Inheritance Pattern of Capsaicin Content of Indonesian Chili Landraces (Capsicum annum L.)

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Abstract. Capsaicin is a compound that produces a spicy taste in chili. Inheritance of capsaicin is valuable information for breeders to determine the selection methods and when the selection will be conducted. The objective of this experiment is to observe the inheritance pattern of the capsaicin content of Indonesian chili landraces. The experiment was conducted at Ciparanje Experimental Station of Universitas Padjadjaran. One hundred sixty-seven F2 plants were analyzed for capsaicin content in the laboratory. The results showed the distribution of capsaicin content was continuous using the Kolmogorov Smirnov test. Many genes might control capsaicin content in Indonesia chili landrace. The capsaicin content of the male parent was 4,565 ppm, and the female parent was 8,540 ppm. The capsaicin content among F2 plants ranged from 621 ppm to 14,348 ppm. The average of capsaicin content in the F2 population was 4,814 ppm. The capsaicin content of some F2 progenies showed higher than their male parents. However, some F2 progenies showed also low capsaicin content compared with their female parent. Segregation transgressive of capsaicin content occurred in F2 generation.

1. Introduction
The spiciness taste in chili due to capsaicinoid content, including dihydro-capsaicin and capsaicin. Inheritance of capsaicin content is essential for researchers because it determines the effectiveness of the breeding process in chili. Heterosis obtained on F1 chili hybrid from the crossing between spicy chili pepper and non-spicy chili pepper, and also observe the transgressive variation in F2 [1]. The spiciness in the genus Capsicum is the qualitative character that is affected by the function of the pun1 allele. On the non-spicy chili 'Nara Murasaki,' function of pun1 alleles was lost due to a mutation of a single nucleotide adenine insertion with on allele pun1 and turned into a pun14 allele [2]. Capsicum chinense hybrid of 'No. 3441' and 'Habanero' shows the dominant gene controlled of the spiciness and non-spicy flavor is recessive genes controlled [3]. The pungency of C. chinense peppers was controlled by Pun1 locus. On the other hand, non-pungency was controlled by a recessive allele, named pun1[4]. The level of spiciness in spicy chili was determined by capsaicin content. In this experiment, we would examine the inheritance pattern of the level of spiciness Indonesian chili landracte.

2. Materials and Methods
Segregation population of the progenies crossing among Indonesian chili landrace was used in this experiments. The experiment was conducted in the field at Ciparanje experimental station in Universitas Padjadjaran (UNPAD). Capsaicin content of 167 of F2 plants was analyzed in the Pharmacy Laboratory. Capsaicin content of 167 progenies was analyzed the normality distribution by Kolmogorov Smirnov test. The normal distribution of data shows the polygenic trait and have a quantitative variation. The number of F2 plants has similar capsaicin content with a parent could be counted using equation according to [5]: (1/4)n, where n is the number of gene pairs controlling capsaicin. The phenotypic class in F2 was estimated by equation (2n+1). The phenotypic ratio in F2 population was calculated using...
(a+b)^2n [5]. If the discreet distribution data was observed in the F₂ population, the data then was computed using the Chi-square test. The result was then compared with the Mendelian ratio [6].

3. Result and Discussion

Performance of parents and the F₂ plants could be seen in Figure 1 and Figure 2. The F₂ population from crossing two landrace Indonesian cultivars called curly chili (male) and cayenne pepper (female). This chili was grouped in to Capsicum annum (L.). Curly chili is a chili with a dropping fruit position, fruit more than 10 cm long with a diameter of less than 1 cm. While cayenne pepper usually has an upright fruit position, the length of the fruit is about 2-4 cm with a diameter of less than 1 cm.

In the F₂ population, there was an apparent variation in fruit length, and fruit position. In Figure 2, the most appearance of fruits looked like cayenne pepper (Figures 2a and 2b), but there were also variations such as curly chili with an upright fruit position (Figure 2c) or cayenne pepper fruit with a dropping fruit and about 6 cm long, longer than usual (Figure 2d). Variations occur because of the gene segregation in the second generation of these.

The result of the Kolmogorov-Smirnov Test in Table 1. showed that the data was normal distribution or the capsaicin content is a quantitative character, controlled by many genes. The result is similar to the research of an interspecific hybridization of Capsicum annum/ C. chinense. This crossing showed significant additive gene effect for the capsaicinoid [7]. The existence of transgressive variation showed that the Indonesian chili landrace parent did not have all active genes controlling the spicy flavour. From the data, it was found that there were three plants of 167 F₂ plants showed the lowest performance for capsaicin content, and three plants showed the highest capsaicin. The estimated number of genes controlling the capsaicin content was three pairs of genes at least (n=3) and phenotypic classes 2n+1=7 with distribution as shown in Table 2 and Figure 3. The lowest capsaicin content was 621 ppm, and this plant was considered without effective allele (0 genes effective), and the highest capsaicin content of plant was 14348 ppm and was considered have six effective alleles (Table 2).

A unit used to express pungency called the Scoville heat unit. Symbol, SHU [8] in Table 2, capsaicin content was converted to SHU by multiplying the ppm value by 16 because the pure capsaicin is 16,000,000 SHU. Habanero was a hot chili cultivar with 150,000 – 350,000 SHU. In this population, the capsaicin content of transgressive variation more than 150,000 SHU and could be classified as hot pepper. The study of capsaicin content and pungency level of different fresh and dried chilli peppers showed six Habanero varieties (Habanero Red Savina (HRS), Habanero Yellow (HY), Habanero Maya Red (HMR), Habanero Tasmania (HT), Habanero Paper Latern (HPL), and Habanero Red (HR), HRS has the highest capsaicin content of 147,870 SHU among other Habanero [9].

The hot chili progeny higher than the parents in the F₂ population, enriching the Indonesian chili collection and it is also possible to obtain a higher spiciness because the genes controlling spiciness could be more than three pairs. The breeders could hybrid another Indonesian landrace, to get spiciness variations with a combination of another spicy gene in another Indonesian chili landrace.

![Figure 1](image1.png)

(a) (b)

**Figure 1.** Performance of Parent : (a) female, (b) male
Figure 2. Performance of F₂ Progeny Crossing of Indonesian Landrace Chili Cultivars, (a) male type, (b) female type, (c) and (d) variation

Table 1. Result of Kolmogorov-Smirnov Test

| Data                  | 167   |
|-----------------------|-------|
| N                     | 167   |
| Normal Parameters     |       |
| a, b Mean             | 0.4695|
| Std. Deviation        | 0.17487|
| Most Extreme Differences|     |
| Absolute              | 0.061 |
| Positive              | 0.061 |
| Negative              | -0.039|
| Kolmogorov-Smirnov Z  | 0.726 |
| Asymp. Sig. (2-tailed)| 0.668 |
| Test distribution     | Normal|

Table 2. Segregation of Capsaicin Content

| The number of genes effective | The Number of Plant | Capsaicin content (ppm) | Scoville Heat Units (SHU) (ppm x 16) | Parent |
|-------------------------------|---------------------|-------------------------|-------------------------------------|--------|
| 0                             | 2                   | 621 - 2,582             | 9,936 - 41,312                      |        |
| 1                             | 17                  | 2,583 - 4,543           | 41,328 - 72,688                     |        |
| 2                             | 40                  | 4,544 - 6,504           | 72,704 - 104,064                    | Male   |
| 3                             | 54                  | 6,501 - 8,464           | 104,016 - 135,424                  |        |
| 4                             | 39                  | 8,465 – 10,425          | 135,440 – 166,800                  | female |
| 5                             | 13                  | 10,426 – 12,386         | 166,816 – 198,176                  |        |
| 6                             | 2                   | 12,387 – 14,348         | 198,192 – 229,568                  |        |
Transgressive variation of capsaicin content were the homozygote recessive and the plants having one effective gene for negative transgressive, while homozygote dominant and the plants having five effective genes for positive transgressive (Figure 4).

| Scoville Heat Units (SHU) | Genotypes |
|---------------------------|-----------|
| 9936 - 41312             | 1 aabbcc  |
| 72704 - 104064           | 2 Aabbcc  |
| 104016 - 135424          | 2 AAbbCc  |
| 135440 – 166800          | 1 AABbCc  |
| 166816 - 198176          | 2 AABBcc  |
| 198192 - 229568          | 1 AABBCC  |

4. Conclusion
The results of the distribution analysis of capsaicin content showed normal data distribution using the Kolmogorov Smirnov test. Capsaicin segregation in the F2 populations was polygenic inheritance controlled by three gene pairs. The capsaicin content of the female parent was 1535 ppm, and the male parent was 7340 ppm. Capsaicin content on the F2 population ranges between 622 ppm – 11,348 ppm. The middle value of F2 capsaicin was 4,814 ppm. There was transgressive variation shown by higher capsaicin content in F2 progeny compared to the male parent and lower than female.

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