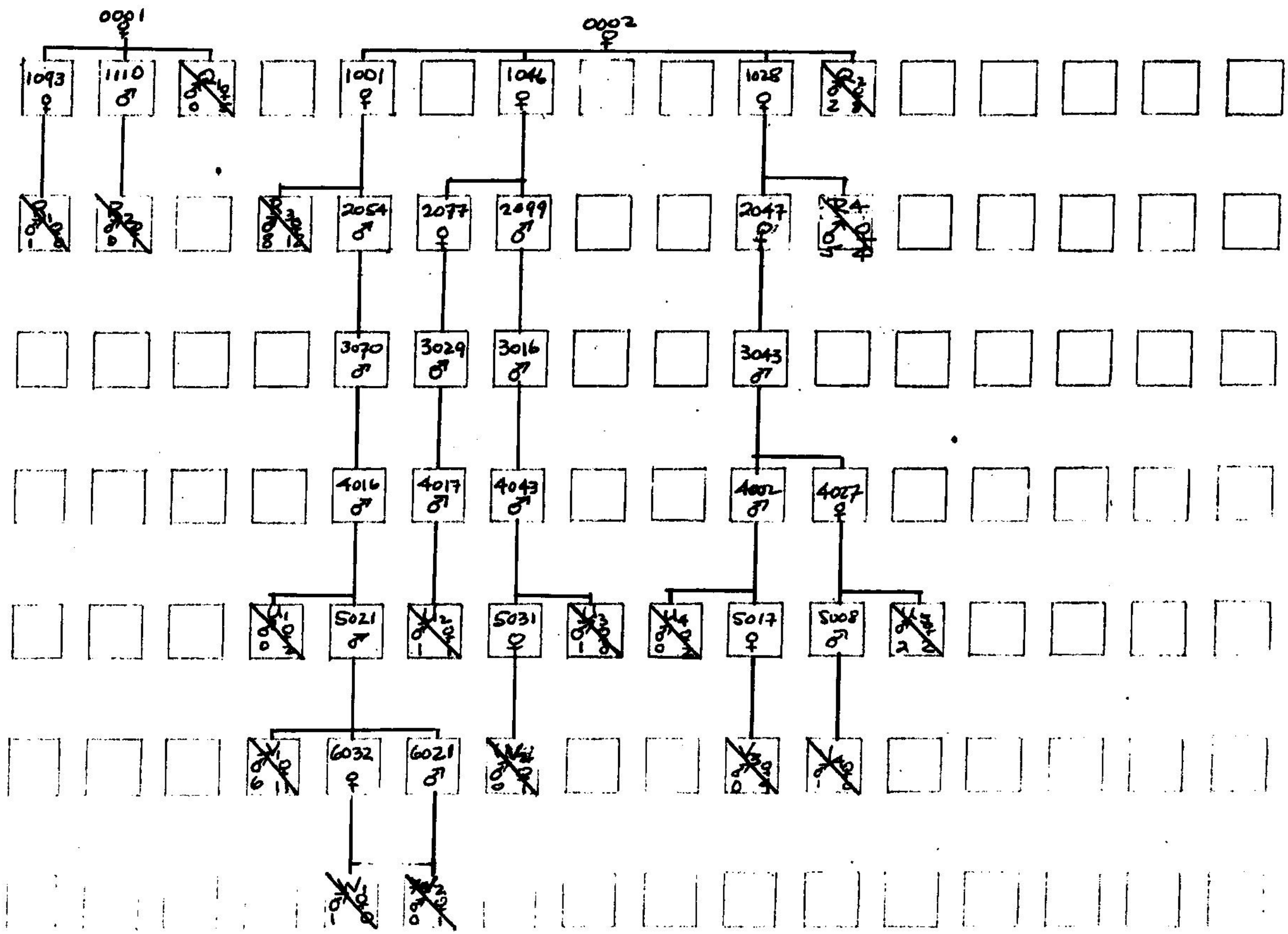


Figure 10: Lineage diagram of table 10

Table 11

Outbred Offspring from 6 K_{rad} Female Mated to Male Normal (Code B2-0003)

TITLE=B2 ANCESTOR IS 3

TITLE	B	F	F/B	G	M	M/G
B2 3 3	207	130	0.6280	128	45	0.3516
B2 31002	407	94	0.2310	91	54	0.5934
B2 31045	420	183	0.4357	150	51	0.3400
B2 31070	378	348	0.9206	300	62	0.2067
B2 31073	1029	498	0.4840	345	110	0.3188
B2 31077	815	595	0.7301	295	174	0.5898
B2 31080	496	0	0.0000	0	0	0.0000
B2 31081	60	0	0.0000	0	0	0.0000
B2 31101	65	0	0.0000	0	0	0.0000
B2 31102	627	92	0.1467	65	0	0.0000
B2 31119	315	195	0.6190	85	6	0.0706
B2 31122	619	590	0.9532	445	83	0.1865
B2 31123	180	105	0.5833	80	5	0.0625
B2 31134	446	46	0.1031	0	0	0.0000
B2 31161	468	18	0.0385	0	0	0.0000
B2 31162	635	110	0.1732	50	0	0.0000
B2 31175	58	0	0.0000	0	0	0.0000
B2 31189	566	66	0.1166	0	0	0.0000
B2 31213	661	301	0.4554	215	3	0.0140
B2 31217	90	5	0.0556	0	0	0.0000
B2 31234	243	105	0.4321	0	0	0.0000
B210022087	581	261	0.4492	60	13	0.2167
B211022088	477	377	0.7904	160	44	0.2750
B211022141	341	6	0.0176	0	0	0.0000
B210452073	394	111	0.2817	15	8	0.5333
B210452105	516	80	0.1550	0	0	0.0000
B21045 274	9	0	0.0000	0	0	0.0000
B210452106	518	40	0.0772	0	0	0.0000
B210452107	614	271	0.4414	95	11	0.1158
B210452108	461	50	0.1085	0	0	0.0000
B210452111	444	24	0.0541	0	0	0.0000
B210452120	513	270	0.5263	105	76	0.7238
B210452143	580	163	0.2810	0	0	0.0000
B210732014	386	180	0.4663	70	9	0.1286
B210772069	104	3	0.0288	0	0	0.0000
B210772075	376	222	0.5904	150	6	0.0400
B210772080	476	228	0.4790	20	11	0.5500
B210772082	214	31	0.1449	0	0	0.0000
B210772118	261	31	0.1188	0	0	0.0000
B210772119	284	40	0.1408	30	1	0.0333
B210772135	179	130	0.7263	0	0	0.0000
B210022006	295	130	0.4407	125	48	0.3840
B210022007	274	16	0.0584	0	0	0.0000
B210022012	535	134	0.2505	115	0	0.0000
B210022013	206	64	0.3107	45	0	0.0000
B210022015	160	7	0.0437	0	0	0.0000
B210022024	524	386	0.7366	319	4	0.0125
B210022025	155	67	0.4323	35	13	0.3714
B210022026	176	71	0.4034	71	4	0.0563
B210022028	64	0	0.0000	0	0	0.0000
B210022029	393	261	0.6641	180	31	0.1722
B210022030	636	502	0.7893	220	31	0.1409
B210022031	370	100	0.2703	50	4	0.0800
B210022038	12	0	0.0000	0	0	0.0000
B210022040	482	337	0.6992	214	17	0.0794
B210022041	193	0	0.0000	0	0	0.0000
B210022042	699	432	0.6270	303	2	0.0066
B210022043	153	84	0.5490	0	0	0.0000
B210022044	263	65	0.2471	0	0	0.0000
B210022045	484	325	0.6715	155	5	0.0323
B210022097	553	310	0.5606	110	29	0.2636
B210022098	301	6	0.0199	0	0	0.0000
B210022102	319	131	0.4107	0	0	0.0000
B210022130	257	29	0.1128	0	0	0.0000
B210022131	257	149	0.5798	25	5	0.2000
B210732002	466	45	0.0966	0	0	0.0000
B210452121	441	176	0.3991	176	150	0.8523
B220063077	0	0	0.0000	0	0	0.0000
B220063078	355	24	0.0676	0	0	0.0000
B220803040	457	230	0.5033	230	64	0.2783
B220293049	67	9	0.1343	0	0	0.0000
B220293051	303	148	0.4884	148	0	0.0000
B220973065	651	128	0.1966	128	5	0.0391
B220243066	239	131	0.5504	0	0	0.0000
B220243069	136	22	0.1618	0	0	0.0000
B220243081	0	0	0.0000	0	0	0.0000
B221073031	882	306	0.3469	130	37	0.2846
B220873021	550	336	0.6109	200	4	0.0200
B220883033	734	247	0.3365	140	14	0.1000
B220883034	315	156	0.4952	0	0	0.0000
B220883052	459	188	0.4096	51	1	0.0196
B221203035	120	85	0.7083	85	1	0.0118
B221203036	369	312	0.8455	0	0	0.0000
B221213001	411	111	0.2701	105	1	0.0095
B221213056	459	80	0.1743	80	20	0.2500
B221213057	656	251	0.3826	95	14	0.1474
B221213076	548	141	0.2573	0	0	0.0000
B220303006	417	146	0.3501	35	7	0.2000
B220303007	209	44	0.2105	18	8	0.4444
B220303072	591	300	0.5076	170	46	0.2706
B220253010	216	106	0.4907	95	17	0.1789
B220423023	718	420	0.5850	220	75	0.3409
B220423046	300	153	0.5100	0	0	0.0000
B220423047	536	226	0.4216	125	2	0.0160
B220873020	622	192	0.3087	55	21	0.3818
B210022087	581	261	0.4492	60	12	0.2000
B230104040	814	520	0.6388	520	11	0.0212
B230404004	48	3	0.0625	0	0	0.0000
B230404005	174	90	0.5172	90	0	0.0000
B230404006	521	206	0.3954	140	1	0.0071
B230404007	519	196	0.3776	110	24	0.2182
B230404013	161	28	0.1739	0	0	0.0000
B230404018	423	137	0.3239	137	3	0.0219
B230404029	541	148	0.2736	148	7	0.0473
B230514019	307	0	0.0000	0	0	0.0000
B230514020	0	0	0.0000	0	0	0.0000
B230234024	297	150	0.5051	150	4	0.0267
B230724028	694	320	0.4611	320	16	0.0500
B230404008	695	387	0.5568	240	0	0.0000
B230204015	70	20	0.2857	15	0	0.0000
B230214046	0	0	0.0000	0	0	0.0000
B240405028	646	500	0.7740	500	19	0.0380
B240405030	295	0	0.0000	0	0	0.0000
B240075003	43	33	0.7674	0	0	0.0000
B240075010	220	99	0.4500	85	16	0.1882
B240285004	725	141	0.1945	135	2	0.0148
B240285005	672	107	0.1592	80	1	0.0125
B240285013	456	16	0.0351	0	0	0.0000
B240285016	868	480	0.5530	325	67	0.2062
B240285019	536	41	0.0765	25	1	0.0400
B240065009	646	348	0.5387	200	6	0.0300
B240185015	132	2	0.0152	0	0	0.0000
B240245027	996	731	0.7339	520	5	0.0096
B240245029	602	462	0.7674	390	8	0.0205
B250046022	433	0	0.0000	0	0	0.0000
B250046016	807	25	0.0310	25	1	0.0400
B250106001	851	455	0.5347	360	54	0.1500
B250106002	837	601	0.7180	270	18	0.0667
B250106003	733	460	0.6276	460	3	0.0065
B250106005	78	0	0.0000	0	0	0.0000
B250166004	765	250	0.3268	95	6	0.0632
B250166009	854	349	0.4087	230	37	0.1609
B250166018	735	388	0.5279	300	11	0.0367
B250166019	916	519	0.5666	365	8	0.0219
B250166020	516	115	0.2229	115	10	0.0870
B250046027	433	0	0.0000	0	0	0.0000
B260017001	328	110	0.3354	75	0	0.0000
B260017005	222	0	0.0000	0	0	0.0000
B260017010	948	441	0.4652	390	0	0.0000
B260187002	813	319	0.3924	130	2	0.0154
B260187004	615	165	0.2683	114	0	0.0000
B260187013	766	102	0.1332	102	0	0.0000
B260047003	721	85	0.1179	85	0	0.0000
B260027006	79	0	0.0000	0	0	0.0000
B260027008	117	31	0.2650	0	0	0.0000
B260027009	581	382	0.6575	340	0	0.0000
B260027011	529	255	0.4820	255	0	0.0000
B260027012	46	0	0.0000	0	0	0.0000
B260097007	938	96	0.1023	70	0	0.0000
B260097015	125	5	0.0400	0	0	0.0000
B260097016	190	0	0.0000	0	0	0.0000

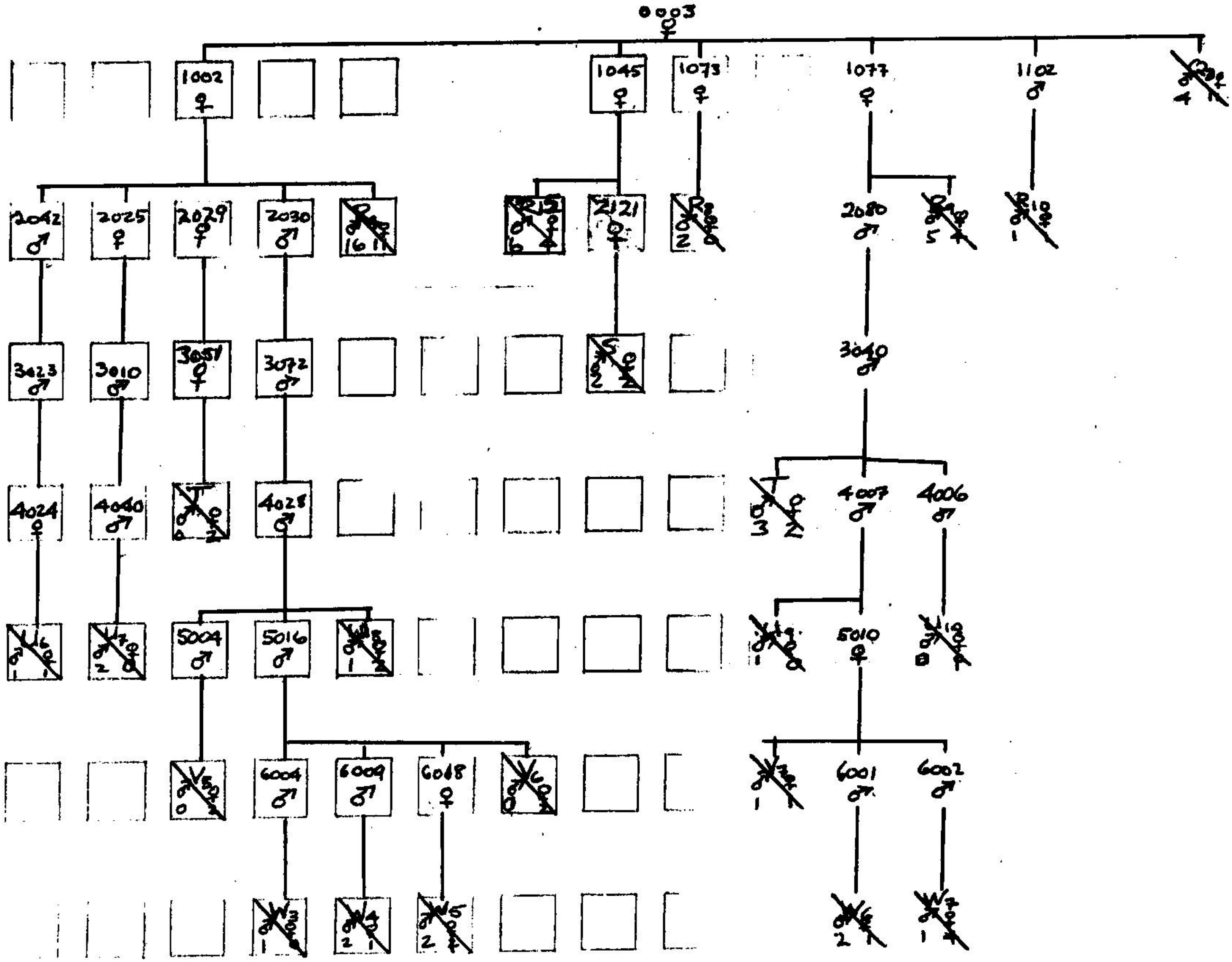


Figure 11: Lineage diagram of table 11

Table 12

Outbred Offspring from 6 K_{rad} Female Mated to Male Normal (Code B2-0004)

TITLE=B2 ANCESTOR IS 4

TITLE	B	F	F/B	G	M	M/G
B2 4 4	569	159	0.2794	147	32	0.2177
B2 41003	604	1	0.0017	0	0	0.0000
B2 41014	18	6	0.3333	0	0	0.0000
B2 41017	298	2	0.0067	0	0	0.0000
B2 41038	389	143	0.3676	105	2	0.0190
B2 41043	790	465	0.5886	300	121	0.4033
B2 41044	776	122	0.1572	20	11	0.5500
B2 41062	950	414	0.4358	245	68	0.2776
B2 41072	410	275	0.6707	190	75	0.3947
B2 41083	526	206	0.3916	61	33	0.5410
B2 41116	495	290	0.5859	40	17	0.4250
B2 41117	660	265	0.4015	235	44	0.1872
B2 41142	76	0	0.0000	0	0	0.0000
B2 41158	370	250	0.6757	75	1	0.0133
B2 41163	490	440	0.8980	310	21	0.0677
B2 41185	382	50	0.1309	0	0	0.0000
B2 41199	170	0	0.0000	0	0	0.0000
B211632161	648	355	0.5478	130	27	0.2077
B210432085	72	0	0.0000	0	0	0.0000
B210432140	306	155	0.5065	0	0	0.0000
B210432145	618	35	0.0566	0	0	0.0000
B210442094	529	292	0.5520	110	18	0.1636
B210442095	301	40	0.1329	0	0	0.0000
B210622059	216	52	0.2407	45	1	0.0222
B210622064	385	73	0.1895	0	0	0.0000
B210622084	180	86	0.4778	0	0	0.0000
B210622103	295	59	0.2000	0	0	0.0000
B210622112	402	125	0.3109	0	0	0.0000
B210622114	248	41	0.1653	0	0	0.0000
B210622136	314	98	0.3121	0	0	0.0000
B210622139	186	13	0.0699	0	0	0.0000
B210622141	341	6	0.0176	0	0	0.0000
B210622146	146	2	0.0137	0	0	0.0000
B220943022	761	551	0.7240	103	24	0.2330
B220943039	686	287	0.4184	220	60	0.2727
B230224003	188	61	0.3245	0	0	0.0000

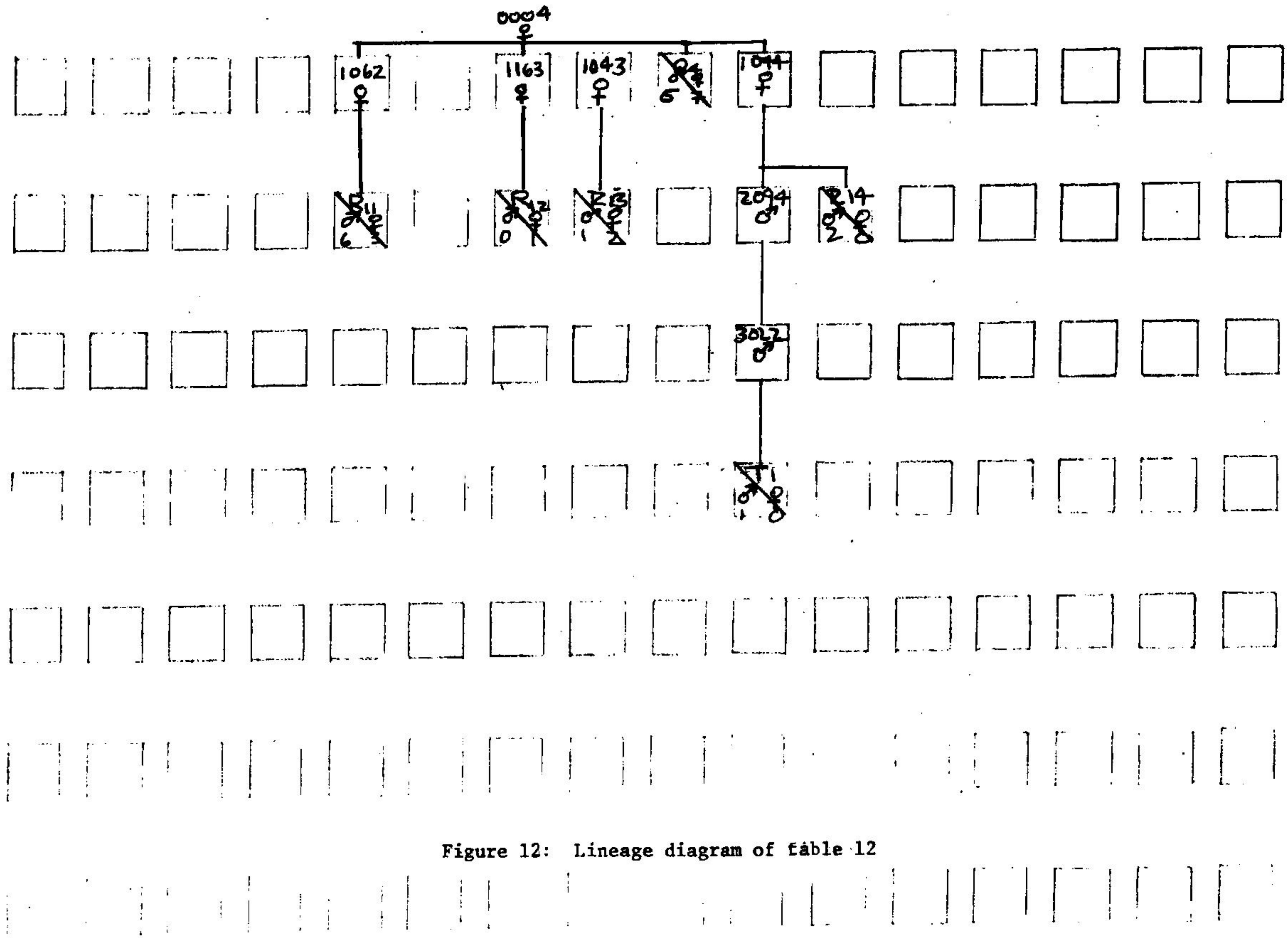


Figure 12: Lineage diagram of táble 12

Table 13

Outbred Offspring from 12 K_{rad} Female Mated to Male Normal (Code B3-0001,2,3)

TITLE=B3 ANCESTOR IS 1

TITLE		B	F	F/B	G	M	M/G
B3	1 1	401	46	0.1147	43	3	0.0698
B3	11006	781	66	0.0845	0	0	0.0000
B3	11019	183	9	0.0492	0	0	0.0000
B3	11071	330	80	0.2424	0	0	0.0000

TITLE=B3 ANCESTOR IS 2

TITLE		B	F	F/B	G	M	M/G
B3	2 2	537	27	0.0503	15	4	0.2667
B3	21027	678	227	0.3348	160	26	0.1625
B3	21043	328	103	0.3140	0	0	0.0000

TITLE=B3 ANCESTOR IS 3

TITLE		B	F	F/B	G	M	M/G
B3	3 3	500	149	0.2980	104	6	0.0577
B3	31028	314	224	0.7134	190	44	0.2316
B3	31031	121	58	0.4793	25	1	0.0400
B3	31039	65	0	0.0000	0	0	0.0000
B3	31042	60	0	0.0000	0	0	0.0000
B3	31044	585	250	0.4274	0	0	0.0000
B3	10282055	167	50	0.2994	0	0	0.0000

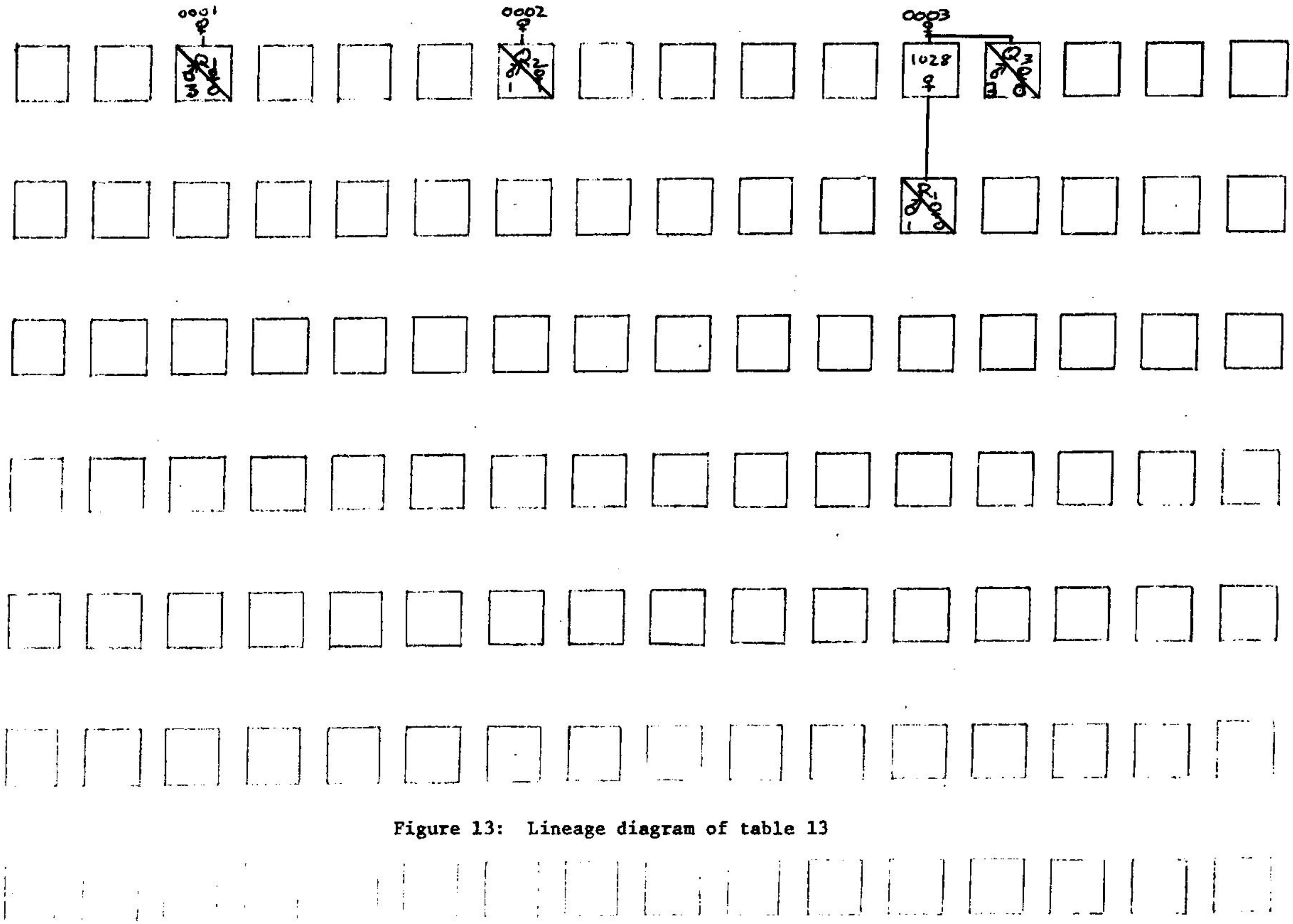


Figure 13: Lineage diagram of table 13

Table 14

Outbred Offspring from 14 K_{rad} Female Mated to Male Normal (Code B4-0001,2,3)

	B	F	F/B	G	M	M/G
B400010001	369	0	0	0	0	0
B400020002	176	0	0	0	0	0
B400030003	0	0	0	0	0	0

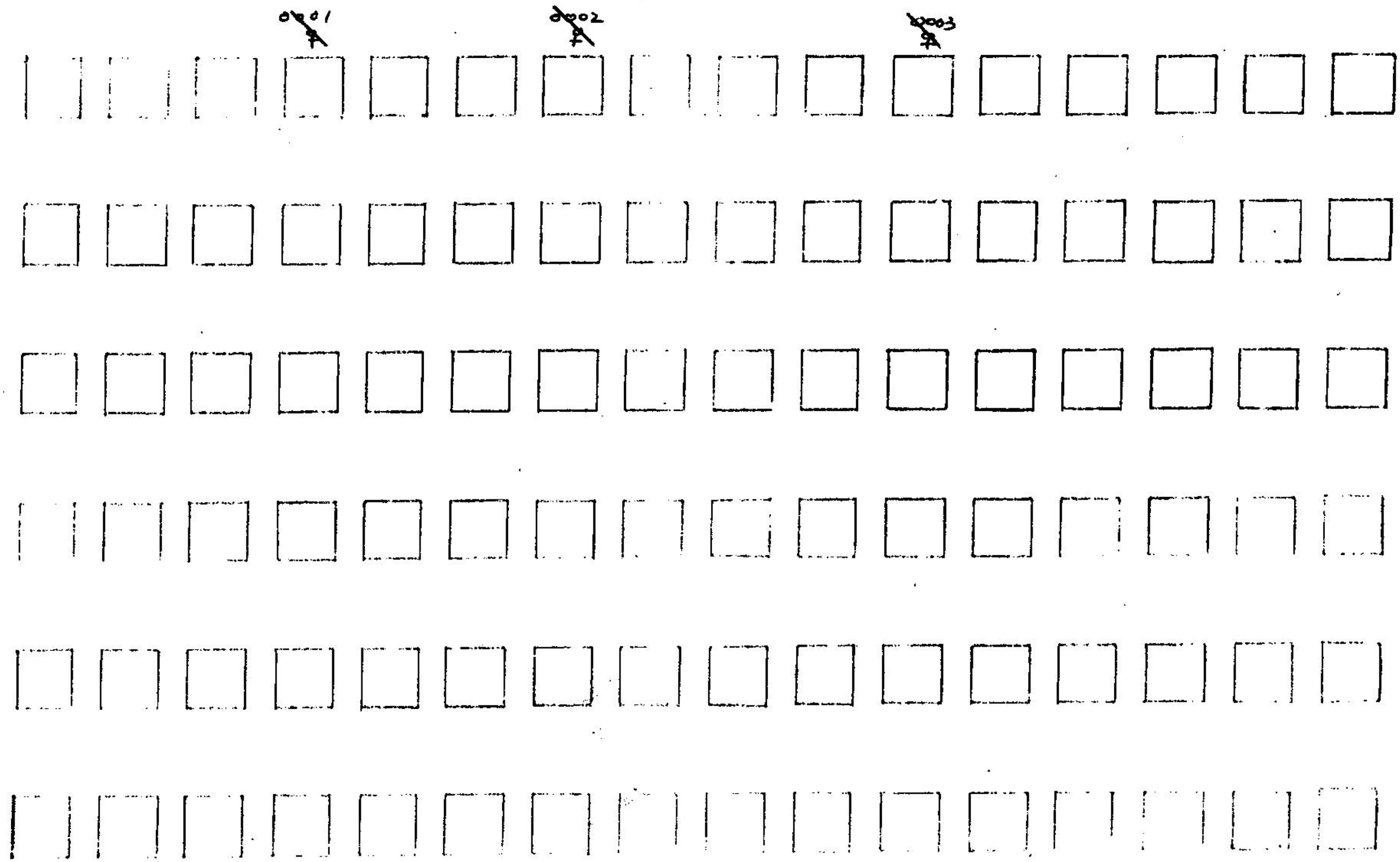


Figure 14: Lineage diagram of table 14

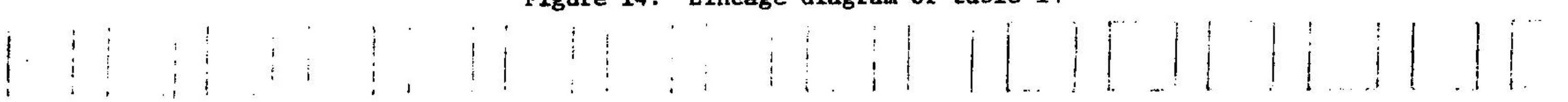


Table 15

Outbred Offspring from 1 K_{rad} Female Mated to Male Normal (Code D1-0002,3,4)

TITLE=D1 ANCESTOR IS 2

TITLE			B	F	F/B	G	M	M/G
D1	2	2	262	185	0.7061	0	0	0.0000

TITLE=D1 ANCESTOR IS 3

TITLE			B	F	F/B	G	M	M/G
D1	3	3	391	195	0.4987	0	0	0.0000

TITLE=D1 ANCESTOR IS 4

TITLE			B	F	F/B	G	M	M/G
D1	4	4	202	0	0.0000	0	0	0.0000

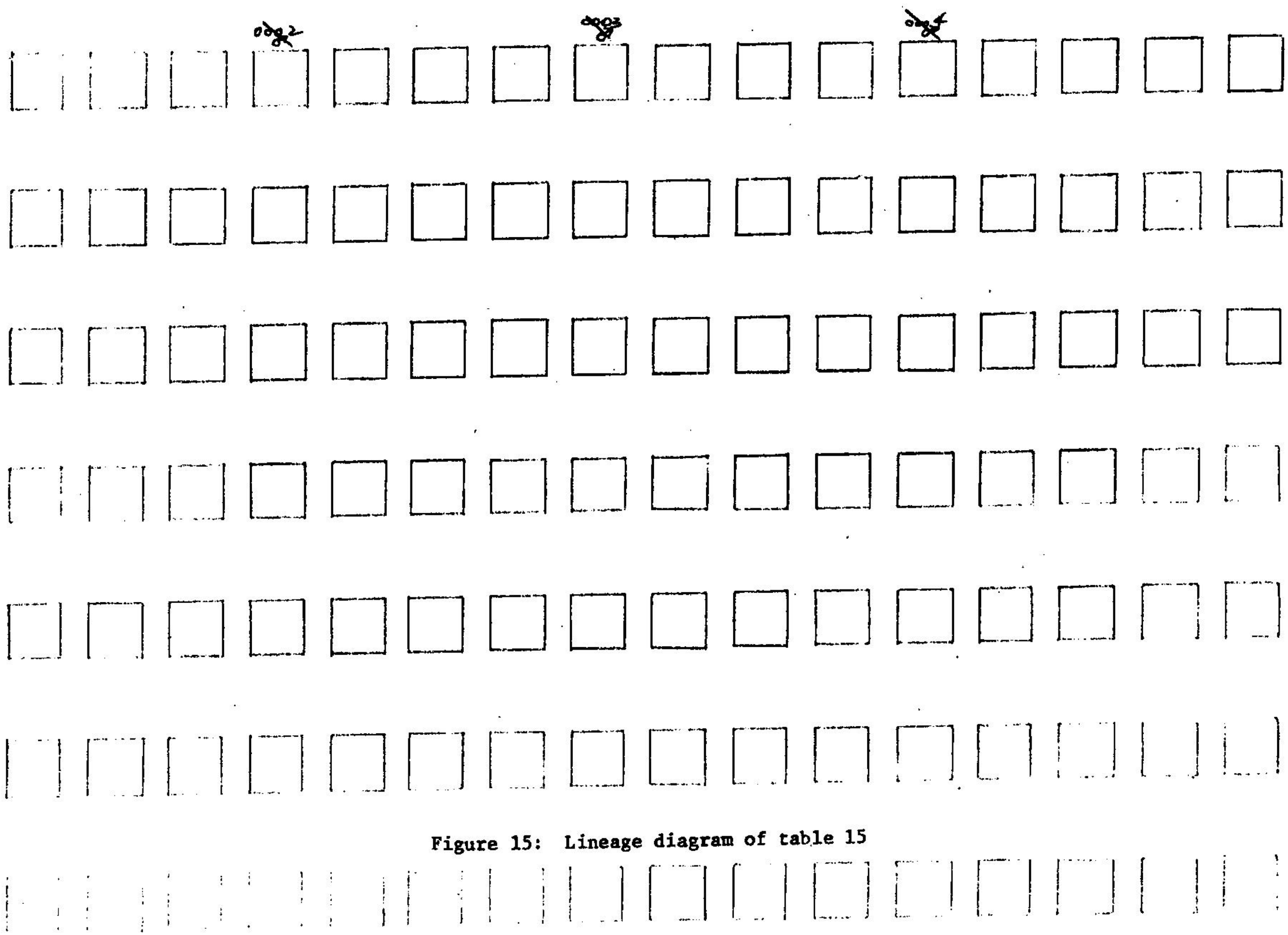


Figure 15: Lineage diagram of table 15

Table 16

Outbred Offspring from 2 K_{rad} Male Mated to Female Normal (Code D2-0002)

TITLE=D2 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
D2 2 2	266	147	0.5526	147	19	0.1293
D2 21003	175	0	0.0000	0	0	0.0000
D2 21034	672	252	0.3750	252	1	0.0040
D2 21052	344	246	0.7151	235	0	0.0000
D2 21057	60	40	0.6667	40	0	0.0000
D2 21062	282	175	0.6206	130	0	0.0000
D2 21067	418	276	0.6603	264	0	0.0000
D2 21079	123	101	0.8211	95	0	0.0000
D210032044	355	8	0.0225	8	0	0.0000
D210342023	411	158	0.3844	158	0	0.0000
D210622039	322	185	0.5745	0	0	0.0000

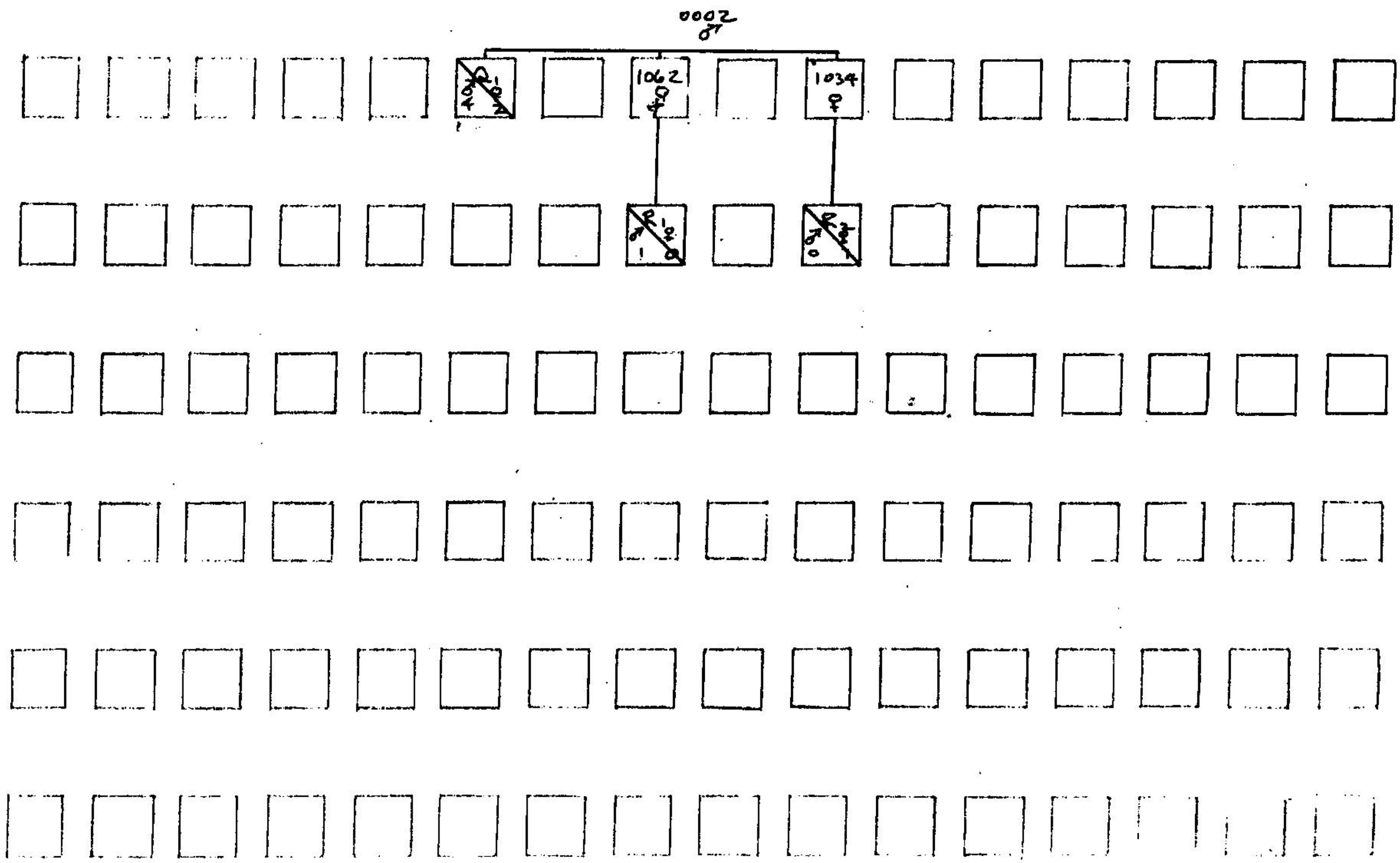


Figure 16: Lineage diagram of table 16

Table 17

Outbred Offspring from 4 K_{rad} Male Mated to Female Normal (Code D3-0001,2)

TITLE=D3 ANCESTOR IS 1

TITLE		B	F	F/B	G	M	M/G
D3	I 1	525	305	0.5810	305	48	0.1574
D3	11178	750	0	0.0000	0	0	0.0000
D3	11101	191	29	0.1518	0	0	0.0000
D3	11110	281	201	0.7153	111	8	0.0721
D3	11113	347	117	0.3372	50	2	0.0400
D3	11117	48	0	0.0000	0	0	0.0000
D3	11120	548	520	0.9489	349	7	0.0201
D3	11123	678	271	0.3997	271	12	0.0443
D3	11126	392	92	0.2347	72	2	0.0278
D3	11133	447	291	0.6510	291	2	0.0069
D3	11138	316	81	0.2563	81	0	0.0000
D3	11141	352	55	0.1563	51	0	0.0000
D3	11142	418	262	0.6268	262	0	0.0000
D3	11145	365	199	0.5452	193	1	0.0052
D3	11148	339	250	0.7375	250	1	0.0040
D3	11150	418	289	0.6914	289	0	0.0000
D3	11153	355	84	0.2366	80	0	0.0000
D3	11156	366	211	0.5765	141	1	0.0071
D3	11159	180	25	0.1389	0	0	0.0000
D3	11161	421	106	0.2518	81	0	0.0000
D3	11168	393	57	0.1450	57	0	0.0000
D3	11176	90	82	0.9111	82	0	0.0000
D3	11177	465	317	0.6817	311	0	0.0000
D3	11110	281	201	0.7153	111	8	0.0721
D3	11113	347	117	0.3372	50	2	0.0400
D3	11120	548	520	0.9489	349	7	0.0201
D3	11123	678	271	0.3997	271	12	0.0443
D3	11133	447	291	0.6510	291	2	0.0069
D3	11138	316	81	0.2563	81	0	0.0000
D3	11141	352	55	0.1563	51	0	0.0000
D3	11142	418	262	0.6268	262	4	0.0153
D3	11145	365	199	0.5452	193	1	0.0052
D3	11148	339	250	0.7375	250	1	0.0040
D3	11150	418	289	0.6914	289	0	0.0000
D3	11153	355	84	0.2366	80	0	0.0000
D3	11156	366	211	0.5765	141	1	0.0071
D3	11151	421	106	0.2518	81	0	0.0000
D3	11168	393	57	0.1450	57	0	0.0000
D3	11176	90	92	0.9111	82	0	0.0000
D3	11177	465	317	0.6817	311	0	0.0000
D311202500		227	1	0.0044	0	0	0.0000
D311201501		139	0	0.0000	0	0	0.0000
D311202528		206	168	0.8155	0	0	0.0000
D311202529		283	209	0.7385	0	0	0.0000
D311202555		395	210	0.5316	0	0	0.0000
D311202566		362	176	0.4862	0	0	0.0000
D311422503		216	88	0.4074	0	0	0.0000
D311422546		593	186	0.3137	0	0	0.0000
D311422556		413	46	0.1114	0	0	0.0000
D311422572		346	0	0.0000	0	0	0.0000
D311232525		341	77	0.2258	0	0	0.0000
D311232526		309	111	0.3592	0	0	0.0000
D311232527		64	0	0.0000	0	0	0.0000
D311232540		399	124	0.3108	0	0	0.0000
D311232557		476	128	0.2689	0	0	0.0000
D311232562		301	101	0.3355	0	0	0.0000
D311262542		670	119	0.1776	0	0	0.0000
D311262543		427	100	0.2342	0	0	0.0000
D311452558		435	120	0.2759	0	0	0.0000
D311562568		188	97	0.5160	0	0	0.0000
D311482574		80	80	1.0000	0	0	0.0000

TITLE=D3 ANCESTOR IS 2

TITLE		B	F	F/B	G	M	M/G
D3	I 2	238	84	0.3529	77	7	0.0909
D3	21105	183	163	0.8907	37	12	0.3243
D3	21106	406	351	0.8645	306	11	0.0359
D3	21108	158	140	0.8861	16	3	0.1875
D3	21124	349	299	0.8567	287	13	0.0453
D311242511		554	372	0.6715	0	0	0.0000
D311242530		54	0	0.0000	0	0	0.0000
D311242532		107	0	0.0000	0	0	0.0000

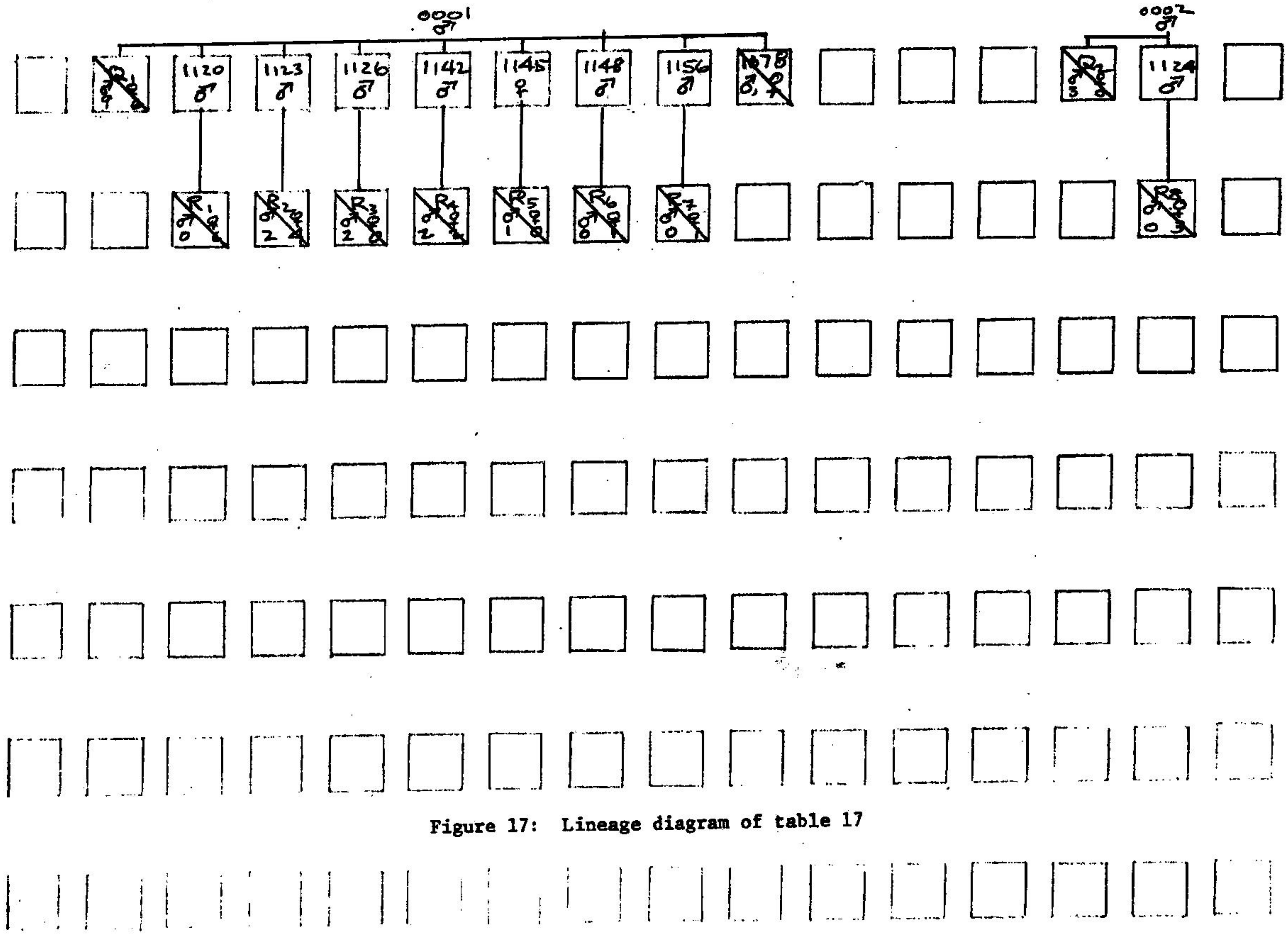


Figure 17: Lineage diagram of table 17

Table 18

Outbred Offspring from 5 K_{rad} Male Mated to Female Normal (Code D4-0001)

TITLE=D4 ANCESTOR IS 1

TITLE	B	F	F/B	G	M	M/G
D4 1 1	540	28	0.0519	28	2	0.0714
D4 11174	472	387	0.8199	50	1	0.0200
D4 11175	194	68	0.3505	0	0	0.0000
D411742549	506	436	0.8617	436	0	0.0000

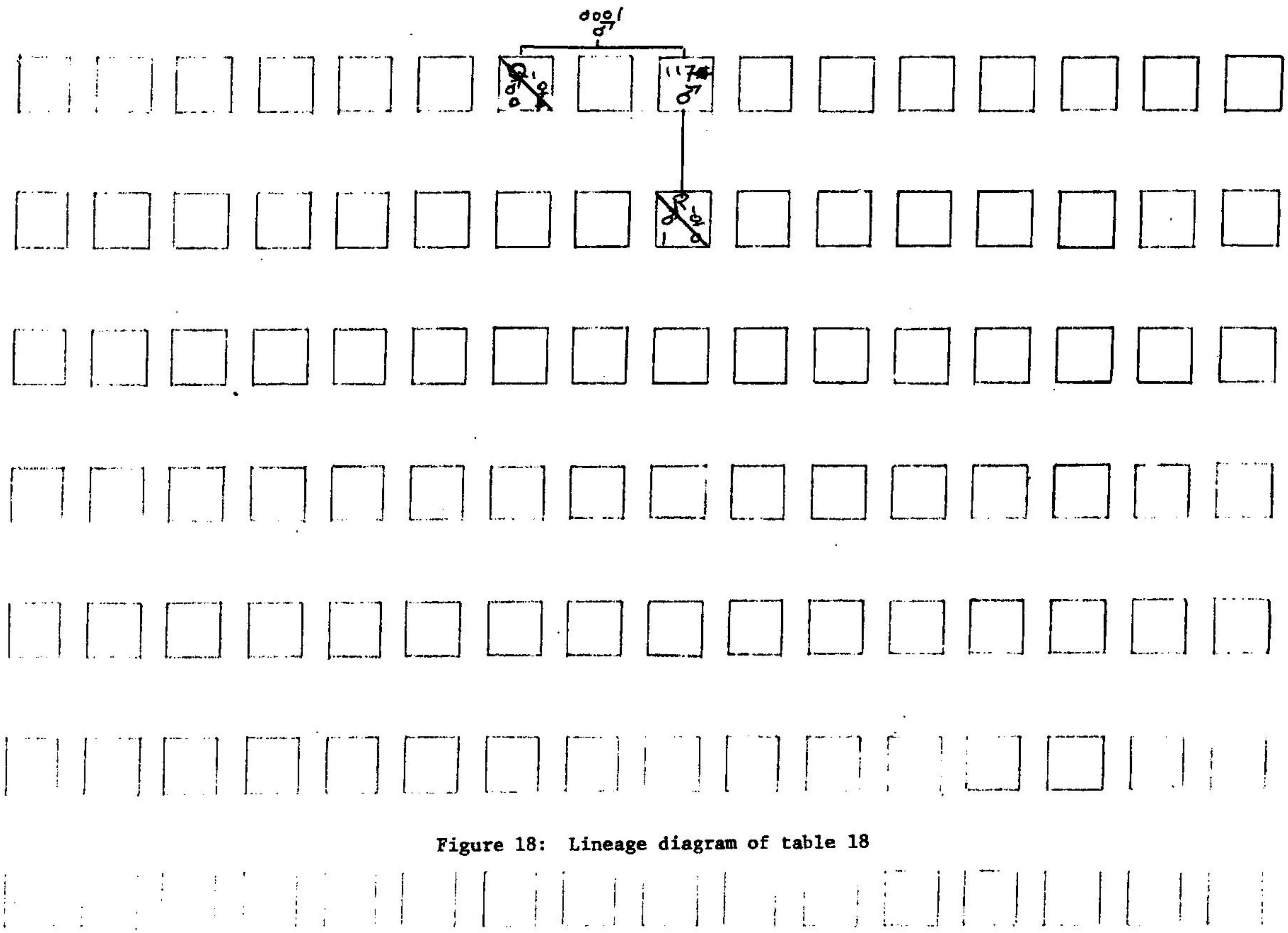


Figure 18: Lineage diagram of table 18

Table 19

Outbred Offspring from 1 K_{rad} Female Mated to Male Normal (Code E1-0002,4)

TITLE=E1 ANCESTOR IS 2

TITLE			B	F	F/B	G	M	M/G
E1	2	2	234	99	0.4231	57	0	0.0000

TITLE=E1 ANCESTOR IS 4

TITLE			B	F	F/B	G	M	M/G
E1	4	4	209	0	0.0000	0	0	0.0000

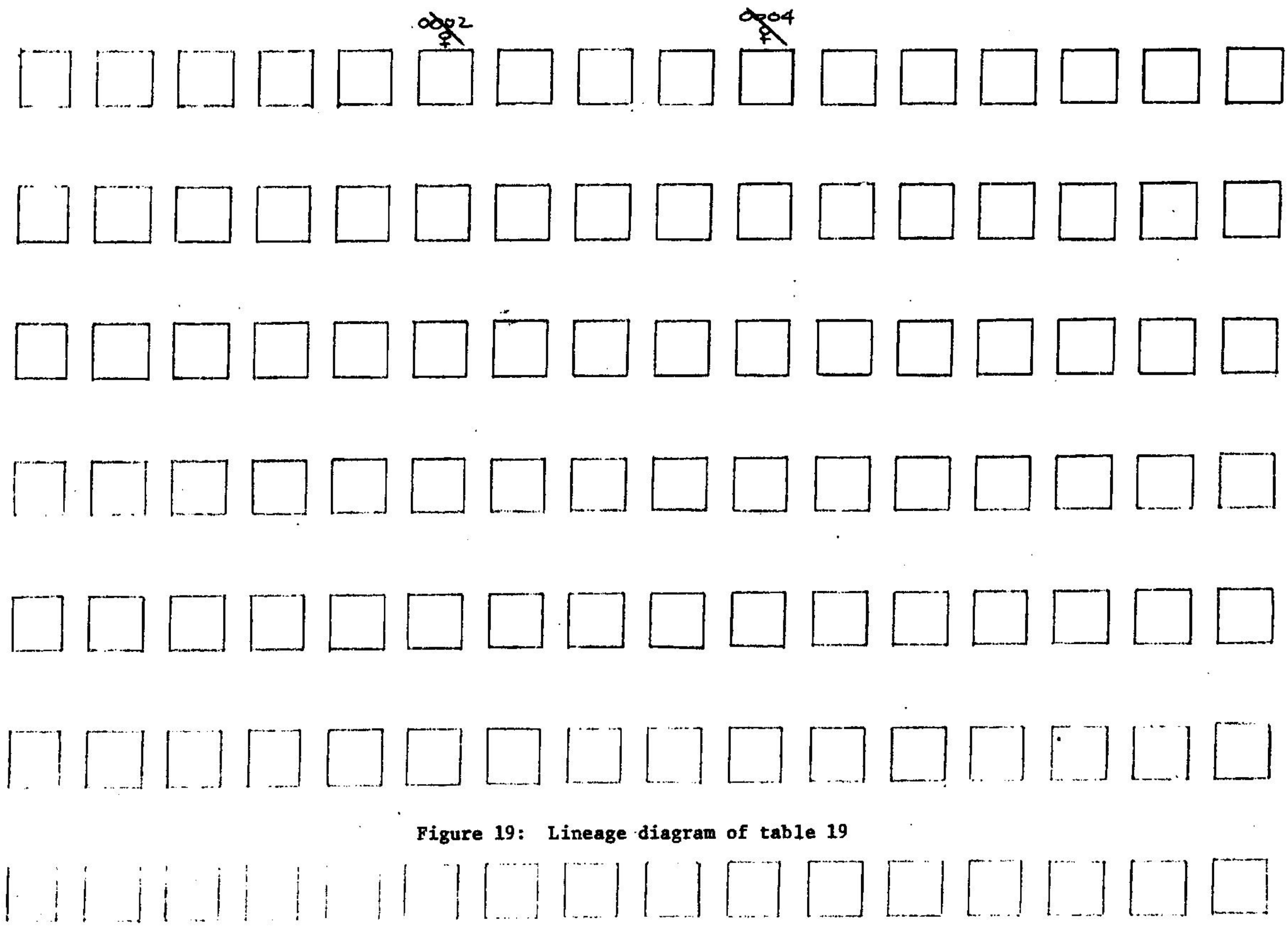


Figure 19: Lineage diagram of table 19

Table 20

Outbred Offspring from 2 K_{rad} Female Mated to Male Normal (Code E2-0002)

TITLE=E2 ANCESTOR IS 2

TITLE		B	F	F/B	G	M	M/G
E2	2 2	350	208	0.5943	208	16	0.0769
E2	21100	94	84	0.8936	30	1	0.0333
E2	21114	540	428	0.7926	174	31	0.1782
E2	21129	80	0	0.0000	0	0	0.0000
E2	21130	345	60	0.1739	50	0	0.0000
E2	21151	332	127	0.3825	123	0	0.0000
E2	21163	268	222	0.8284	208	0	0.0000
E2	21164	140	0	0.0000	0	0	0.0000
E2	21171	186	97	0.5215	93	0	0.0000
E2	21172	429	321	0.7483	321	0	0.0000
E211632561		235	102	0.4340	0	0	0.0000

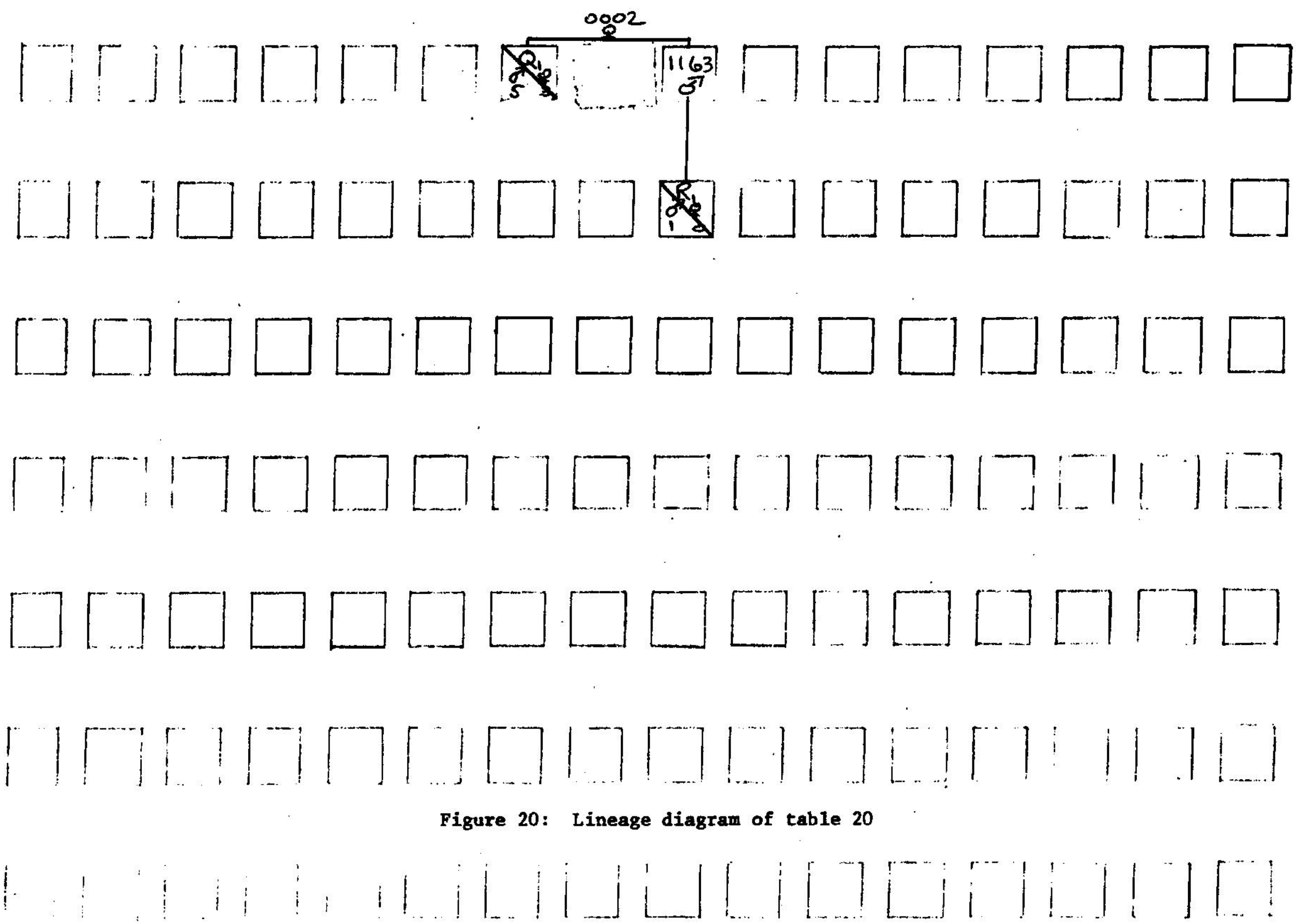


Figure 20: Lineage diagram of table 20

Table 21

Outbred Offspring from 4 K_{rad} Female Mated to Male Normal (Code E3-0002)

TITLE=E3 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
E3 2 2	535	33	0.0617	33	3	0.0909
E3 21119	620	450	0.7258	421	9	0.0214
E3 21127	413	266	0.6441	231	2	0.0087
E311192515	106	66	0.6226	55	0	0.0000
E311192517	297	116	0.3906	0	0	0.0000
E311192519	281	0	0.0000	0	0	0.0000
~~E311192534~~	~~358~~	~~252~~	~~0.7039~~	120	0	0.0000
E311192537	129	103	0.7984	71	0	0.0000
E311192544	210	106	0.5048	34	0	0.0000
E311192548	471	302	0.6412	125	0	0.0000
E311192571	49	49	1.0000	0	0	0.0000

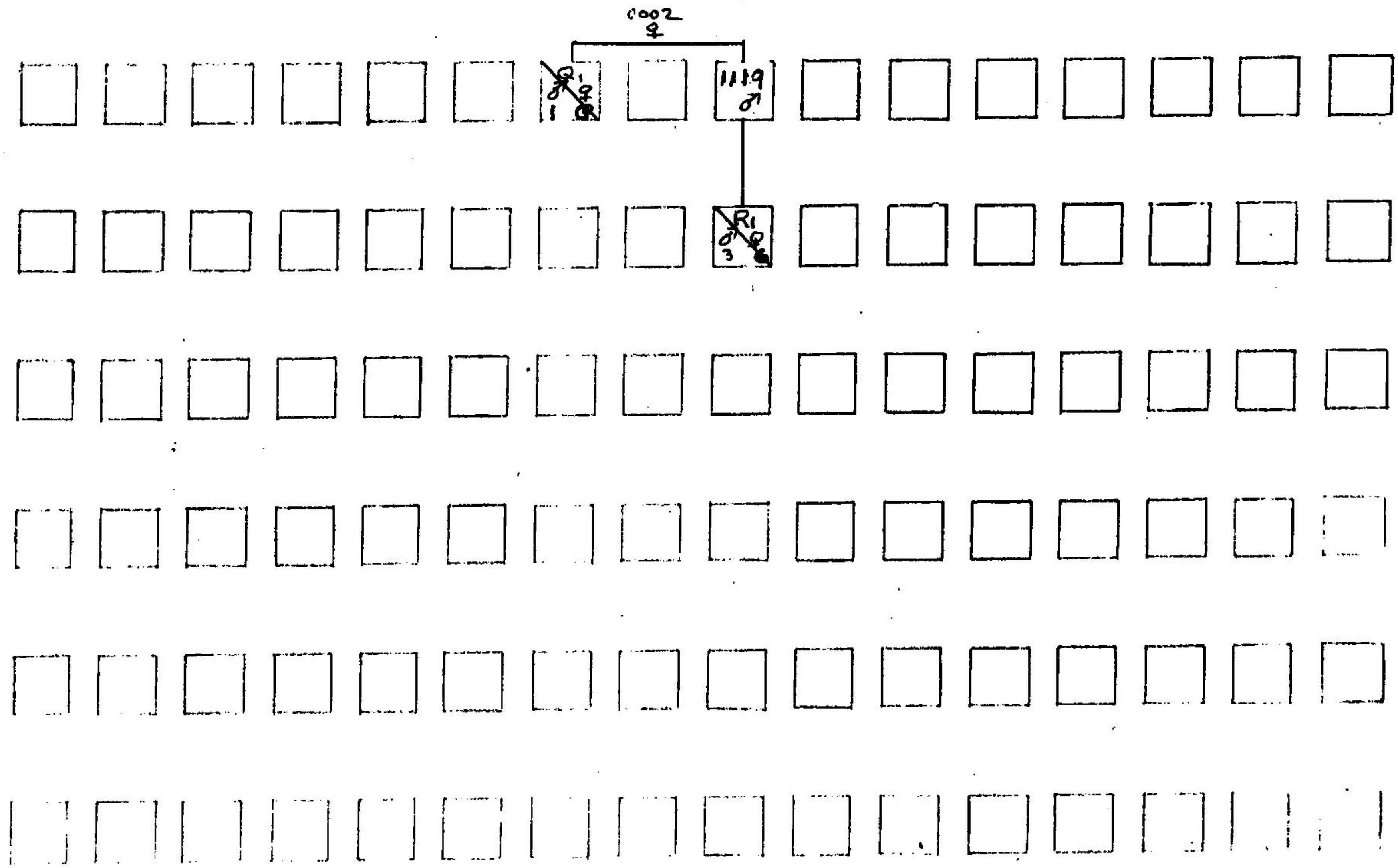


Figure 21: Lineage diagram of table 21

Table 22

Outbred Offspring from 5 K_{rad} Female Mated to Male Normal (Code E4-0001,2)

TITLE=E4 ANCESTOR IS 1

TITLE	B	F	F/B	G	M	M/G
F4 1 1	442	40	0.0905	40	3	0.0750
E4 11125	486	343	0.7058	203	11	0.0542
F411252505	390	142	0.3641	0	0	0.0000
F411252507	338	79	0.2337	20	0	0.0000
F411252509	91	54	0.5934	50	0	0.0000

TITLE=F4 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
E4 2 2	234	27	0.1154	27	2	0.0741

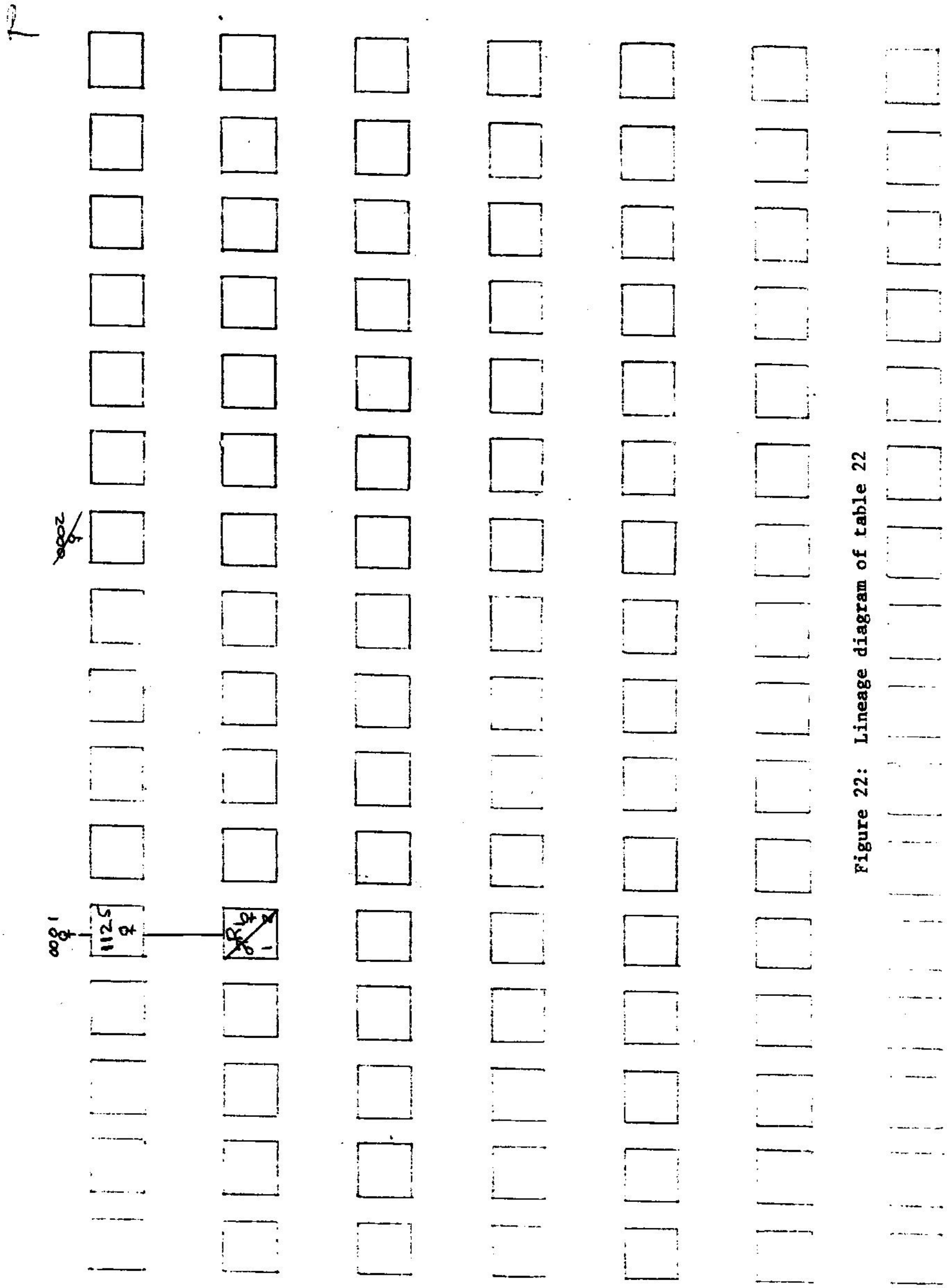


Figure 22: Lineage diagram of table 22

Table 23

Outbred Offspring from 2 K_{rad} Male to Female Normal (Code F1-0001,2,3,6,7)

TITLE=F1 ANCESTOR IS 1

TITLE	B	F	F/B	G	M	M/G
F1 1 1	275	52	0.1891	0	0	0.0000

TITLE=F1 ANCESTOR IS 2

TITLE	B	F	F/B	G	M	M/G
F1 2 2	86	0	0.0000	0	0	0.0000

TITLE=F1 ANCESTOR IS 3

TITLE	B	F	F/B	G	M	M/G
F1 3 3	188	0	0.0000	0	0	0.0000

TITLE=F1 ANCESTOR IS 6

TITLE	B	F	F/B	G	M	M/G
F1 6 6	355	198	0.5577	198	7	0.0354
F1 61015	240	61	0.2542	61	3	0.0492
F1 61022	20	1	0.0500	1	0	0.0000
F1 61023	294	105	0.3571	105	3	0.0286
F1 61027	284	45	0.1585	45	0	0.0000
F1 61055	263	28	0.1065	0	0	0.0000
F1 61064	223	0	0.0000	0	0	0.0000
F1 61087	0	0	0.0000	0	0	0.0000
F110152022	189	118	0.6243	118	3	0.0254
F110152053	262	123	0.4695	123	0	0.0000
F110152054	293	83	0.2833	83	1	0.0120
F110232030	129	7	0.0543	5	0	0.0000
F110232051	263	158	0.6008	110	4	0.0364
F110232085	283	71	0.2509	71	0	0.0000
F120223005	336	15	0.0446	0	0	0.0000
F120223007	425	145	0.3412	0	0	0.0000
F120223012	179	0	0.0000	0	0	0.0000
F120543075	324	0	0.0000	0	0	0.0000
F120513197	410	0	0.0000	0	0	0.0000
F120513227	209	4	0.0191	0	0	0.0000
F120513228	198	112	0.5657	0	0	0.0000
F120513256	364	91	0.2500	0	0	0.0000

TITLE=F1 ANCESTOR IS 7

TITLE	B	F	F/B	G	M	M/G
F1 7 7	279	19	0.0681	0	0	0.0000

TITLE=F1 ANCESTOR IS 11

TITLE	B	F	F/B	G	M	M/G
F1 11 11	160	44	0.2750	44	2	0.0455
F1 111045	235	112	0.4766	112	2	0.0179
F1 111137	278	64	0.2302	64	1	0.0156
F110452001	156	94	0.6026	94	1	0.0106
F110452021	468	217	0.4637	217	1	0.0046
F111372094	343	60	0.1749	60	0	0.0000
F120013003	170	0	0.0000	0	0	0.0000
F120213193	228	0	0.0000	0	0	0.0000

TITLE=F1 ANCESTOR IS 12

TITLE	B	F	F/B	G	M	M/G
F1 12 12	91	0	0.0000	0	0	0.0000

TITLE=F1 ANCESTOR IS 16

TITLE	B	F	F/B	G	M	M/G
F1 16 16	0	0	0.0000	0	0	0.0000

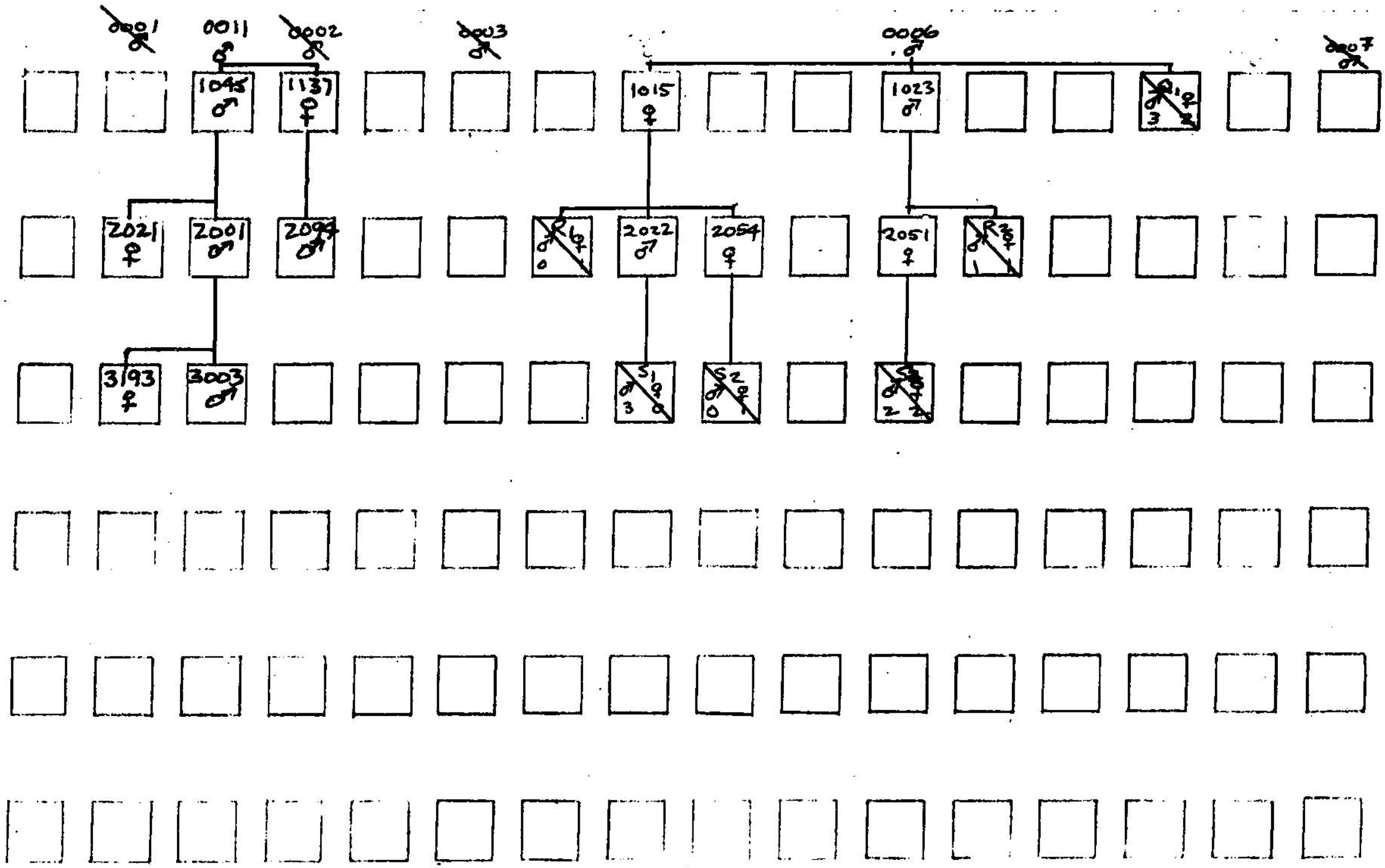


Figure 23: Lineage diagram of table 23

Table 24

Outbred Offspring from 2 K_{rad} Female Mated to Male Normal

(Code G1-0001,4,5,7,9,11,13,15,16,17)

TITLE=G1 ANCESTOR IS 1

TITLE	B	F	F/B	G	M	M/G
G1 1 1	279	43	0.1541	43	1	0.0233
G1 11017	211	64	0.3033	40	1	0.0250
G1 11047	211	64	0.3033	0	0	0.0000
G110472029	413	235	0.5690	235	12	0.0511
G120293008	247	0	0.0000	0	0	0.0000
G120293010	394	278	0.7056	0	0	0.0000
G120293023	190	20	0.1053	12	1	0.0833
G120293024	227	73	0.3216	73	2	0.0274
G120293025	407	138	0.3391	0	0	0.0000
G120293026	303	0	0.0000	0	0	0.0000
G120293028	350	80	0.2286	0	0	0.0000
G120293029	266	71	0.2669	0	0	0.0000
G120293088	256	16	0.0625	0	0	0.0000
G120293089	242	27	0.1116	0	0	0.0000
G120293067	220	65	0.2955	65	0	0.0000
G130234025	179	103	0.5754	102	3	0.0294
G140255023	216	12	0.0556	12	0	0.0000
G140255025	525	84	0.1600	84	0	0.0000
G140255029	363	40	0.1102	40	0	0.0000

TITLE=G1 ANCESTOR IS 4

TITLE	B	F	F/B	G	M	M/G
G1 4 4	365	76	0.2082	76	1	0.0132
G1 41005	282	157	0.5567	157	0	0.0000

TITLE=G1 ANCESTOR IS 5

TITLE	B	F	F/B	G	M	M/G
G1 5 5	482	39	0.0809	39	4	0.1025
G1 51002	277	110	0.3971	110	10	0.0909
G1 51006	134	0	0.0000	0	0	0.0000
G1 51011	0	0	0.0000	0	0	0.0000
G1 51036	220	63	0.2864	60	0	0.0000
G110022000	407	309	0.7592	0	0	0.0000
G110022004	226	24	0.1062	24	1	0.0417
G110022012	394	255	0.6641	0	0	0.0000
G110022013	405	25	0.0617	0	0	0.0000
G110022015	126	0	0.0000	0	0	0.0000
G110022019	211	48	0.2275	0	0	0.0000
G110022024	382	93	0.2435	93	2	0.0215
G110022035	462	185	0.4004	185	2	0.0108
G110022038	152	28	0.1842	0	0	0.0000
G110022063	437	182	0.4165	0	0	0.0000
G120042022	358	96	0.2682	96	0	0.0000
G120243054	295	25	0.0877	25	0	0.0000
G120243126	121	0	0.0000	0	0	0.0000
G120352055	224	24	0.1071	24	0	0.0000
G120353073	301	101	0.3355	101	0	0.0000

TITLE=G1 ANCESTOR IS 7

TITLE	B	F	F/B	G	M	M/G
G1 7 7	228	50	0.2193	30	0	0.0000

TITLE=G1 ANCESTOR IS 9

TITLE	B	F	F/B	G	M	M/G
G1 9 9	351	97	0.2764	97	2	0.0206
G1 91004	260	0	0.0000	0	0	0.0000
G1 91031	180	55	0.3056	0	0	0.0000

TITLE=G1 ANCESTOR IS 11

TITLE	B	F	F/B	G	M	M/G
G1 11 11	197	3	0.0152	3	0	0.0000

TITLE=G1 ANCESTOR IS 13

TITLE	B	F	F/B	G	M	M/G
G1 13 13	237	58	0.2447	58	1	0.0172
G1 131021	373	150	0.4021	150	2	0.0133
G110212011	91	74	0.8132	74	0	0.0000
G110212042	372	0	0.0000	0	0	0.0000

TITLE=G1 ANCESTOR IS 15

TITLE	B	F	F/B	G	M	M/G
G1 15 15	124	31	0.2500	31	0	0.0000

TITLE=G1 ANCESTOR IS 16

TITLE	B	F	F/B	G	M	M/G
G1 16 16	284	25	0.0880	25	0	0.0000

TITLE=G1 ANCESTOR IS 17

TITLE	B	F	F/B	G	M	M/G
G1 17 17	1	0	0.0000	0	0	0.0000

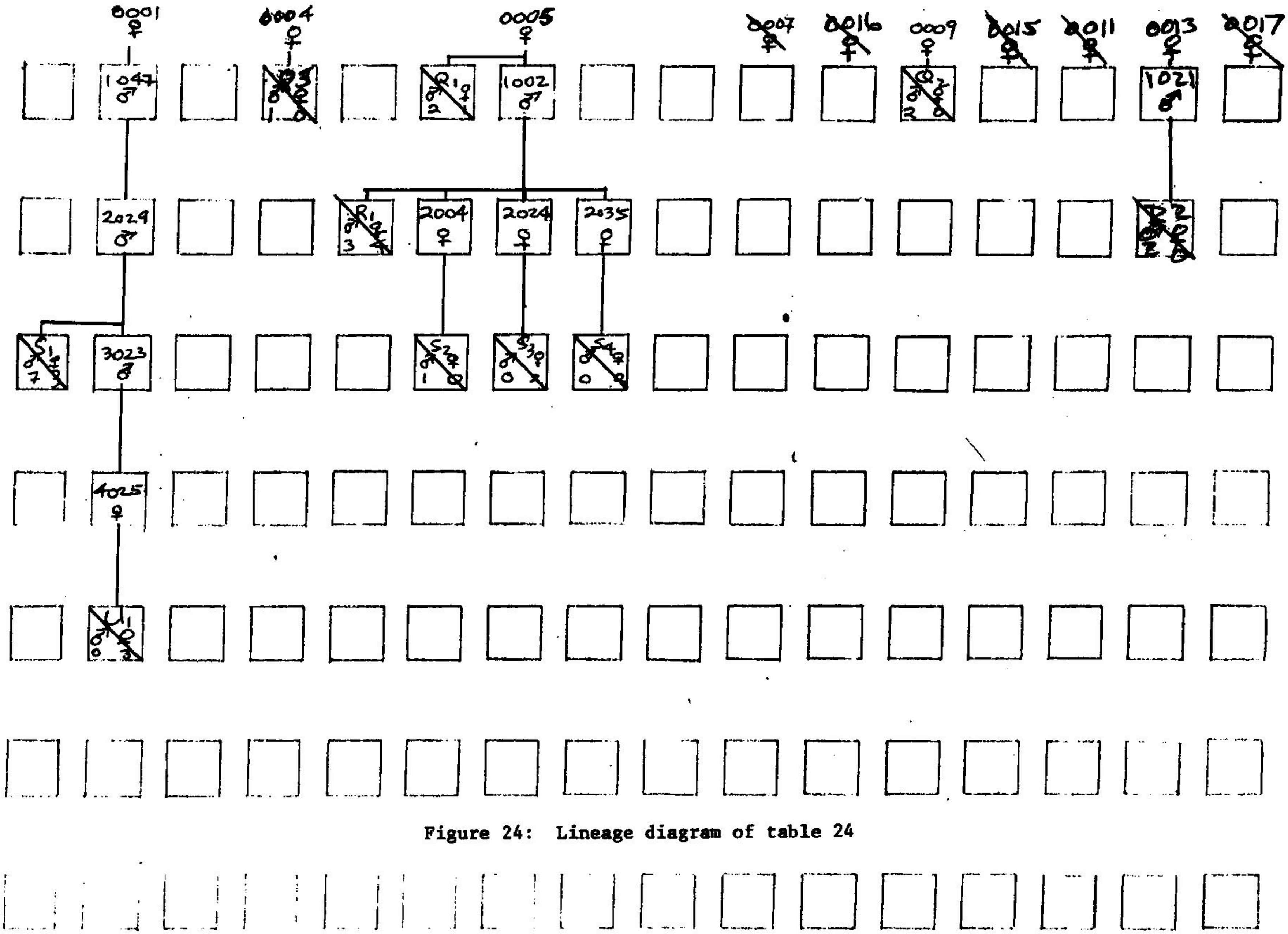


Figure 24: Lineage diagram of table 24

Table 25

Outbred and Inbred Offspring from 2 K_{rad} Male Mated to 2 K_{rad} Female

(Code H1-0002,3,4,5,6,7,8,10,11,13,16,17)

TITLE=H1 ANCESTOR IS 2

TITLE		B	F	F/B	G	M	M/G
H1	2 2	120	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 3

TITLE		B	F	F/B	G	M	M/G
H1	3 3	264	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 4

TITLE		B	F	F/B	G	M	M/G
H1	4 4	189	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 5

TITLE		B	F	F/B	G	M	M/G
H1	5 5	262	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 6

TITLE		B	F	F/B	G	M	M/G
H1	6 6	101	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 7

TITLE		B	F	F/B	G	M	M/G
H1	7 7	324	106	0.3272	106	3	0.0283
H1	71016	487	155	0.3183	120	0	0.0000
H1	71028	224	0	0.0000	0	0	0.0000
H1	71030	383	28	0.0731	20	0	0.0000

TITLE=H1 ANCESTOR IS 8

TITLE		B	F	F/B	G	M	M/G
H1	8 8	175	27	0.1543	27	0	0.0000

TITLE=H1 ANCESTOR IS 10

TITLE		B	F	F/B	G	M	M/G
H1	10 10	361	235	0.6510	235	6	0.0255
H1	101009	218	0	0.0000	0	0	0.0000
H1	101019	522	410	0.7854	410	3	0.0073
H1	101024	133	0	0.0000	0	0	0.0000
H1	101025	96	9	0.0938	9	0	0.0000
H1	101034	247	15	0.0607	12	0	0.0000
H1	101043	142	0	0.0000	0	0	0.0000

	B	F	F/B	G	M	M/G
H110182043	423	331	0.7825	330	0	0.0000
H110182045	253	149	0.5889	145	0	0.0000
H110182070	231	110	0.4762	110	0	0.0000

TITLE=H1 ANCESTOR IS 11

TITLE		B	F	F/B	G	M	M/G
H1	11 11	351	116	0.3305	116	5	0.0431
H1	111008	223	45	0.2018	45	0	0.0000
H1	111032	321	76	0.2368	71	0	0.0000
H1	111033	638	330	0.5172	330	1	0.0030
H1	111035	313	96	0.3067	96	0	0.0000
H1	111040	212	70	0.3302	70	0	0.0000
H110332057		281	2	0.0071	2	0	0.0000

TITLE=H1 ANCESTOR IS 13

TITLE		B	F	F/B	G	M	M/G
H1	13 13	305	135	0.4426	135	2	0.0148
H1	131037	431	366	0.8492	366	9	0.0246
H1	131049	278	34	0.1223	34	0	0.0000
H110372016		389	102	0.2622	102	0	0.0000
H110372017		183	110	0.6011	110	5	0.0455
H110372026		321	78	0.2430	78	0	0.0000
H110372027		471	373	0.7919	373	0	0.0000
H110372048		313	0	0.0000	0	0	0.0000
H110372058		115	0	0.0000	0	0	0.0000
H110372059		260	23	0.0885	23	0	0.0000
H110372071		319	174	0.5455	174	0	0.0000
H110372072		218	83	0.3807	83	0	0.0000
H120173014		160	23	0.1437	18	5	0.2778
H120173018		163	19	0.1166	19	0	0.0000
H120173019		300	230	0.7667	230	0	0.0000
H120173020		213	86	0.4038	86	0	0.0000
H120173021		728	313	0.4299	313	0	0.0000
H130144286		293	50	0.1706	50	0	0.0000
H130144012		132	56	0.4242	56	1	0.0179
H130144014		298	160	0.5369	160	0	0.0000
H130144015		148	29	0.1959	29	0	0.0000
H130144024		184	85	0.4620	85	0	0.0000
H140125035		346	76	0.2197	76	0	0.0000

TITLE=H1 ANCESTOR IS 16

TITLE		B	F	F/B	G	M	M/G
H1	16 16	308	0	0.0000	0	0	0.0000

TITLE=H1 ANCESTOR IS 17

TITLE		B	F	F/B	G	M	M/G
H1	17 17	214	0	0.0000	0	0	0.0000

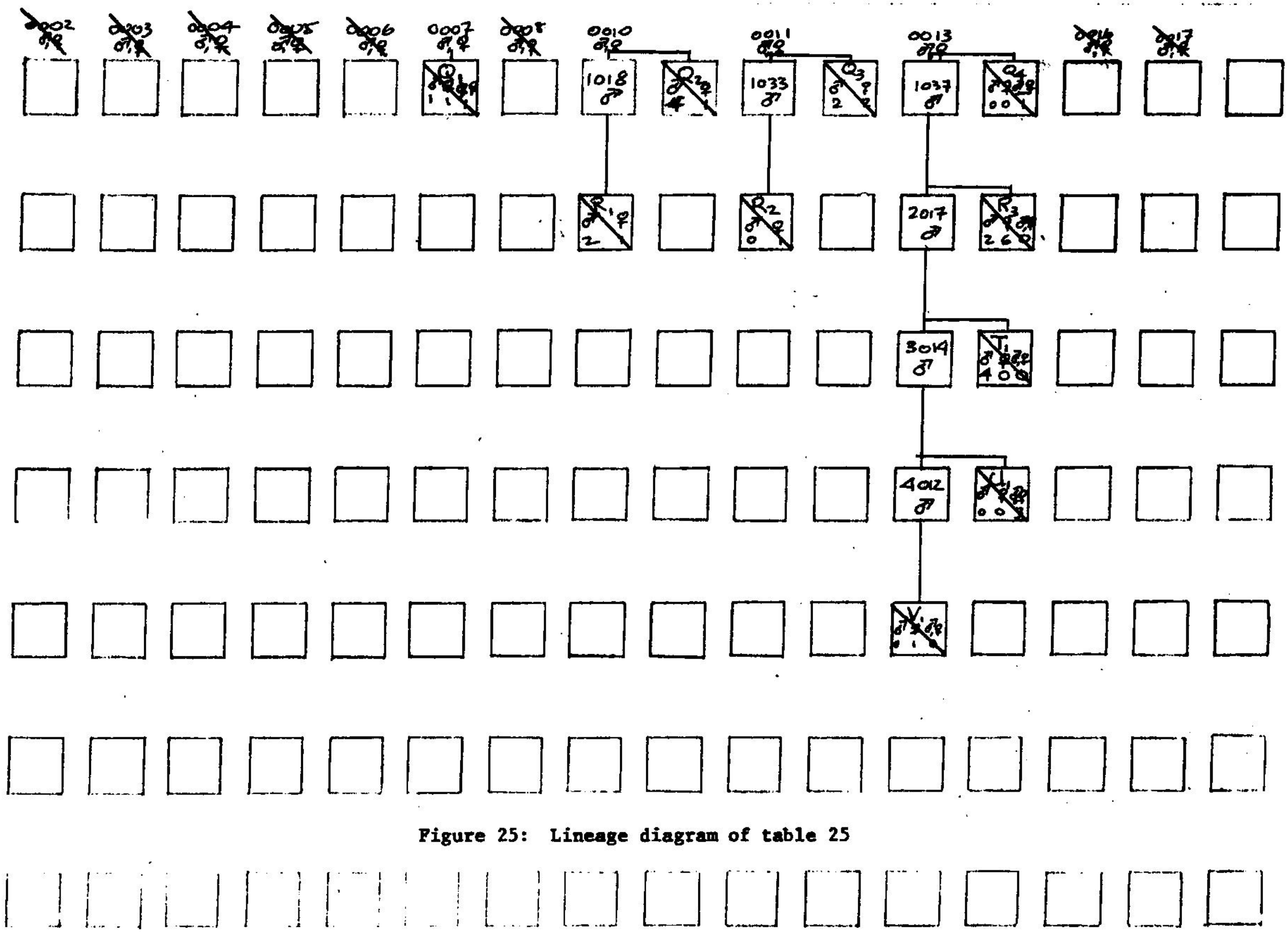


Figure 25: Lineage diagram of table 25

Table 26 IPS in *Nezara*

dose K_{rads}	No. inds. and sex irradiated	No. Fertile Eggs Laid	No. Fertile Eggs Hatched	% Egg Hatch	No. F_1 Adults Harvested
		P Generation Reproduction			
ck	9	659	276	72.5	200
1.5	9 F	121	20	50.0	10
7.5	6 F	298	62	20.8	0
15.0	9 F	563	8	1.4	0
		F_1 Generation Reproduction			
from 1.5 K_{rad} female	3 F[1]	163	44		5 F_2 adults reproducing currently: 2 M x 3 F siblings

1 siblings, 2 M and 3 F
2 still reproducing, all eggs not yet hatched, most appear to be fertile.

APPENDIX A

Appendix A
Diet Evaluations Report

Crianza de Nezara viridula (L.) en el Laboratorio
Rubén Restrepo-Mejía

Nezara viridula (L.) es un insecto de la familia Pentatomidae, cosmopolita y con amplio rango de plantas hospedantes, muchas de las cuales son cultivadas en gran escala. En algunos casos, este hemiptero se ha presentado como plaga importante, por lo cual ha sido objeto de la realización de trabajos en medidas de control. Una de estas ha sido la erradicación utilizando diferentes técnicas ya sean por químicos o por radiación. La utilización de estas medidas conlleva la disposición de gran cantidad de individuos.

Este trabajo en el Centro Nuclear de Puerto Rico bajo la dirección del Dr. David Walker tuvo por objeto desarrollar un método de crianza para N. viridula en condiciones de laboratorio, con miras a obtener una colonia suficientemente estable para proveer individuos en cantidades suficientes como para permitir estudios en relación con radiación y esterilización.

Se consideraron dos aspectos dentro del método de crianza: a) manutención y alimentación de los individuos, es decir cómo tratar y modo de suministrar los requerimientos nutritivos y b) evaluación de dietas artificiales líquidas. Se realizaron observaciones de actividad, preferencia y mortalidad.

Materiales y Métodos:

Se dispuso para este estudio de ninfas y adultos colectados en cultivos de habichuela y "cowpeas" de Mayaguez e Isabela. En condiciones de laboratorio a 23 $\pm$ 4°C y a 50 $\pm$ 20% de humedad relativa se procedió a separar las ninfas de los adultos, colocando en vasos de plástico de 4 onzas, 5 adultos o 10 ninfas. Cada vaso se cerró con una tapa plástica la cual tenía un agujero tapado con algodón para permitir el paso de aire y humedad. Como alimento se les suministró vainas de habichuelas tiernas.

Los anteriores recipientes tuvieron buen resultado con ninfas de ler, 2do. y 3er. instares, no así con adultos, por cuanto las excreciones de los insectos dieron fuerte olor y humedad al interior del vaso, afectando posiblemente la supervivencia. Por esta razón se ensayaron también recipientes de cartón parafinado ("ice cream cartons") de 1 galón, lo que permitió colocar de 10 a 30 individuos en cada uno. Se obtuvo mejor resultado, con menos mortalidad e interior del recipiente más limpio. Estos envases se usaron en todas las pruebas con dietas artificiales. Se taparon con tela de nylon o con "saran" sujetos con bandas de caucho.

Las dietas artificiales se pusieron en vasos plásticos de 1 onza, cerrados con tapa de cartón perforadas con el objeto de pasar un mecha de algodón absorvente ligeramente prensado y amarrado con hilo para evitar el esponjamiento de las mismas con el líquido. En lugar de las mechas de algodón se usaron también trozos alargados de esponja plástica ya colocados a través del agujero de las tapas, o impregnados con las dietas.

Las dietas se prepararon al momento de usarlas, utilizando los ingredientes preparados con anterioridad.

El extracto de vainas de habichuelas tiernas se preparó semanalmente, licuando las vainas de habichuelas, agregando un poco de agua destilada y filtrando de modo que se obtuviera un líquido sin partículas vegetales gruesas.

Cada 2 o 3 días a los insectos se les cambió el alimento ya fueran las vainas o las dietas líquidas; esto con el objeto de que dispusieran siempre de alimento fresco, evitando también la fermentación de las mismas.

Hay que anotar que las diferentes dietas a evaluar en las diferentes pruebas se prepararon siempre con el mismo extracto. La preparación de los extractos fué similar en todos los casos, utilizando la misma variedad de habichuelas, de tal modo que no hubo diferencias: "siempre el extracto tuvo igual preferencia por parte de las "chinches".

Durante las pruebas se mantuvieron individuos continuamente los que completaron su ciclo de vida en el laboratorio, usando vainas de "cowpeas" (Vigna sinensis). Se usaron las chinches de esta colonia para las diferentes pruebas con dietas artificiales, además de ninfas y adultos del campo.

Antes de iniciar cada prueba se pusieron los insectos que se iban a utilizar, a dieta de hambre, es decir sin alimento por 12 horas más o menos.

Los datos de ciclo de vida en el laboratorio se presentan en la tabla I.

Resultados:

Para la cría de N. viridula (L.) se descartaron los vasos plásticos de 4 onzas, considerando los factores mencionados anteriormente y el reducido espacio que se presentó especialmente para los adultos.

Los cartones de 1 galón cubiertos con tela de nylon fueron los más efectivos, siempre y cuando el número de individuos no excediera de 20. La temperatura parece que fué un factor importante en la cría de los insectos.

Las "mechas' de esponja plástica fueron muy adecuadas, siempre y cuando se mantuvieran un poco saturadas con las soluciones de dietas.

A. Pruebas Preliminares. Cuatro Dietas

1. Dieta de vainas de habichuelas tiernas.

Los insectos se alimentaron bien y completaron su ciclo hasta adultos; a pesar de la alta mortalidad en éstos hubo apareamiento y oviposición. No se obtuvieron nuevos individuos. En conclusión las vainas son adecuadas para alimentar los "chinches". Las causas de la alta mortalidad en adultos no se pudieron confirmar, sospechandose fué en parte la temperatura y humedad del laboratorio.

Las "chinches" aparentemente rechazaron el olor y el sabor.

B. Pruebas de Preferencia por: diferentes niveles de azúcar (Sucrosa)

1. Dietas Artificiales IV y V

Composición:	IV	V
Agua	20 cc	20 cc
Gerber "Baby Food Strained Beans"	10 gr	10 gr
Solución de Vitamina (Vanderzant)	2 cc	2 cc
Sucrosa	2 cc	5 cc

Estas dos dietas se evaluaron durante una semana en dos grupos de ninfas y adultos. Se utilizaron recipientes de cartón parafinado dentro de los cuales y en cada uno se colocaron los dos vasos con las dietas IV y V.

No hubo diferencias en esta prueba de preferencia. Los insectos se alimentaron bien y en ambas dietas.

C. Pruebas de Preferencia por Amino Acidos. Dieta Compuesta VII

Composición:

Extracto de vainas de habichuelas tiernas	60 cc
Solución de Vitaminas (Vanderzant)	3 cc
Sucrosa	6 gr
Acido Ascórbico	1 gr

5. Amino Acidos:

a) Glycina	6 gotas
b) Asparagina	" "
c) Isoleucina	" "
d) Alanina	" "
e) Arginina	" "
f) Fenilalanina	" "
g) Tyrosina	" "

Se probaron ocho dietas diferentes para preferencia a partir de la Dieta Compuesta VII:

Dieta No.

1. Todos los ingredientes, 1 a 5g inclusive.
2. Ingredientes 1 a 4 más 5a.
3. Ingredientes 1 a 4 más 5b.
4. Ingredientes 1 a 4 más 5c.
5. Ingredientes 1 a 4 más 5d.
6. Ingredientes 1 a 4 más 5e.
7. Ingredientes 1 a 4 más 5f.
8. Ingredientes 1 a 4 más 5g.

Para esta prueba se usaron ocho "cartones" de 1 galón. Dentro de cada recipiente se colocaron las ocho diferentes dietas. Inicialmente se introdujeron de 10 a 15 individuos por cartón. Posteriormente para facilitar las lecturas se redujo el número a 5 individuos por cartón y se aumentó el número de cartones.

Se hicieron lecturas durante 2 a 2 y media semanas, anotando cuántos individuos estaban alimentándose sobre cada una de las dietas. Las observaciones se realizaron por un mínimo de 2 diarias.

Los individuos adultos utilizados en estas pruebas, vinieron de ninfas criadas en el laboratorio con vainas de habichuelas tiernas y antes de iniciar la prueba se les suprimió todo alimento por un tiempo de 12 horas aproximadamente.

Las diferentes dietas alimentaron satisfactoriamente a los insectos. Estos produjeron gran cantidad de excreciones líquidas. No hubo aumento significativo en la producción de huevos a pesar de que se apareaban.

En conclusión podemos decir que todos los amino ácidos presentaron igual preferencia. Un amino ácido específico en las concentraciones usadas no fué significativamente diferente individualmente o en combinación.

D. Pruebas para preferencia por diferentes dietas artificiales

Se probó preferencia por viaras de las dietas usadas anteriormente, tratando de comparar con la dieta VII.

Se utilizaron siete "cartones" de a galón. En cada uno se colocaron las siete diferentes dietas.

Las dietas probadas fueron: I, II, III, V, VI, VII y una dieta con la siguiente composición:

Extracto de vainas de habichuelas tiernas	30 cc
Sucrosa	5 cc
Solución de Vitamina (Venderzant)	3 cc

Se utilizaron adultos provenientes de ninfas colectadas en el campo y criadas en el laboratorio y ninfas de tercer instar provenientes de huevos ovipositados en el laboratorio por adultos provenientes de ninfas del campo. Esta prueba se hizo por un periodo de dos semanas al cabo del cual las conclusiones fueron:

a) El ingrediente más atractivo fué el extracto:
b) La dieta VII fué más satisfactoria que la I, II, III, V y VI y la de composición dada en esta parte;
c) La producción de huevos fué bastante reducida y fueron o infértiles o no se desarrolló el embrión.

Los nuevos fueron depositados tanto en el cartón como en la tela de nylon; nunca en el "sarán". No se obtuvieron nuevos individuos: se presentó ovofagia por parte de los adultos.

2. Dieta Artificial I

Composición:

Agua destilada	30 cc
Azúcar (Sucrosa)	1.5 gr
Solución de Vitamina (Venderzant)	2 cc

Con esta dieta las ninfas no sobrevivieron para completar el ciclo biológico. Los adultos presentaron alta mortalidad; las hembras fertilizadas no ovipositaron.

Característico de esta dieta y todas las líquidas fué la abundante excreción líquida de los insectos.

Esta dieta no fué aceptable para proveer los requerimientos nutritivos de los insectos.

3. Dieta Artificial II

Composición:

Agua destilada	20 cc
Gerber "Baby Food Strained Beans"	10 gr
Sucrosa	5 gr

Los adultos y ninfas sobrevivieron por una semana más que con la dieta anterior (o sea 3 semanas a partir de la iniciación de la prueba). Los adultos se aparearon; no hubo oviposición.

Al cabo de 3 semanas los adultos perecieron.

4. Dieta Artificial III

Composición:

"Corn Hidrolizate" (NBC)	2 cc
Sucrosa	5 grs
Solución de Vitamina (Vanderzant)	3 cc
Acido Ascórbico	1 gr
Extracto de vaina de habichuelas tiernas	30 cc
Agua	20 cc

Esta dieta se acidificó con HCl a un pH de 5, similar al del jugo de las vainas de habichuela.

Esta dieta fué poco atrayente; los insectos demoraban en gustarla y no permanecían mucho tiempo alimentándose sobre ella. El "corn hidrolizate dió a la dieta un fuerte olor a maíz y se fermentó con frecuencia.

Conclusiones Generales:

1. Esta especie completa su ciclo de vida alimentandose sólo de vainas de habichuelas tiernas, pero la producción de huevos es baja;

2. las dietas a base de extracto de vainas de habichuelas fueron más atractivas que cualquier otra sin extracto;

3. la sucrosa actuó como estimulante y atrayente;

4. los amino ácidos en conjunto o individualmente no obraron ni como estimulantes ni como atrayentes de acuerdo a las concentraciones usadas (0.0015%/150 mgrs/10 grs de H_2O).

Tabla 1 - Ciclo de vida de Nezara viridula (L.) en el laboratorio a 70±10°F y a 50±20% de humedad relativa, alimentados con vainas de habichuelas tiernas

Periodo	Tiempo promedio en días de cada periodo	Tiempo promedio en días desde la postura	Tiempo promedio en días desde la eclosión
Incubación	6	6	
ler Instar	5	11	5
IIdo Instar	7	18	12
IIIer Instar	6	24	18
IVto Instar	6	30	24
Vto Instar	8	38	32
Adulto			