Developing enrichment module of polyploidy on shallot (Allium ascalonicum L.) for 12th grade students

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Abstract. The objectives of this research were to determine the effect immersion duration and concentration of colchicine on polyploidy of shallots (Allium ascalonicum L.), to develop enrichment module based on the study, and to assess the enrichment module feasibility based on assessment of material experts, media experts, biology teachers, and responses of students. The research was development research using ADDIE model limited to development stage. Data of the study was the description of chromosome counting. The module feasibility data was obtained from the assessment by the reviewers and the responses of the respondents. The module feasibility assessment data was processed into quantitative data. The aspects analysed include the assessment of appropriateness of the concept, feasibility of content, presentation, language, and graphic. The results showed that colchicine’s immersion duration and concentrations had effects on polyploidy of shallots. The results of the research were used to develop module of mutation learning based on 2013 curriculum. Module review from material experts showed that most of the module’s substances were appropriate. Module review from media experts and responses of students showed that the module was feasible, and from biology teachers was highly feasible. The overall assessment results showed that polyploidy module was eligible feasible as teaching material in enrichment program for 12th grade students.

1. Introduction

Mutations are phenomenon of genetic changes in organisms. A mutation occurring in plants is chromosomal mutation. Chromosomal mutations can be in the form of polyploidy, a change in number of chromosomes that are doubled. This phenomenon can occur naturally or artificially. Artificially, polyploidy can be obtained by induction using colchicine with certain concentration and immersion duration [14]. Critical concentration and appropriate immersion duration can stimulate polyploidy in plants, while concentrations that are too low or high with inappropriate immersion cannot stimulate polyploidy or can damage the chromosomes. Therefore, it is necessary to study the effect of immersion duration and the concentration of colchicine on polyploidy of plants. Plants that are easy to be applied by colchicine to observe the polyploidy are shallots because they have a small number of chromosomes and are quite large to be easily observed [13].

Mutation is biology learning material in class XII of high school in basic competence 3.8 analyse the phenomenon of mutations in organisms. Mutation learning in most schools still does not provide much experience in exploration or experimental activities include polyploidy experiment. Diploid plants can be induced into polyploidy through colchicine treatment with certain immersion duration and concentration. This procedure is quite simple to do by students in learning mutations. However, most of biology learning in high school does not carry out these activities due to certain limitations:
time allocation of mutation learning is short, practical materials is not provided, and the teacher is less experienced in carrying out these activities.

Based on interviews with biology teachers at Senior High School of 1 Kebumen, the mutation learning condition was teachers only provide remedial programs for students who have not achieved the limit score but do not provide enrichment programs for students who have achieved limit scores. Teachers did not provide enrichment programs because lack of time available to hold enrichment programs and the limited of teaching materials used for enrichment programs. These conditions can be overcome by providing teaching materials in the form of enrichment modules for students who have reached the limit score of mutation material. Teachers can use modules to increase students’ experience in enrichment programs [10]. Modules is self-instructional or independent teaching materials so that it does not depend on the teacher in learning and also time of use of the module can be adjusted to the students’ abilities [6].

The objectives of this research were to determine the effect of immersion duration and concentrations of colchicine on polyploidy of shallots (Allium ascalonicum L.), to develop enrichment module based on the study, and to assess the enrichment module feasibility based on assessment of material experts, media experts, biology teachers, and responses of students. The enrichment modules are expected to facilitate students to be able to learn independently and to add insight to polyploidy on shallot (Allium ascalonicum L.) due to immersion treatment using colchicine.

2. Research Method
This study consisted of two stages: 1) biological research on the effect of immersion duration and concentration of colchicine on polyploidy of shallots (Allium ascalonicum L.) and 2) developing enrichment module based on research data.

2.1. Research type
This study was an experimental research design and Research and Development using ADDIE model that is limited to the Development stage.

2.2. Time and place of research
Biological research was carried out from March 1, 2018 to April 6, 2018 at the Research and Development Laboratory, Yogyakarta State University and Laboratory of Genetics and Plant Breeding, Faculty of Biology, Gadjah Mada University. The writing of the enrichment module draft was carried out on February 15, 2018 to April 18, 2018. The partial trial was held on April 20, 2018 to May 11, 2018. The drafting of the enrichment module was carried out at the Department of Biology Education, Yogyakarta State University. Partial trial was conducted at Senior High School of 1 Kebumen, Mayjend Sutoyo Street Number 7 Kebumen.

2.3. Research subjects and objects
The object of biological research was shallots. The population was all shallots (Allium ascalonicum L.), while the sample was shallot grown on ten tubes of water. The research sample was taken randomly.

The subject of module development research was respondents and reviewers. Respondents were 20 students of 12th grade of Senior High School of 1 Kebumen who had achieved the limit score on the mutation learning. Respondents gave responses to enrichment modules on aspects: the easiness of understanding the material, presentation, language, and graphic. The selection of respondents was done by purposive sampling technique. Reviewers were 2 material experts, 2 media experts, and 2 biology teachers at Senior High School of 1 Kebumen. Material experts assessed the content of the material in the module. Media experts and biology teachers assessed aspects of content feasibility, language, presentation, and graphic. The object of the research was research products namely the enrichment module of polyploidy on shallot (Allium ascalonicum L.).
2.4. Instruments
Research on the effect of immersion duration and concentration of colchicine to polyploidy of shallots used tools: a set of slide preparation tools, microscope, and Optilab device. Research on the development of enrichment modules used questionnaires as research instruments. Questionnaire was used to assess the appropriate of concept, feasibility of content, presentation, language, graphic, and easiness of understanding material. The instrument used was adapted from the Biology High School textbook assessment instrument from education national standard institution with some modifications. The instruments had passed validity test with valid result by expert judgment.

2.5. Procedure
The procedure of this research consisted of two stages as follows.

2.5.1. Research on the effect of immersion duration and concentration of colchicine to polyploidy of shallots (Allium ascalonicum L.)
The procedure of this study followed the research step adapted from Adisewoyo et al., namely: growing the root of shallots, preparing colchicine solution, immersing the root of shallot using colchicine based on table 1, making squash microscopic slide of the root tip of shallots and observing the squash microscopic slide of the root tip of shallots [1].

| Immersion duration (D) | Concentration (C) |
|------------------------|------------------|
| 0 % (0)                | 0,025% (1)       |
| 0,050% (2)             | 0,075% (3)       |
| 12 hours (1)           | C1D1             |
| 18 hours (2)           | C2D1             |
| 24 hours (3)           | C3D1             |

2.5.2. Development of enrichment module
Packaging research results as enrichment modules was carried out through the stages: analysis, design, and development. The analysis phase consisted of: 1) competency analysis, 2) students’ characteristics analysis, and 3) instructional analysis. The design phase consisted of: 1) writing a draft framework for the enrichment module structure, 2) writing a systematic draft of the enrichment module, and 3) designing evaluation tools. The development phase consisted of six steps: 1) pre-writing, 2) draft writing, 3) editing 1, 4) revision 1, 5) partial trial, and 6) revision 2.

2.6. Data analysis technique
The data obtained from the research was the number of chromosomes and formed or not polyploidy of shallots. Data were analysed descriptively quantitative and presented in frequency tables because the form of data were the number of occurrences of phenomenon from a variable through counting activities [11].

The analysis technique of enrichment module feasibility data used steps as follows.
1. Relevant suggestions data for the enrichment module were selected to be used as references for the revision of the enrichment module.
2. Feasibility assessment data of enrichment modules obtained through research instruments using the Guttman and Likert scale. This data were used to determine the total score of each aspect assessed. The data were analysed quantitatively in descriptive with the following steps.
   a. The qualitative data obtained from material experts were converted into quantitative data with details: True: 1, False: 0.
   b. Qualitative data obtained from media experts and biology teachers were converted into quantitative data with details: Very Good: 4, Good: 3, Not Good: 2, Very Poor: 1.
   c. Qualitative data obtained from responses of students were converted into quantitative data with details: Strongly Agree: 4, Agree: 3, Disagree: 2, Strongly Disagree: 1.
   d. Calculating the average score of each aspect assessed by the following formula.
The average score is calculated as:

\[ \text{average score} = \frac{\text{number of score}}{\text{number of respondents}} \]

e. Converting the average score to a 100-scale in the following way.

\[ \text{score of each aspects} = \frac{\text{average score}}{\text{maximal score}} \times 100 \]

f. Changing the score of each aspect into a description of feasibility according to Riduwan (2009). The score of each assessment aspect of the assessment instrument and its criteria can be seen in Table 2.

| Score   | Category      |
|---------|---------------|
| 81-100  | Very feasible |
| 61-80   | Feasible      |
| 41-60   | Enough        |
| 21-40   | Poor          |
| <20     | Very Poor     |

Table 2. Product Feasibility Categories

g. Standardization of module feasibility determined by researchers, namely if the assessment of the enrichment module gets 61-80 with feasible category.

3. Results and Discussion

3.1. Effect of immersion duration and concentration of colchicine to polyploidy on shallots (*Allium ascalonicum* L.)

Shallots have a normal chromosome number of 16 units. The chromosome number of shallot more than 16 indicates polyploidy cells. Polyploidy was induced using colchicine solution in certain concentration and immersion duration treatments. The results of the observation showed the number of chromosomes was 16 and 32, as shown in Figure 1 and 2.

![Figure 1](image1.png) **Figure 1.** Chromosome number of shallots without colchicine treatment (16).

![Figure 2](image2.png) **Figure 2.** Chromosome number of shallots by colchicine treatment (32).
The counting of the chromosome number of shallots cell after being given colchicine treatment are presented in table 3.

**Table 3. Number of chromosome control shallots and after colchicine treatment**

| Concentration (%) | Control | 0.025 | 0.050 | 0.075 |
|-------------------|---------|-------|-------|-------|
| Immersion duration (hours) | 24 | 12 | 18 | 24 | 12 | 18 | 24 | 12 | 18 | 24 |
| Number of chromosome | 16 | 16 | 32 | 32 | 16 | 32 | 32 | 32 | 32 | 32 |
| Number of chromosome | 16 | 16 | 32 | 32 | 16 | 32 | 32 | 32 | 32 | 32 |
| Number of chromosome | 16 | 16 | 32 | 32 | 16 | 32 | 32 | 32 | 32 | 32 |
| Number of chromosome | 16 | 16 | 32 | 32 | 16 | 32 | 32 | 32 | 32 | 32 |
| Number of chromosome | 16 | 16 | 32 | 32 | 16 | 32 | 32 | 32 | 32 | 32 |

Based on the chromosome counting on the shallots cell, polyploidy was obtained from the shallot root that had been treated using colchicine with concentration of 0.025% for 18 and 24 hours, 0.050% for 18 and 24 hours, and 0.075% for 12 hours, 18 hours and 24 hours. Polyploidy cells were induced by immersing the root of shallots using a minimum of 0.025% colchicine concentration for 18 hours. Colchicine generally works effectively at concentrations of 0.01-1% or 0.001-1% with immersion duration ranging from 3-24 hours. However, each type of plant has a different response depending on the organs being treated [14].

Based on the results of observations, the number of chromosomes that obtained was 16 and 32. The number of chromosomes 2n=16 showed normal cells, while the number of chromosomes more than 16 showed polyploidy cells. The level of polyploidy obtained was tetraploid (4n = 32). In some colchicine treatments individuals were still found as diploid cells. Not all cells that get the same colchicine immersion treatment had same chromosome numbers. Colchicine can induce random mutations so that the effect on each individual cell can be different. In addition to 16 and 32, variations in the number of chromosomes 15, 33, 36, and others were found. This variation was possible because squashing of making slide microscopic was done too hard so that the cell wall was broken. It caused the chromosomes were scattered and the counting of chromosome was incorrect [13].

The increase of chromosome number is caused by the concentration of colchicine treatment and critical immersion duration can prevent tubulin polymerization into microtubule (spindle threads) so that chromosomal separation that marks the transition from the metaphase to anaphase stage does not occur [15]. As a result, cell walls are not formed and chromosomes and their duplicates remain in the same cell. However, chromosomes can separate themselves from the centromere and begin the c-anaphase stage followed by the formation of cell walls so that the nucleus "restitution" occurs and contains the double chromosomes number [14].

Morphological analysis was done by observing the treated roots of the shallots by colchicine. Based on observations, the root tip of the shallot had been immersed with colchicine became larger. It is caused by colchicine treatment can increase the number of chromosomes in cells. An increasing of number of chromosomes causes an increasing cell size and root cell diameter so that the root tip is enlarger [8].

3.2. Feasibility of enrichment module

The feasibility of the enrichment module was determined based on the results of the assessment of material experts, media experts, biology teachers, and responses of students.

3.2.1. Assessment of feasibility of enrichment module by material experts

The assessment of appropriateness of the module concept is presented in table 4.
### Table 4. The assessment of enrichment module by material experts

| Material experts | Assessment results of feasibility | Category       |
|------------------|----------------------------------|----------------|
| 1                | 94.74                            | Very feasible  |
| 2                | 95                               | Feasible       |
| Average          | 94.87                            | Very feasible  |

The appropriateness of concept is important to be assessed to determine the quality of teaching materials [2]. The average score of appropriateness of the module was 94.87. It showed feasibility of appropriateness of concepts of the enrichment module included into very feasible category. Suggestions given by material experts were followed up by researchers to revise the module.

### 3.2.2. Assessment of feasibility of enrichment module by media experts and biology teachers

The assessment of enrichment module by media experts and biology teachers was carried out on aspects: content, presentation, language, and graphic. The results of the assessment of enrichment module are presented in tables 5 and 6.

#### Table 5. The assessment of enrichment module by media experts

| Assessment aspects | Assessment results of feasibility | Category       |
|--------------------|----------------------------------|----------------|
| Feasibility of content | 83.33                            | Very feasible  |
| Presentation       | 75                               | Feasible       |
| Language           | 76.92                            | Feasible       |
| Graphic            | 75                               | Feasible       |
| Average            | 77.56                            | Feasible       |

#### Table 6. The assessment of enrichment module by biology teachers

| Assessment aspects | Assessment results of feasibility | Category       |
|--------------------|----------------------------------|----------------|
| Feasibility of content | 81.94                            | Very feasible  |
| Presentation       | 78.91                            | Feasible       |
| Language           | 78.12                            | Feasible       |
| Graphic            | 83.75                            | Very feasible  |
| Average            | 80.68                            | Very feasible  |

The assessment of the content feasibility aspects were material coverage, material accuracy, and material updates. The assessment of the feasibility contents were 83.33 from media experts and 81.94 from biology teachers showed a very feasible category. The suggestions given by biology teachers were necessary to write the scientific name of organisms correctly and need to replace non-HOTS (Higher Order Thinking Skills) questions become HOTS type questions.

The assessment of presentation aspects was used to review whether the contents of the module were in accordance with the needs of students’ learning [9]. The presentation aspects contain the completeness of the module presentation organization, the appropriateness of presentation and the module’s presentation clarity. The aspect of presentation was assessed as 75 by media experts and 78.94 by biology teachers showed feasible category. Suggestions from media experts to the presentation aspects were: 1) to use the conjunctions of concept maps in two phrases, 2) add the
explanatory sentences related to images presented so that there is coherence between images and text, 3) place the morphological analysis first then cytology analysis, and 4) add the vocabulary in the glossary.

The assessment of language aspects contained the suitability of language with the level of students’ thinking, suitability of writing and language with good, correct, and communicative Indonesian language rules, explanations for difficult or unusual terms, and consistency in the use of terms or symbols. Language aspects were categorized as feasible with the assessment results of 76.92 from media experts and 78.12 from biology teachers. Suggestions to language aspects of modules were: 1) need to revise the writing system, 2) use the standard words and effective sentences and 3) need to translate foreign language texts contained in pictures into Indonesian language.

The graphic aspects of teaching material are important because it is related to aesthetics so that it can get students’ attention [15]. The graphic aspects assessment included cover design, content design, content layout, and content typography. The graphic aspects were feasible based on the assessment of media experts and very feasible based on the biology teachers’ assessment. Suggestion from media experts to graphic aspects was need to select the clear and relevant image.

The results of the enrichment module assessment based on media experts and biology teachers in general showed the feasibility of the enrichment module was feasible.

3.2.3. Responses of students to the enrichment module

The results of the assessment based on responses of students are presented in table 7.

| Assessment aspects         | Assessment results of feasibility | Category |
|----------------------------|------------------------------------|----------|
| Easiness of understanding the content | 78.25                              | Feasible |
| Presentation               | 78.75                              | Feasible |
| Language                   | 72.81                              | Feasible |
| Graphic                    | 77.75                              | Feasible |
| Average                    | 78.25                              | Feasible |

Based on the results of responses of students to the enrichment module on the easiness of understanding the material, presentation, language, and graphic aspects the enrichment module was feasible. The suggestions given by students for module revision, among others: 1) aspect of presentation: need to revise incorrect page in the module, 2) language aspects of the module, among others: need to correct typos in some word writing, need to revise some writing were not in accordance with EYD rules and lessen foreign terms, 3) graphic aspects, including: font size is too large, font type should be Times New Roman, the space between lines was too large, the design of each module page was too excessive, and the chromosome image in the background should be removed.

The suggestions given by material experts, media experts, biology teachers, and students were used as references for module revision. The assessment of the feasibility of enrichment modules based on material experts, media experts, biology teachers, and responses of students included in the feasible category. The enrichment module had advantages and disadvantages. The advantages of this enrichment module were: 1) enrichment module can be used anywhere, anytime, according to the style and celerity of students’ learning; 2) module can be used many times for a long period for learning by means of modules given to students but the tasks in the module was written on the copy; 3) enrichment module had an attractive, simple, and not confusing display appearance. The disadvantage of the enrichment module was the module only describes one of the mutation topics, namely polyploidy, and the feasibility of the module was assessed through instruments made by researchers with instrument validation only carried out by an expert.
The enrichment module was expected to be able to develop students’ knowledge of polyploidy on shallots. Students can develop independent learning skills with celerity of learning and how to learn respectively. The advantages of learning using modules are: (1) providing feedback, (2) complete feeling (mastery) (3) goals, (4) motivation, (5) flexibility, (6) lead to cooperation [3].

4. Conclusions
Conclusions of this research were:
1. Immersion duration and concentration of colchicine had effects on polyploidy of shallots (Allium ascalonicum L.). Polyploidy of shallot was induced using colchicine with a minimum concentration of 0.025% for 18 hours.
2. The enrichment module was suitable to use as teaching material based on the assessment of material experts, media experts, biology teachers, and responses of students.

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