Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 4 ~ Issue 2 (2016) pp: 01-10
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

The Effect of Dark Condition on the Fecundity and Development Time of *Drosophila melanogaster*, Strains of *Wild Type*, *White*, and *Ebony* for Several Generations

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Received 09 August, 2016; **A**ccepted 13 August, 2016 © The author(s) 2014. **P**ublished with open access at **www.questjournals.org**

ABSTRACT: *Daily light condition change is believed to disrupt the synchronization of circadian time, and it has been reported to affect a number of determinant characters related to fitness of Drosophila melanogaster. This research was conducted to investigate the effect of dark condition on fecundity and development time of D. melanogaster strains of wild type, white, and ebony for several generations. Fecundity and development time of D. melanogaster in dark conditions (DD) and normal light conditions (12:12h/LD) were recorded. The results showed that D. melanogaster treated in DD conditions had lower fecundity (18.19%), and faster development time (2.61%) compared to that in LD conditions. The results of the comparison among the strains also showed that the wild type strain had higher fecundity and faster development time than the white and ebony strains. Fecundity of white and ebony strains decreased 17.45% and 20.31% respectively; while the development time of white and ebony strains became slower 6.49% and 4.87% respectively than that of the wild type strain. The interaction between light conditions and generation and the interaction between light, strains, and generation also affected fecundity and development time. Fecundity of white and ebony strain was lower in DD conditions in generations 1 and increased by 226% and 112% respectively in the 2nd generation. The fecundity of these strains in DD conditions in the 3rd generation was not significantly different; while fecundity of wild type strain did not differ significantly either on the light conditions or between the different generations. On the other hand, wild type strain development time was faster in DD conditions in generation 1 and became slower and significantly different in the 3rd generation (slower 27.92% than that of generation 1). The development time of white and ebony strains across generations in DD conditions was not significantly different. This suggests that factors such as the condition of light and generation had more effect on the fecundity of both mutant strains than on wild type strains. Conversely, these two factors had more effect on the development time of wild type strain than that of the two mutant strains.*

Keywords: *Dark conditions, development time, Drosophila melanogater, fecundity, white strain*

I. INTRODUCTION

Light is an important environmental factors having significant effect on the life of organisms [1]. Some components of light such as the wavelength, intensity, and periodicity or the length of the day are factors that can affect the physiological and behavioral processes [2,3]. One important role of light in the lives of many organisms is associated with the function of light related to a period of dark/day light. In this case, light is used as the primary environment signal in the timing of circadian [4], that is the setting system of the internal time used by organisms to regulate their physiological processes and behaviors in order that it occurs at the right time [5-7].

Several previous researches showed that the organisms can live better if placed in similar conditions with their daily periods of dark/light [8,9]. In contrast, the changes in the daily light conditions might cause disturbance of the synchronization of various physiological and behavioral processes, so that it would affect the fitness of the organisms. In Drosophila, the results of the previous researches showed that the changing of daily light conditions had an effect on fertility, fecundity, longevity, and the development time [10-14]. In line with these reports, Lone and Sharma [15] reported that the light conditions also had an effect on the size of the nest, egg viability and development time prior to the adult stage of two sympatric species of ants.

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Fecundity is an important component of fitness because it relates directly to the reproductive success of the organisms [16]. The fecundity of the female is known not only influenced by factors such as genetic circumstances, body size, age, and married couples [17], but also influenced by external environmental factors such as light conditions. Fecundity of *D. melanogaster* is higher in normal light condition *(*light-dark change/LD 12: 12h), drastically reduced in the continuous light (LL) and continuous dark condition (DD) [13]. On the other Drosophila species, namely *D. agumbensis* and *D. nagarholensis*, the female fecundity is also known to be higher in LD conditions than the other two light conditions [14].

Development time is another important character that can support the overall fitness [18,19]. Development time is defined as the time required in completing all phases of development, known as a trait that has the bases of complex genetic control [19]. Several stages in the development life cycle of *D. melanogaster* include the step of egg, larva, pupa, and adult individuals. Those developmental stages occur regularly while each stage of the development can be affected by environmental conditions [20-22]. The results of previous researches indicate that the development time of *D. melanogaster* is not only influenced by the environment temperature and growth media [23,24], but it is also affected by light condition [6,10,11,15,22].

Though there have been previous reports related to the effect of light conditions on fecundity and development time, but the information is still very limited. Further researches still need to be conducted by exposing *D. melanogaster* in light or dark conditions continuously for several generations. The exposure of *D. melanogaster* in dark conditions can be an option because, exposure to dark conditions had the potential to give greater environmental pressure for *D. melanogaster* naturally requiring light to adjust its cicarcadian time [25].

The dark conditions treated continuously for several generations will also be necessary because in nature living things are likely to face the sustainable pressure of environment. In such circumstances, the organism can also show the adaptive character toward environmental conditions encountered [26]. Thus, during the exposure to the dark environment, a clearer picture of the phenotypic responses emerging from generation to generation can be obtained. Furthermore, the information obtained from this research may provide exact information about optimal light conditions to support the fitness of *D. melanogaster*, so it can be used as a reference for setting the breeding conditions in the laboratory in the future.

Drosophila melanogaster has long been known as a model animal in many biological studies that has so many variations of mutants, such as *white* and *ebony* strains. Both kinds of these strains are characterized by the presence of a recessive mutation in the gene locus resulting in the appearance of characters such as white eye color on *white* strain and black body color on the *ebony* strain [21]. The mutant strains in this research could be used to determine the differences in the ability of *D. melanogaster wild type* and mutant strains in responding to environmental stress given on an ongoing basis from generation to generation.

Even though the mutation carried by the *white* and *ebony* strain is related to the character of the pigmentation of the eye or the body color, some reports indicated that there were still differences in the fitness between the mutant and the *wild type* strains. The previous research showed that *D. melanogaster* of *wild type* strain had higher mating frequency than the other three kinds of mutant strains, namely *white*, *sepia*, and *ebony* [27]. In line with the report, Singh [28] also reported that the *wild type* individual males had higher mating success than the individual males of *ruby-eye* strain. Related to *D. melanogaster* of *white* strains, the results of previous research showed that the mutations not only led to blindness, but also led to inefficient mating of the male individuals [29], and to a slower development [3]. Thus, there is a physiological advantage which impacts the acquisition of better fitness in the *wild type* strains than the mutant strains. In this research, two characteristics associated with the fitness, namely the fecundity and the development time of each strain when placed in LD and DD conditions for 5 generations, will be studied further.

II. MATERIALS AND METHODS

This research used three strains of *Drosophila melanogaster* namely *wild type*, *white* (white eyed color) and *ebony* (black body color) obtained from the Genetics laboratory at Department of Biology, State University of Malang, Indonesia. Breedings and crossbreedings of each strain were performed on a glass jam bottle (9 cm high and 5.5 cm diameter) containing a medium of the mixture of banana, cassava, and sugar (7:2: 1), and 5-7 grain yeast.

The study was carried out by placing *D. melanogaster* individuals in continuous dark (DD) as well as in normal light conditions (light-dark change/LD 12:12h) for 5 generations. The setting of DD condition was carried out by placing each cross breeding bottle in a sealed opaque box. The Crossbreeding box was then coated with black plastic and placed in a room that was not much exposed to light. On the other hand, the crossbreeding in the LD condition was carried out by placing *D. melanogaster* individuals in normal light conditions dayly.

The data of fecundity measured was the number of offspring produced by a female individual throughout its life (life time fecundity); while the development time measured was the amount of time (in hours) needed for the development from egg phase until the first appearance of mature individuals. To know the fecundity of the female, a pair of virgin male and female aged ± 1 day was crossbred for 2 days. The male individual was then released, while the female individual was not released in order to enable it to do ovoposition and then was moved to other bottle containing a new medium when any larva was seen. Any adult individuals appeared were counted every day until the female individual died. The collected data were then analyzed using a statistical test of three-way ANOVA, and then a post hoc test was carried out using the LSD test.

III. RESULTS

3.1 Description Of The Crossbreeding Results

The crossbreedings between *wild type*><*wild type*, *white*><*white*, and *ebony*><*ebony* strains were carried out for 5 generations in the LD and DD conditions, but under DD conditions not all the crossbreed strains reached the 5th generation. The crossbreedings in DD conditions had more failures than those in the LD conditions. The failure of the crossbreeding was partly caused by the fact that there was no offspring produced by mating pairs to be used in the crossbreeding for the next generation. In some crossbreeding bottles, there were eggs produced by the female parent, but the eggs did not develop further; while in some other crossbreeding bottles, there were not any eggs at all.

The ability of each strain in facing DD conditions was also different. The results showed that the percentage of crossbreeding failures was more often found in the crossbreeding of *ebony* and *white* strains than that of the *wild type* strains (Fig. 1). In the *wild type* strain, the crossbreeding was carried out for 13 times, but only 5 of them were able to survive until the 5th generation. In the *ebony* strain, 19 crosses were carried out, but only 4 of them were able to survive until the 5th generation. A more severe impact happened on the *white* strain that from 27 crosses carried out, none of them were able to survive until the 5th generation; there were only three crosses, which were able to survive until the 3rd generation.

The number of offspring growing in DD conditions fluctuated from generation to generation (Fig. 2). Nonetheless, there was a tendency in which the number of offspring produced always declined dramatically in the first generation for each strain. The mean number of offspring produced in each strain also had a tendency to increase in the 5th generation. The number of *wild type* and *ebony* strain offspring produced increased as much as 27.94% and 17.39% in the 5th generation following a decrease occuring in the 4th generation. Such pattern was not observed related to *white* strain because there were not any crosses conducted on the 4th and 5th generation.

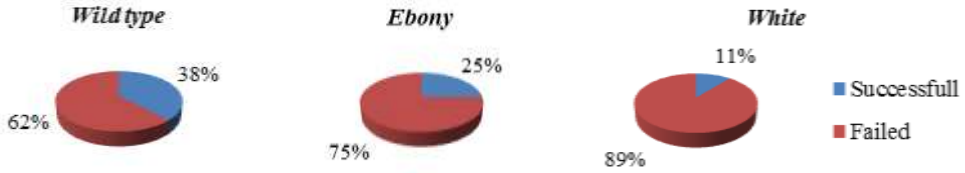

Figure 1. The crossbreeding success of *wild type*, *white*, and *ebony* strains in the DD condition

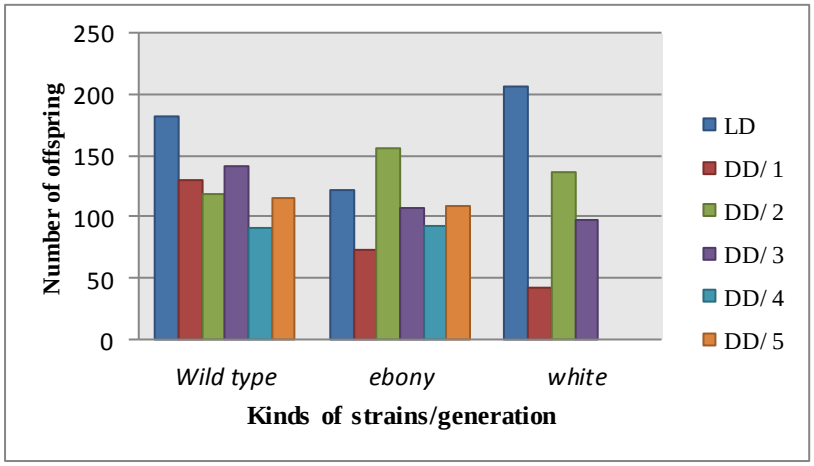

Figure 2. The average number of *D. melanogaster* offspring in DD condition for several generations

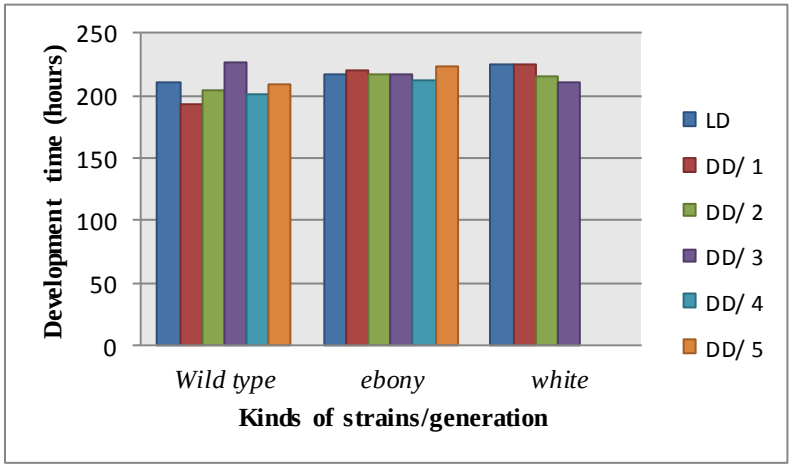

Figure 3. The mean of the development time of *D. melanogaster* in DD condition for several generations

The development time of *D. melanogaster* in DD conditions over several generations can be seen in Fig. 3. In line with the information revealed from the data of fecundity, the development time of *D. melanogaster* tended to be slower in the 5th generation after it was faster in the 4th generation. The development time of *wild type* and *ebony* strain became slower as much as 3.89% and 4.77% respectively in the 5th generation. However, such pattern was not observable in *white* strain. Similarly, the development time of *wild type* strain became much faster 8.6% in the first generation, while the development time of *white* and *ebony* strains became slower as much as 0.14% and 1.3% respectively in the first generation.

To determine the effect of light conditions and the kinds of strain on fecundity and development time of *D. melanogaster*, statistical tests using ANOVA were carried out. However, the data of fecundity and the development time used in the Anova test were restricted only to the 3rd generation for all strains, both in LD and DD conditions, because not all the crosses in the DD condition reached the 5th generation.

3.2 Fecundity

The results of ANOVA (Table 1) showed that the fecundity was significantly different in different light conditions (F = 6.932; *P* = 0.012) as well as in different strains (F = 3.653; *P* = 0.036). *D. melanogaster* placed at LD conditions had higher mean of fecundity (136.22) than that in DD conditions (111.44). In other words, there was a decrease in the number of offspring as much as 18.19% in DD conditions. The mean of the fecundity of the *wild type* strain was also known to be higher and significantly different from that of the *white* and *ebony* strains (Table 2). It can be seen from the decline in the offspring number of *white* and *ebony* strains as much as 17.45% and 20.31% respectively. On the other hand, the fecundity between generations did not show a significant difference.

Table 1. Summary of ANOVA Results related to Fecundity of *wild type*, *white*, and *ebony* Strain of *D. melanogaster* in Different Light Conditions for 3 Generations

Treatment	Type III Sum of Squares	df	mean Square	F	p
Light condition	8288.167	1	8288.167	6.932	.012
Strain	8734.778	2	4367.389	3.653	.036
Generation	3219.111	2	1609.556	1.346	.273
Light condition * strain	5293.000	2	2646.500	2.213	.124
Light condition * generation	41769.333	2	20884.667	17.466	.000
Strain * generation	10179.444	4	2544.861	2.128	.097
Light condition * strain * generation	17230.333	4	4307.583	3.603	.014

The analysis results also showed that the interaction between light conditions and generation (F = 17.466; P = 0.000); and the interaction between light, strains, and generation (F = 3.603; P = 0.014) had a significant effect on the fecundity. The results of the post hoc analysis of the effect of the interaction between light condition and generation (Table 3) showed that fecundity was lower in DD conditions in generations 1, and it increased by 67.34% in the 2nd generation. Fecundity subsequently declined again in the 3rd generation, but it was not significantly different from the fecundity in DD conditions in the 1st generation and the 2nd generation. Regarding the effect of the interaction between light conditions, strains, and generation (Table 4), the results of post hoc analysis showed that the fecundity of *white* and *ebony* strains was lower in DD conditions

in the 1st generation and increased dramatically in DD conditions in the 2nd generation. The fecundity increase of *white* and *ebony* strains in DD conditions in the 2nd generation was 226% and 112% respectively; while the fecundity of the strains in DD condition in the 3rd generation was not significantly different from the fecundity in DD conditions in the 1st generation and the 2nd generation. On the other hand, the fecundity of the *wild type* strain was not significantly different, both in light conditions and between the different generations. Furthermore, the analysis results showed that the interaction between light conditions and the kinds of strain, and the interaction between the kinds of strain and generation did not have significant effect (P > 0.05).

Table 2. Summary of the Post Hoc Analysis Results Related to the Fecundity Differences among *wild type*, *white* and *ebony* Strains of *D. melanogaster*

Types of strain	Average number of offspring	LSD notation
Ebony	112.889	a
White	116.944	a
wild type	141.667	b

Table 3. Summary of the post hoc Analysis Results related to the Effect of Interaction between Light condition and the Generation on the Fecundity of *D. melanogaster*

Combination groups	Average number of offspring	LSD notation
DD -1	82,000	a
LD -2	89.778	a b
DD -3	115.111	a b
DD -2	137.222	b c
LD -3	149.000	b c
LD -1	169.889	c

Table 4. Summary of the post hoc Analysis Results related to the Effect of Interaction between Light Condition, Types of Strain, and Generation on the Fecundity of *D. melanogaster*

Combination groups	Average Number of offspring	LSD notation
DD *white* 1	42,000	a
LD *ebony* 2	52,000	a b
DD *ebony* 1	73,333	a b
DD *white* 3	96,667	a b
LD *white* 2	106,333	b c
DD *ebony* 3	106,667	b c
LD *wild type* 2	111,000	b c
LD *white* 3	113,333	b c
DD *wild type* 2	118,667	b c
LD *ebony* 1	121,000	b c
DD *wild type* 1	130,667	b c
DD *white* 2	137,000	b c
DD *wild type* 3	142,000	b c
DD *ebony* 2	156,000	c d
LD *wild type* 3	165,333	c d
LD *ebony* 3	168,333	c d
LD *wild type* 1	182,333	c d
LD *white* 1	206,333	d

3.3 Development Time

The results of Anova (Table 5) showed that there was a difference of the development time in different light conditions (F = 6,591; P = 0.015) and in different strains (F = 13 271; P = 0.000). *D. melanogaster* placed in DD conditions had a faster mean of development time (213.926 hours) than that in the LD conditions (219.667 hours). In other words, the development time became faster 2.68% in DD conditions. The development time of the *wild type* strain was also faster and significantly different than the *white* and *ebony* strains (Table 6). The development time of *ebony* and *white* strains become slower by 4.64% and 6.09% respectively compared to the *wild type* strain. On the other hand, the development time among generations did not show any significant difference.

The results of the analysis also showed that the interaction between strain and generation (F = 4815; *P* = 0.003), as well as the interaction between light condition, strain, and generation (F = 5015; *P* = 0.003) had a significant effect on the development time. The results of a post hoc test related to the effect of the interaction between strain and generation (Table 7) showed that the *wild type* strain in generation 1 had the fastest development time, and it became slower until it was significantly different from the development time in the 3rd generation (7.91% slower than generation 1). While, the development time of *white* and *ebony* strains was not significantly different among different generations. Similarly, regarding to the effect of the interaction between

light condition, strain, and generation (Table 8), the results of post hoc tests indicated that the development time was faster on the *wild type* strain in DD conditions in generation 1, and it became slower and significantly different in the 3rd generation (27.92% slower than that of generation 1). On the other hand, the development time of *white* and *ebony* strains was not significantly different both in the different light conditions and different generations. Further, the results of the analysis showed that the interaction between light condition and strain and the interaction between light condition and generation did not have significant effect (P> 0.05).

Table 5. Summary of the Results of ANOVA related to the Development Time of *wild type*, *white*, and *ebony* Strains of *D. melanogaster* in different Light Conditions for 3 Generations

	Type III Sum of Squares	D f	Mean Square	F	*P*
Light condition	444.907	1	444.907	6.591	.015
Strain	1791.593	2	895.796	13.271	.000
Generation	66.926	2	33.463	.496	.613
Light condition * strain	179.148	2	89.574	1.327	.278
Light condition * generation	286.037	2	143.019	2.119	.135
Strain * generation	1300.074	4	325.019	4.815	.003
Light condition * strain * generation	1354.074	4	338.519	5.015	.003

Table 6. Summary of the Results of post hoc Test related to the Difference of the Development Time among the *wild type*, *white* and *ebony* Strain of *D. melanogaster*

Types of strain	Mean of developmental time (hours)	LSD notation
wild type	208 889	a
ebony	219 056	b
white	222 444	b

Table 7. Summary of the Results of post hoc Test related to the Effect of Interaction between the Types of Strain and the Generation on the Development Time of *D. melanogaster*

Treatment (Types of strain * generation)	Mean of development time (hours)	LSD notation
wild type -1	201.667	a
wild type -2	206.000	a b
ebony -3	213.667	b
wild type -3	219.000	b c
white -3	220.000	b c
ebony -2	220.833	b c
white -1	221.333	b c
ebony -1	222.667	b c
white -2	226.000	c

Table 8. Summary of post hoc Test Results related to the Effect of Interaction among Light Condition, Type of Strain, and Generation on the Development Time of *D. melanogaster*

Treatment (light * type of strain * generation)	Mean of development time (hours)	LSD notation
DD *wild type* 1	192.667	a
DD *wild type* 2	203.333	a b
LD *wild type* 2	208.667	b c
DD *white* 3	210.333	b c
LD *wild type* 1	210.667	b c
LD *ebony* 3	211.333	b c
LD *wild type* 3	212.333	b c
DD *white* 2	215.667	b c
DD *ebony* 3	216.000	b c
DD *ebony* 2	216.333	b c
LD *white* 1	217.667	c
DD *ebony* 1	220.333	c
LD *ebony* 1	225.000	c d
DD *white* 1	225.000	c d
LD *ebony* 2	225.333	c d
DD *wild type* 3	225.667	c d
LD *white* 3	229.667	c d
LD *white* 2	236.333	d

IV. DISCUSSION

The results of the analysis showed that the light conditions had an effect on the fecundity of *D. melanogaster*. *Drosophila melanogaster* placed in LD conditions had higher fecundity, and it decreased by

18.19% in DD conditions. The decline in the number of offspring in DD conditions showed that the absence of stimulus in the form of light can disturb the physiological processes supporting the reproductive success of *D. melanogaster*. Sweat et al. [7] described that organisms use light to induce changes in the transcription of several genes involved in the regulation of circadian time. The regulation is also known involving epigenetic mechanisms that take place through the work of light in inducing an increase in histone acetylation of H3 and H4 in the promoter region of the mPer1 and mPer2 genes, so that the genes can be expressed appropriately to support the physiological and behavioral processes regularly.

In conditions where there was no stimulus in the form of light received by the photoreceptors (DD), many physiological processes could still take place [4,30], but the length of circadian time which happened was not exactly for 24 hours. The available light during the period of daily light dark (LD cycle) was required to synchronize the regulation of internal time [4]. Failure to synchronize the environmental conditions could cause disturbances in various physiological and behavioral processes, so it could affect the fitness of the organisms [14].

The results of the previous researches supported the findings in this research. The results of the previous researches reported that fecundity of some species of Drosophila became lower in DD conditions than that in LD conditions [13,14,25]. The changing of light conditions was also reported to cause physiological and behavioral disturbances in a number of other multicellular organisms. The research conducted using rats showed that the changing of light conditions might result in the decrease of the longevity, and might stimulate the growth of tumors, and it might result in a variety of metabolic abnormalities [31]. Similarly, the changes in modern lifestyles that made humans to be exposed to bright conditions longer were thought to cause many serious health and behavioral problems, such as obesity, cardiovascular disease, diabetes, and cancer [32-36].

The difference in the female fecundity between LD and DD conditions could also be influenced by other factors, namely the difference of mating success of *D. melanogaster* in both conditions. DD conditions are known to increase the engagement length of sexual play time and reduce the length of copulation time in some species of *Drosophila* [25]. DD condition also causes the male individual to become less attractive; while the female individuals become less responsive, so that it has an impact on the mating frequency decreasing and the latency time increasing of copulation in the fruit fly of *Anastrepha ludent* [2]. The decrease of copulation time and mating frequency, the longer mating latency time in dark conditions are several explanations for the low fecundity of females in DD conditions compared to that of in the LD conditions. This is in line with the report by Harini [25] that the length of copulation time was positively correlated with fertility. Singh & Singh [37] also added that the *mating latency* was an important mating behavior in Drosophila, and directly correlated with other components such as fecundity, fertility, and longevity.

The results of ANOVA test also showed that the fecundity of the three kinds of strains was significantly different. The *wild type* strain had higher fecundity than *white* and ebony strains. It could be seen from the decrease in the number of offspring as much as 17.45% on the *white* strain and 20.31% on the *ebony* strain. The number of offspring of *white* and *ebony* strains was not significantly different. This showed that there was a better fitness in the *wild type* strain than that of both mutant strains.

Drapeau [38] explained that any mutant in *D. melanogaster* related to pigmentation showed pleiotropic effects. The analysis on the gene mutations playing a role in the pigmentation process is known to play a role not only during the formation of the cuticle pigmentation or eye color but also in the neurobiological/behavioral processes. A number of research findings showed that *D. melanogaster* carrying mutations in the ebony locus had a lower mating success, and some other mating behavior disorders caused by visual defects [39,40]. Some other sources reported that the mating behavior disruption of the ebony strain was also related to other aspects such as the less frequency of wing-extension, the breaking of marriage stages, and the acoustic parameters changes of the 'singing' displayed during the stages of marriage [40]. Similar conditions also occur in *white* strain. The results of the previous researches showed that the mutation carried suffered by *white* strain not only caused blindness, but also caused inefficient mating process by male individual [29], and slow development [3].

The other analysis results showed that the interaction between light conditions and the generation had a significant effect on fecundity. The lowest fecundity occured during the exposure to DD condition in generation 1, and it increased by 67.34% in the 2nd generation. The sharp decline of the offspring number at DD conditions in generation 1 indicated that dark condition gave huge environmental pressures for *D. melanogaster* that naturally lived in normal light conditions. On the other hand, the adaptation effort began at the 2nd generation resulting in the increased fecundity than that of the previous generation. Fecundity of *D. melanogaster* at DD conditions in the 3rd generation experienced a decline, even though it was not significantly different from the fecundity in the 1st generation and 2nd generation.

Environmental pressure that *D. melanogaster* faced in the first generation not only affected the fecundity but also affected the success of mating couples to produce offspring. The results of the observation showed that the failure of crossbreeding in the three kinds of *D. melanogaster* strains during the exposure to DD conditions generally occurred in generation 1. Conversely, the failure of crossbreeding on generation 2, 3, 4, and

5 respectively was rare. In some of the crossbreeding bottles, there were not any eggs produced by the female parent; while at the other crossbreeding bottles, there were some eggs, but they did not develop further. There has not been any exact explanation about whether the extreme conditions occurred during the exposure to DD conditions in the 1st generation was very disturbing to mating process or to other conditions such as any disturbance occurred during the process of oogenesis. In this regard, under DD condition, *Drosophila* might fail to perform copulation, while the LL condition caused the eggs not to be able to hatch in large numbers [13].

The interaction between light conditions, kinds of strains and generation is also known to have a significant effect on fecundity. The *white* and *ebony* strains have lower fecundity in DD condition in generation 1, but their fecundity increased dramatically by 226% and 112% respectively at DD conditions in the 2nd generation. The fecundity of the strains then decreased in the 3rd generation, but it was not significantly different from the fecundity in DD conditions in the 1st generation and 2nd generation. On the other hand, fecundity of *wild type* strain was not significantly different, both in light conditions and between the different generations. Thus, the factors such as light conditions and generation did not have significant effect on the *wild type* strain, but instead they had an effect on the ability to produce offspring of both the mutant strains.

The development time is the other *fitness* component studied in this research. Mos [41] explained that the temporal regulation of the developmental stages was important for insects because of their role in many important processes such as cell cycle, tissue growth, the emergence of character patterns on the body, organ formation, and a number of other post embryonic processes. Few changes occurring during the development stages can lead to the disruption of the developmental processes that occurs; or even can cause new phenotypic variation that probably will continue to be carried through selection. Therefore, the stages as well as the length of time of the developments in insects are important components to support the overall fitness.

The test results showed that the light conditions had a significant effect on the development time. The development time in DD conditions became 2.68% faster than that in the LD conditions. The difference in the length of the development time in DD and LD conditions indicated that the light conditions had an effect on several aspects involved in the development regulation [10]. One of the aspects considered to have an effect on the development time of many insects, including *D. melanogaster* is the releasing time of ecdysone hormone (prothoracicotropic hormone). The premature release of ecdysone hormones could accelerate the development, while the delay in the release of the hormones could cause the development to be slower [19,22].

The results of ANOVA test also showed that the development time among the three kinds of strains was significantly different. The development time of *wild type* strain occurred more rapidly than that of the white and *ebony* strains. It can be seen from the increase in the length of the development time as much as 4.87% in the *ebony* strain and 6.49% in the *white* strain compared to the *wild type* strain. The length of the development time between the *ebony* and the white strains was not significantly different.

Based on the length of the development time observed, the *wild type* strain not only showed higher fecundity, but also had faster development time than the *white* and the *ebony* strains. This showed that there was a considerable genetic variation among *wild type* and mutant strains that supported the better acquisition of fitness on the *wild type* strain. Genetic variation among several types of strains of Drosophila has also been previously reported involving several characters associated with fitness, such as the population size, competition ability and productivity [18].

The interaction among the types of strain and generation, as well as the interaction between light condition, strain, and generation had a significant effect on the development time of *D. melanogaster*. The faster development time was experienced by the wild type strain of the 1st generation in DD condition, and it became slower until it was significantly different from the development time of the 3rd generation (27.92% slower compared to the generation 1). On the other hand, the development time of the *white* and *ebony* strains was not significantly different both in the light conditions and in the different generations. Thus, the factors such as the light condition and generation had bigger effect on the development time of the *wild type* strain, while these two factors did not have any effect on the development time of both the mutant strains.

The data that has been previously mentioned showed that the characteristics associated with the life history of *D. melanogaster* such as development time and fecundity were not only influenced by genotype or the environment, but it was also determined by the interaction between the two. Reed et al., [42] stated that in the interaction, genotype will produce different phenotype variations as a result of the environmental conditions encountered. Similarly, the contribution of each factor on the interaction may vary for each character observed [43]. In this research, the interaction among the three factors including the condition of light, types of strain, and generation had an effect on both the fecundity and the development time of *D. melanogaster*.

V. CONCLUSION

The results of this research showed that dark condition gave a huge environmental pressure on *D. melanogaster*, so that it affected the fitness of the organisms. Exposure to DD conditions caused *D. melanogaster* to have a lower fecundity (18.19%), and faster development time (2.61%) compared to

that in LD conditions. The results of the comparison between strains also showed that the *wild type* strain not only had higher fecundity and slower development time, but also it was more capable producing offspring for the next generation. The fecundity of *white* and *ebony* strains decreased by 17.45% and 20.31% respectively; while the development time of *white* and *ebony* stains became slower at 6.09% and 4.64% respectively compared to the *wild type* strain.

The interaction between light conditions and generation as well as among light, strain, and generation also had an effect on fecundity. Related to the interaction between light condition and generation, the fecundity declined drastically at DD condition in generation 1 and the ability to produce offspring increased again by 67.34% in generation 2; fecundity at DD condition in generation 3 declined although it did not show a significant difference. This fact suggested that the ability of *D. melanogaster* to adapt to extreme environmental condition (DD) led to an increase of better fecundity in the next generation. Similarly, the results of posthoc analysis related to the interaction among light, strain, and generation showed that the fecundity of the *wild type* strain at LD as well as DD condition during several generations was not significantly different.

In this research, the interaction between strain and generation as well as among the light, strain, and generation also had an effect on the development time. The faster development time occurred in the *wild type* strain at DD condition in generation 1, and it became slower and significantly different from the development time of the 3rd generation. On the other hand, the development time of *white* and *ebony* strains was not significantly different both in the light conditions and in different generations. Thus, the factors such as the light condition or generation had more significant effect on the development time of *wild type* strain than that of both the mutant strains.

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