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Sex Linkage in *Drosophila melanogaster* Male Wild Type (N) x Female *Miniature* (*m*) Strains

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Abstract
Introduction: *The existence of sex links was first discovered by T. H. Morgan and C. B. Bridger in 1910. He found the existence of derivatives that are not in accordance with Mendel's concept.* ***Objective:*** *This study used Drosophila melanogaster with N (wild type) and m (miniature) strains. The crosses performed are ♀N><♂m and its reciprocal. The results of the cross will be observed regarding the phenotype of the F1 offspring until the resulting F2 is obtained.* ***Method:*** *This research is quantitative descriptive research. Data collection was done by direct observation. The data collected are sex and phenotype of Drosophila melanogaster strain N (normal) and strain m (miniature) for 7 consecutive days. Data analysis used was through comparison of cross reconstruction and chi square test.* ***Result and Discussion****: The crossing ratio obtained from the F1 cross ♀N >< ♂m with the result of ♀N and ♂N pups respectively are 1:1 after crossing with each other obtained ♀N, ♂N, ♂m pups with a ratio of 1.1:1, 8:1 respectively. While the reciprocal of the F1 cross ♀m >< ♂N with ♀N and ♂m pups is 1:1 after crossing each other, we get ♀N, ♂N, ♀m, ♂m pups with a ratio of 1.2:1, 2:1:1 respectively* ***Conclusions:*** *Sex Linking Phenomenon occurred in F2 of ♀m x ♂N cross.*

Keywords: Sex Linkage; Drosophila melanogaster; Criss Cross Inheritance; Genetics

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Introduction

Genetics is the science of heredity and variation, which includes the concepts of genes, DNA, and chromosomes; the relationship between gene polypeptides (DNA)-RNA with the process of protein synthesis; the relationship between the process of mitotic division and meiosis heredity; the principle of heredity in the mechanism of inheritance of traits and mutation events and their consequences (Snustad & Simmons, 2015)

Drosophila melanogaster (fruit fly) is a type of fruit fly commonly found on fruit and is often used as a subject in genetic experiments because of its very fast life cycle (Snustad & Simmons, 2015). In addition, these flies are so fertile that a single female can produce hundreds of fertilized eggs in a short period of time (Snustad & Simmons, 2015). *Drosophila melanogaster* is an easily reproducing insect (Nainu, 2018). A single mating can produce hundreds of offspring, and a new generation can form every two weeks. These characterizations suggest that fruit flies are suitable organisms for genetic research (Campbell, Reece, & Mitchell, 2021)

It is generally known that there are factors that cause sex linkage to occur such as how many of the same chromosomes tend to be linked to each other during the reduction division in meiosis and these factors are said to form a linkage. Sex linkage occurs when genes located on the sex chromosomes, the X and Y chromosomes, determine the inheritance of certain traits from parents to offspring. In general, the X chromosome contains more genes than the Y chromosome. Therefore, genes located on the X chromosome tend to be associated with sex linkage more often than genes located on the Y chromosome (Isen, Gaspari, & Baker, 2020). Linkage is a normal occurrence, as factors on a single chromosome are linked to each other (through chemical bonds). It is also clear that the number of links in diploid living things is as many as the number of chromosome pairs (Natsir, 2020)

The existence of sex links was first discovered by T. H. Morgan and C. B. Bridger in 1910. When these findings were obtained were studying deviations from the expected results (circumstances) by. T. H. Morgan had a strain of *Drosophila melanogaster* that had white eyes, so it was classified as a pure strain. However, it turns out that the results obtained if the white-eyed strain is crossed with a red strain produces derivatives that are not in accordance with Mendel's concept (Old & Primrose, 2003)

To prove the existence of the linking phenomenon as described above, we conducted an experiment using *Drosophila melanogaster* fruit flies with normal strains and *miniature* strains that have undergone mutations in the wings. The rationale for this experiment was based on T.H. Morgan's experiment involving *Drosophila melanogaster* with mutations on the gonosomal X chromosome, but at a different locus than the model tested. In this research project, *Drosophila melanogaster* strains N and m were used. The crosses performed on these strains are ♀N><♂m and their reciprocals. The results of the cross will be observed regarding the phenotype of the F1 offspring until the resulting F2 is obtained. Based on this background, this study took the title “Sex Linkage Event of *Drosophila melanogaster* crossing strain ♀N >< ♂m and its Reciprocal”.

This study aims to determine the phenotypes and F1 and F2 ratios of *Drosophila melanogaster* crosses of the ♀N><♂m strain and its reciprocals and to determine whether there is a sex linking phenomenon in the crosses.

Method

This study is a quantitative descriptive study that aims to determine the results of the ratio of F1 and F2 and the number of pups in the cross of *Drosophila melanogaster* wild type strain (N) and *miniature* strain (m) and its reciprocal. Crosses were conducted nine times to determine whether there is a sex linking phenomenon that occurs in this cross. Variables that will be used in this study include a) Dependent Variable: sex of *Drosophila melanogaster* crosses. b) Independent Variable: *Drosophila melanogaster* wild type strain (N) and *miniature* strain (m), c) Control Variables: media environment and media type.

The research was conducted in the genetics laboratory of the Faculty of Mathematics and Natural Sciences, State University of Malang, from February to May 2023. The population used in this study was *Drosophila melanogaster*. While the samples used were *Drosophila melanogaster* strain N (normal) and *miniature* strain (m). The equipment used were

Table 1

Tools and their Functions

Tools	Function
Stereo microscope	Identify types of fruit fly strains through observation
Plastic	Containers for placing strains when identifying
Jam bottle	As a container to place the fly breeding process
Brush	Cleaning the hose and pushing the banana medium during bagging
Cotton buds	Picking up pupae during bagging
Scales	Weighing the materials used as medium
Gas stove	Cooking medium
Knife	Cutting medium making materials
Cardboard	Container for placing bottles of observed strains
Blender	Blending the medium ingredients
Hose	As a place for bagging
Gauze	As a hose baffle when sanding
Pot	Container when cooking medium
Stirrer	Stirring the medium
Sponge	Cover for strain bottles
Tissue	Cleaning the bottle from medium residue
Label paper	Marking (name) the observation bottle
Scissors/cutter	Cutting the sponge
Pupation paper	As a home / shelter for flies when breeding

Table 2

Materials and their Functions

Material	Function
Fermipan	Increases the content of nutrients that are good for the growth of fruit flies
Banana rajamala	Medium and sanding ingredients
Brown sugar	Medium ingredients
Cassava tapai	Medium ingredients
Water	Medium preparation solvent
Stock of *Drosophila melanogaster* strain N (normal) and strain *miniature* (*m*)	Supplies used for rejuvenation

Data collection was done by direct observation. Data collected in the form of sex and phenotype of *Drosophila melanogaster* strain N (normal) and strain m (*miniature*) crosses for 7 consecutive days.

The data analysis used was through comparison of cross reconstruction and chi square test to test the relationship between the occurrence of the linking phenomenon with phenotypes and the ratio of the number of pups in crosses of *Drosophila melanogaster* strain N (normal) and strain m (*miniature*), and its relation to the phenomenon of criss cross pattern of inheritance.

Research and Discussions

Result

The subjects used in the observation of this sex-linking phenomenon are using *Drosophila melanogaster* wild type (N) and *miniature* strains (m). The wild type (N) strain can be observed with the characteristics of having red eye colour, slightly elliptical round compound eyes and a single eye on the top of the head, brownish yellow body color with a black ring on the back of the body, having fairly long and transparent wings, the position of the wings starts from the thorax, the wing margin vein has two parts that are interrupted close to the body (Markow & O’Grady, 2005). The thorax has bristles, both long and short with a five-segmented abdomen and black stripes as in Figure 1.

Figure 1 *Drosophila melanogaster* wild type strain (N)

Source: Personal Documentation, (2022)

The *miniature* strain (*m*) can be observed with the same characteristics as the wild type (N) strain, namely having red, slightly elliptical compound eyes and a single eye on the top of the head, having a brownish yellow body color with a black ring on the back and having a long and short *bristle*, on the thorax with five segments and black stripes. The location of the mutation in this strain is a shorter wing that does not exceed the length of the abdominal body as shown in Figure 1

Figure 2 *Drosophila melanogaster* strain *miniature* (*m*)
Source: Personal Documentation, (2022)

The difference between the two strains is that the wings of the *miniature* strain are shorter without passing through the abdomen. This is a mutation in the first pair of alleles on the X chromosome at locus 36.1. Based on observations and calculations on the crossing culture of *Drosophila melanogaster* wild type strain (N) and *miniature* (*m*), the following data were obtained:

Table 3
Data of F1 crosses ♀N x ♂*m***:**

Cross	F	Gender	Total
♀N x ♂*m*	N	♀	133
	N	♂	130
	m	♀	0
	m	♂	0

Note: this data is a summary of the table data in appendix 2.

Table 4

Data from F2 crosses ♀N x ♂*m*:

Cross	F	Gender	Total
♀N x ♂N	N	♀	59
	N	♂	94
	m	♀	0
	m	♂	53

Note: this data is a summary of the table data in appendix 2

Table 5

Data of F1 crosses ♀*m*x ♂N:

Crosses	F	Gender	Total
♀*m*x ♂N	N	♀	98
	N	♂	0
	m	♀	1
	m	♂	99

Note: this data is a summary of the table data in appendix 2

Table 6

Data from F2 crosses ♀*m* x ♂N:

Cross	F	Gender	Total
♀N x ♂*m*	N	♀	61
	N	♂	59
	m	♀	49
	m	♂	51

Note: this data is a summary of the table data in appendix 2

Tabel 7

Chi-Square Result Test

Crosses	Asymptotic Significance Value (2-sided)	Chi-Square Table Value	Calculated Chi-Square Value
F1 ♀N x ♂*m*	0,157	2.773	2.000
F2 ♀N x ♂N	0,199	6.592	6.000
F1 ♀*m* x ♂N	0,199	6592	6.000
F2 ♀*m* x ♂N	0,213	11.090	12.000

Drosophila melanogaster cross P1 ♀N x ♂m produces ♀N and ♂N pups with a ratio of the number of ♀N as much as 133 and ♂N as much as 130, the ratio obtained is 1:1 which according to the reconstruction is 1: 1 according to the theory that the closer the ratio, the more valid the data. Then the pups from P1 will be crossed with each other to become P2. In addition, even though it is in accordance with the reconstruction ratio, according to the Chi-Square test results, the results obtained are Chi-Square count < Chi-Square Table with a 2-sided asymptotic significance value of 0.157.

The *Drosophila melanogaster* P2 ♀N x ♂N cross produced ♀N, ♂N, ♀m, and ♂m pups with a ratio of ♀N of 59, ♂N of 94, and ♀m of 53, the ratio obtained was 1.1: 1,8 : 1 where according to the reconstruction is 1:2:1 according to the theory the closer to the comparison, the more valid the data. In addition, even though it is in accordance with the reconstruction ratio, according to the results of the Chi-Square test, the results obtained are Chi-Square calculated < Chi-Square Table with a 2-sided asymptotic significance value of 0.199.

The cross of *Drosophila melanogaster* P1 ♀m x ♂N produces ♀N, ♀m, and ♂m pups with a ratio of the number of ♀N as 98, ♀m as 1 and ♂mas 99, the ratio obtained is 1:1 which according to the reconstruction is 1: 1 according to the theory the closer to the comparison, the more valid the data. Then the pups from P1 will be crossed with each other to become P2, based on the reconstruction results there should be no ♀m pups. We assume this can happen because there is an error in fly identification, besides that even though it is in accordance with the reconstruction ratio, according to the Chi-Square test results obtained are Chi-Square count < Chi-Square Table with a 2-sided asymptotic significance value of 0.199.

The *Drosophila melanogaster* P2 ♀N x ♂m cross produced ♀N, ♂N, ♀m, and ♂m pups with a ratio of ♀N of 61, ♂N of 59, ♀m of 49 and ♂m of 51, the ratio obtained was 1.2: 1,2 : 1 : 1 where according to the reconstruction is 1:1:1:1 according to the theory the closer to the comparison, the more valid the data. In addition, even though it is in accordance with the reconstruction ratio, according to the Chi-Square test results, the results obtained are Chi-Square count > Chi-Square Table with a 2-sided asymptotic significance value of 0.213.

Discussion

1. The F1 Phenotype in Crosses of ♂N><♀m and its Reciprocals

Based on the observation of phenotypes of crossing normal male strain (♂N) with female *miniature* strain (♀m), F1 offspring produced normal females (♀N) and *miniature* males (♂m) as well as in the phenotype of *miniature* males (♂m) obtained from the traits of their female parent (♀m). This is because the wing trait *miniature* is controlled by the X chromosome factor. This event is related to the theory of cross inheritance (Criss cross inheritance), where all male offspring traits are derived from the female parent, while the male parent trait X will be given to all female offspring (Natsir, 2020)

The occurrence of the sex-linking phenomenon is evidenced by the results of the reciprocal cross ♀N>< ♂m which obtained F1 phenotypes are all normal for both males and females. The male offspring obtained the normal wing trait from the female parent (♀N) while the male parent *miniature* (♂m) gave the wing trait to the female offspring. This event is in accordance with the reconstruction of sex chromosome linkage crosses, where the results of the reciprocal crosses are different. This shows as a marker of sex linkage and in accordance with the scientist T.H. Morgan in 1910 mentioned that genes associated with inheritance, sex linked located on the X chromosome (Snustad & Simmons, 2015)

Criss cross pattern of inheritance is a cross inheritance where phenotypic characteristics present in the female parent are inherited and expressed in the male offspring and in the male parent are inherited (not expressed) through the female offspring F2 male offspring and expressed (Old & Primrose, 2003), (Effendi & Rumah, 2020). This is in accordance with the results of the experiments we have done, where when the female normal strain is crossed with the male *miniature*, the results of F1 all have normal strains if the normal factor is dominant to the factor *miniature*.

2. F2 Phenotype of F1 Peer Cross Results

The X-sex linkage trait can be seen in F1 (♀N *x* ♂N) produced from parent (♀N *x* ♂m), it was found that the F2 offspring, ♀N, ♂N, ♂m, where the trait *miniature* is always male, did not obtain female offspring *miniature* (♀m). These results prove the existence of sex linkage indicated by the non-appearance of *miniature* females (♀m), which resulted because the normal male parent (♂N) of F1 did not contain the *miniature* gene. However, in the experiments conducted, the number of pups obtained did not match the theoretical ratio. The genotype ratio obtained in the cross ♀N *x* ♂N was 1.1: 1,8: 1, while theoretically, the ratio shown is 1: 2: 1. There is a slight difference shown in the ratio obtained with the theoretical ratio. This is thought to be caused by external factors that also affect it, such as ticks and fungi.

The presence of ticks has always been considered a parasite because they can disrupt the survival of Drosophila through the larvae and pupae they consume (Michalska, Mrowi ska, & Studnicki, 2023). Dihybrid crosses with a ratio of 1: 2: 1 is only a theoretical calculation, so the data obtained in the actual experiment is not always the same as the ratio, but the closer the value of the actual ratio to the theoretical ratio, the data used shows the more perfect data (Firdaushi, 2014). This statement proves that the data is close to perfect because of the closeness of the ratio of reality to theory. However, according to the results of the Chi-Square test, the results obtained in both F1 and F2 results in this treatment are Chi-Square count & Chi-Square Table with 2-sided asymptotic significance values of 0.157 and 0.199. The data shows that H0 is accepted, H1 is rejected, which means there is no effect of crossing type on the phenomenon of sex linking in *Drosophila melanogaster*.

The observation of the reciprocal cross showed that the result of the cross (♀m *x* ♂N) obtained F1 offspring ♂m with short wing phenotype (*miniature*) and ♀N with long wing phenotype (normal heterozygous). However, according to the results of the Chi-Square test, the result obtained is the calculated Chi-Square, Chi-Square Table with a 2-sided asymptotic significance value of 0.199, which also indicates that H0 is accepted, H1 is rejected. The results obtained based on this experiment also prove that there is no effect of crossing type on the phenomenon of sex linking in *Drosophila melanogaster*. In addition, the F1 results are different from F1 in the cross ♀N *x* ♂m. The difference in the result of the pups is in the short-winged male individuals (*miniature*), which is caused by a recessive gene on the X chromosome carried by the parental female. After crossing by each other, the F2 offspring are: ♀N, ♀m, ♂N, ♂m which means all the traits appear in the cross. This is because the wing is attached to the X sex chromosome while the Y chromosome does not contain factors for the wing (Old & Primrose, 2003). In addition, this phenomenon has proven the occurrence of cross inheritance (criss cross inheritance).

In the F2 results obtained in this reciprocity, the apparent ratio was 1.2: 1,2: 1: 1, which theoretically, the ratio should be 1: 1: 1: 1. In addition, after the chi-square analysis test, it was found that the calculated Chi-Square, Chi-Square Table with a 2-sided asymptotic significance value of 0.213. This result means that H0 is rejected, H1 is accepted, which means that there is one type of cross that affects the phenomenon of sex linking in *Drosophila melanogaster* in this experiment. According to T. H. Morgan, the crossing data can be explained if the first wing condition factor on the X chromosome and the second male sex chromosome Y do not contain the wing condition factor.

Female individuals in *Drosophila melanogaster* have two identical X sex chromosomes (Aurora & Susilawati, 2020). In contrast to male individuals who only have XY sex chromosomes. Female individuals of *Drosophila melanogaster* inherit one X sex chromosome from the male parent, and another X sex chromosome from the female parent while males of the XY sex chromosome. The X chromosome is passed on to female offspring and the Y chromosome is passed on to male offspring. Traits controlled from factors located on the X sex chromosome will experience cross inheritance, so that male individuals will pass the trait to male grandchildren through their female offspring (children) and will not pass through male offspring (children).

In T.H. Morgan's theory, it can be concluded that in addition to the eye color factor in the *Drosophila melanogaster* experiment that has been carried out, there are also factors of normal wing condition and *miniature* which prove the occurrence of sex linkage adrift in the X sex chromosome. According to (Ayala & Kiger, 1984) mentioned that the pattern of sex-linked inheritance in *Drosophila melanogaster* is also found in all animals and plants in heterogametic male individuals. Based on the observation of phenotypes of crossing normal male strain (♂N) with female *miniature* strain (♀m), F1 offspring produced normal females (♀N) and *miniature* males (♂m) as well as in the phenotype of *miniature* males (♂m) obtained from the traits of their female parent (♀m). This is because the wing trait *miniature* is controlled by the X chromosome factor.

This event is related to the theory of cross inheritance (Criss cross inheritance), where all male offspring traits are derived from the female parent, while the male parent trait X will be given to all female offspring (Natsir, 2020). The occurrence of the sex-linking phenomenon is evidenced by the results of the reciprocal cross ♀N>< ♂m which obtained F1 phenotypes are all normal for both males and females. The male offspring obtained the normal wing trait from the female parent (♀N) while the male parent *miniature* (♂m) gave the wing trait to the female offspring. This event is in accordance with the reconstruction of sex chromosome linkage crosses, where the results of the reciprocal crosses are different. This shows as a marker of sex linkage and in accordance with the scientist T.H. Morgan in 1910 mentioned that genes associated with inheritance, sex linked located on the X chromosome (Snustad & Simmons, 2015)

Criss cross pattern of inheritance is a cross inheritance where phenotypic characteristics present in the female parent are inherited and expressed in the male offspring and in the male parent are inherited (not expressed) through the female offspring F2 male offspring and expressed (Old & Primrose, 2003). This is in accordance with the results of the experiments we have done, where when the female normal strain is crossed with the male *miniature*, the results of F1 all have normal strains if the normal factor is dominant to the factor *miniature*.

3. Comparison of Sex Linkage with Mendel's Law

The results of the reconstruction of the cross ♀N >< ♂m obtained that all the phenotypes of the offspring were normal, both males and females. Based on the results of the F1, crossing with each other, namely ♀N >< ♂N from the parent ♀N x ♂m, to obtain the results of the F2 comparison, namely 2 normal females: 1 normal male: 1 male *miniature*. The F2 results show that there is a deviation from Mendel's Law. This occurs because in F1 crosses, the female carries a mutant gene that has a heterozygous normal genotype. This genotype undergoes sex-linking which is passed on to some male offspring.

In the reciprocal cross, ♂N>< ♀m, the pups were the opposite of their parents, ♀N>< ♂m. The result of the F1 cross was obtained in a ratio of 1:1, which is also a deviation of Mendel's Law, which should be based on Mendel's Law, cross reconstruction will produce 100% normal offspring. Then, after obtaining the results of F1, crossing with each other is done to obtain F2 offspring. The results of the F2 cross resulted in a phenotype comparison, namely 1 ♀N: 1 ♂N: 1 ♀m: 1 ♂m. The offspring obtained based on the F2 cross also shows that there is a deviation of Mendel's Law. If adjusted to Mendel's Law, the offspring that appear should be 3 normal: 1 *miniature*. The deviation to Mendel's Law occurred in this experiment because the wing (*miniature*) is linked to the sex chromosome (gonosome) on chromosome number 1, locus 36.1. The term sex-linked or sexed refers to characteristics (or traits) influenced by genes carried on the sex chromosomes, which generally often refers to traits or disorders influenced by the X chromosome, as it contains more genes than the smaller Y chromosome.

Males or males who have only one copy of the X chromosome are more likely to be affected by sex-linked disorders than females or females, who have two copies (Bilkis, Khan, Rahman, & Uddin, 2013). Sex-linked inheritance is said to be an example of non-mendelian inheritance for several reasons, including

1. Any pattern of heredity in which any trait cannot be separated according to Mendel's Law is known as non-Mendelian inheritance.
2. Mendelian inheritance will be seen in autosomal traits, while non-Mendelian inheritance will be seen in sex-linked traits.
3. Sex-linked traits are controlled by genes found exclusively on the X chromosome and there is no corresponding allele on the Y chromosome, the characters are sex-linked characters. Therefore, it is said to deviate from Mendel's Law.

4. Criss cross dan non-criss cross inheritance

The inheritance pattern of the mutation that occurred in this experiment belongs to the cross-inheritance pattern or also known as criss cross inheritance. This character shows that the trait on the mother's X chromosome will be inherited by the son, while the trait on the father's X chromosome will be inherited (but not always expressed) by the daughter. This is because females have two X chromosomes. This characteristic cross pattern (criss cross inheritance) is typical of the inheritance of genes strung on the X chromosome (Mitiku, Tolera, & Tolesa, 2020)

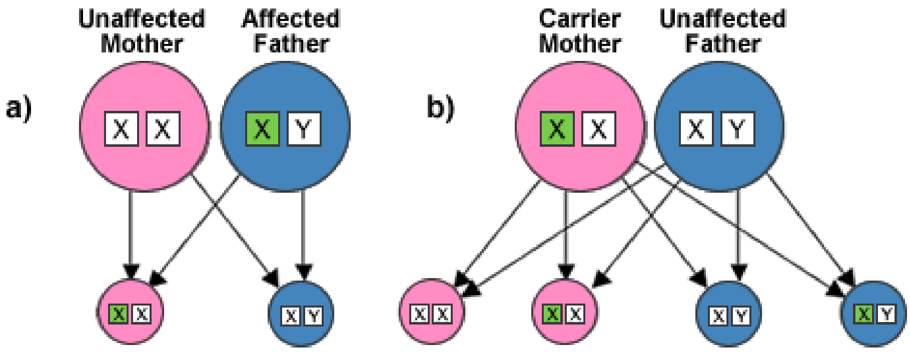

Figure 3 Criss Cross Inheritance
Source: Kaur, R. (2017)

In natural selection, variation in individual traits can provide a survival advantage during environmental changes. In addition, criss cross inheritance is a phenomenon in which recessive traits linked to the mother's sex chromosome will be inherited in sons, while characteristics dominated by alleles from the father will be shown by daughters (Morgan, 1922). traits encoded by genes on the X chromosome exhibit X-linked inheritance. When a female carries two recessive X-linked alleles and is crossed with a wild-type male, the male's Y chromosome acts as a null allele.

This results in the recessive alleles of the female parent always being expressed in the male offspring, but the female offspring receiving only one wild-type allele from the father. Females have two X chromosomes and males have one X chromosome and one Y chromosome. Mutations on the X chromosome in females can be hidden by a normal allele on the other X chromosome, whereas mutations on the X chromosome in males are more likely to cause observable biological abnormalities, as there is no normal X chromosome to compensate. Trait variation caused by mutations on the X chromosome is called X-linked (Bruce, 1983). According to (Morgan, 1922) in *Drosophila melanogaster*, non-criss cross inheritance occurs when recessive sex-linked characters are inherited by mothers in daughters and dominating paternal allelomorphic characters are inherited in sons. This phenomenon can be explained by the assumption that the two X chromosomes in the mother bind and behave as one body. Whereas in sex-linked inheritance (criss cross inheritance), recessive sex-linked maternal traits are transmitted to sons, and daughters show dominating paternal allelomorphic characters.

In a study conducted by reconstructing a cross between a normal strain and a *miniature* strain, different results were obtained from the two crosses performed. The cross between ♀N><♂m showed a criss cross event in the F2 cross, where a m male was produced in the F2, but all the offspring were normal in the F1. The concept of criss cross is proven to occur in this cross, where males will pass on their traits to female offspring and females will pass on their traits to male offspring. In addition to the criss cross event, in this cross there was a non-criss cross event, namely in this F1 all the pups produced were normal, namely ♀N > < ♂N. It was concluded that ♀N continued to inherit the ♀N trait and in F2 also inherited the ♀N trait. On the other hand, in the reciprocal cross between ♂N >< ♀m, ♀N >< ♂m for F1, and 1 ♀N 1 ♂N: 1 ♀m: 1 ♂m for F2, which can prove that all of them experienced a criss cross event.

Conclusion

Based on the research data obtained, the results of the cross (♀N >< ♂m) obtained F1 offspring namely ♀N and ♂N which after crossing between each other obtained F2 offspring in the form of ♂N, ♀ N, ♂m. In reciprocal crosses, namely (♀m ><♂N), the offspring obtained are the opposite of their parents, namely ♀N and ♂m. Then, after crossing with each other. Then, the P2 pups were ♀N, ♂N, ♀m, ♂m.

The crossing ratio obtained from the F1 cross ♀N >< ♂m with the result of ♀N and ♂N pups respectively is 1:1 after crossing with each other obtained ♀N, ♂N, ♂m pups with a ratio of 1.1:1.8:1 respectively. While the reciprocal of the F1 cross ♀m >< ♂N with ♀N and ♂m pups is 1:1 after crossing each other, we get ♀N, ♂N, ♀m, ♂m pups with a ratio of 1.2:1, 2:1:1 respectively. Sex Linking Phenomenon in F2 cross of ♀m x ♂N

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