Bulgarian Journal of Agricultural Science, 25 (No 5) 2019, 1024–1029

Agronomic characteristic, genetic variability and heritability of mutant samosir shallot M_1V_2 generation irradiated by gamma rays

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Abstract

Sinuraya, M., Rosmayati, R., Hasanuddin, H., & Hanafiah, D. S. (2019). Agronomic characteristic, genetic variability and heritability of mutant samosir shallot M_1V_2 generation irradiated by gamma rays. *Bulgarian Journal of Agricultural Science, 25*(5), 1024–1029

Induced mutagenesis by gamma rays irradiation is an established method especially for plant improvement of vegetatively propagated plants like shallot. In this research, nine mutant populations namely 1 Gy, 2 Gy, 3 Gy, 4 Gy, 5 Gy, 6 Gy, 7 Gy, 8 Gy and 9 Gy were planted along with O Gy (control plants) to evaluate agronomic characteristic, genetic coefficient variation and heritability estimates value of mutant samosir shallot genotype M_1V_2 generation, irradiated by gamma rays. Results showed that almost all mean values of agronomic characters observed on irradiated shallot in M_1V_2 generation were lower than those of control plant. Low doses of gamma rays irradiation increase genetic variation with high heritability estimate values on several characters of samosir shallot. Wide genotypic coefficient of variation (GCV) and high heritability values were obtained in the plant length character on 4 Gy and 9 Gy populations, tiller number on 1 Gy population, leaves number on 1 Gy to 4 Gy and 8 Gy populations, bulb fresh weight on 1 Gy to 3 Gy populations, and dry weight on 1 Gy to 4 Gy populations.

Keywords: agronomic characteristic; genetic variability; genetic heritability; gamma rays; irradiation; M_1V_2; shallot mutant

Introduction

Samosir shallot (*Allium cepa* L. var. ascalonicum Backer) has a great prospect to be developed in Indonesia, for up to now to fulfill requirement of domestic shallot, the government still import it from overseas especially from Thailand and India. The effort to increase shallot bulb yield must be done for the increasing demand is in line with the growth of population.

Samosir shallot was generally developed vegetatively by bulbs. Breeding through a cross to improve genetic diversity is difficult to perform because it is rarely flowering. An effort that can be done to improve genetic variation is through breeding program using physical mutagen with gamma ray irradiation. The effect of physical irradiation is very efficient causing changes in genetic material (Medina et al., 2005). The genetic changes that occur due to irradiation can be seen phenotypically, anatomically, or at the DNA level but can also be unexpressed. The more morphological differences between mutant plants and their control types, the more the changes are due to gamma ray irradiation (Amjad & Anjum, 2002).

Induction of mutation by gamma rays irradiation is an alternative to obtain a new genetic variation faster than breeding hybridization. In addition, induce mutation in vegetative part of the plants with gamma rays showed a better results than chemical mutagen (Aisyah, 2006). Increasing genetic diversity and improved varieties for one or two traits can be done through induction of genetic mutations. Mutation is the ultimate source of variability in organisms (Khan & Tyagi, 2010).

Increasing the genetic diversity of onion crops will facilitate the process of plant selection as it provides a greater opportunity to obtain a plant with the desired characters. According to Surya and Hoeman (2009), the success of plant breeding programs is highly dependent on the inherited genetic diversity of characters and the ability to sort out the superior genotypes in the selection process. In every plant breeding program, evaluation and selection are the main activities after obtaining high genetic diversity.

In the previous study, we conducted research to evaluate radiosensitivity of local samosir shallot on gamma ray irradiation, using doses of gamma irradiation range from 0 to 20 Gy. It was found that radiosensitivity of local samosir shallot on gamma rays is 11.6 Gy (Sinuraya et al., 2015). Research was continued to evaluate the effect of gamma rays irradiation on morphological and agronomical characters of samosir shallot in M_1V_1 generation (Sinuraya et al., 2017). In this study, the research continued in M_1V_2 generation to determine the heritability and genetic variability values of samosir shallot mutant M_1V_2 generation irradiated by gamma rays.

Material and Methods

This research was conducted in Medan, North Sumatra Province, which is about 25 m above the sea level. All bulbs yielded from each treatment in M_1V_1 generation after having undergone dormancy period of 2.5 months were replanted with spacing 20 cm × 20 cm for generation advance in an experimental field. All technical cultivation such as watering, fertilizing, weeding and pest control were carried out during the period of plant growth. Each plant then was harvested individually, giving rise to M_1V_2 genotype.

The observed variables were plant length measured from the base of the leaf to the longest end of the leaf, leaf number, and tiller number per hill observed at sixth week, bulb fresh weight per hill weighted at harvest time, and bulb dry weight per hill weighted two weeks after harvest and air dried.

Data were analyzed by calculating the mean value of each quantitative character observed. The difference between the irradiated dose treatment and the control treatment was tested with t-test using minitab 16. Data analysis was followed to quantify phenotypes and environmental variations and to estimate the genotypes variation, heritability and genetic variability coefficient values of each population according to the irradiated dose. Genetic diversity in M_1V_2 generation was calculated using the following formula:

$$\sigma^2 = \frac{(\sum x^2) - [(\sum x)^2/n]}{n-1}$$

$\sigma^2 M_2 = \sigma^2 p$;

$\sigma^2 p = \sigma^2 g + \sigma^2 e$

$\sigma^2 g = \sigma^2 p - \sigma^2 e = \sigma^2 M_1V_2 - \sigma^2 M_0$

σ^2 = variance; n = number of population; $\sigma^2 p$ = phenotype variance; $\sigma^2 g$ = genotype variance; $\sigma^2 e$ = environmental variance

$\sigma^2 M_1V_2 = M_1V_2$ population variance

$\sigma^2 M_0 = M_0$ population variance

Heritability values were calculated using the following formula:

$$h^2 = \frac{\sigma^2_g}{\sigma^2_P} \text{ (Singh \& Chaundhary, 1977)}$$

$\sigma^2 p = \sigma^2 g + \sigma^2 e$

$$h^2 = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2 e}$$

Heritability value criteria:

$h^2 > 0.5$: high heritability value

$0.2 \leq h^2 \leq 0.5$: moderate heritability value

$h^2 < 0.2$: low heritability value

Genetic variation was determined based on the coefficient of genetic variation (CGV) with the formula:

$$CGV = \frac{\sigma_g}{\bar{X}} \times 100\% \text{ (Singh \& Chaundhary, 1977)}$$

σ_g = genotypic standard deviation; $\bar{X}$ = character means

Results and Discussion

The results showed differential response of genotype characters observed in M_1V_2 generation population with respect to different doses of gamma rays. Quantitative analysis of the treated plants showed wide range of significant phenotypic variations (Table 1).

Changes in mean values of plant length and leaf number characters were recorded in all irradiated populations and were significantly different from control population. Irradiated plants were shorter and have fewer leaf than control plants except for 1 Gy population.

The length of the plant, the number of tillers and the leaf number in 5 Gy populations were not observed to avoid contamination, for some plants were attacked by disease.

In general, the yield of irradiated populations (bulb dry weight) was lower than untreated population. Mean values of bulb fresh weight and bulb dry weight of irradiated populations (except for 8 Gy population) were significantly differ-

Table 1.The effect of different doses of gamma rays on agronomic characters in M_1V2 generation

Irradiation doses	Plant length/plant	Tiller number/plant	Leaf number/plant	Bulb fresh weight/plant	Bulb dry weight/plant
Gy	cm	tiller	blade	g	g
0	30.57±3.35	4.88±1.22	18.40 ±3.53	20.67±3.22	18.01±2.90
1	29.74±3.95	6.34**±2.25	20.31±7.89	15.96**±8.31	13.19**±7.78
2	25.19**±3.51	4.24**±1.47	14.36**±5.14	17.84*± 8.11	14.12**±8.01
3	23.14**±4.19	4.09**±1.63	13.43**±6.02	10.93**±6.20	8.97**±5.76
4	23.12**±4.79	4.10**±1.22	13.38**±5.60	13.84**±5.76	11.48**±5.19
5	–	–	–	9.11**±4.62	6.74**±4.09
6	21.48**±4.04	3.93**±1.25	10.62**±3.70	7.03**±3.29	5.50**±3.64
7	18.78**±4.08	2.76**±0.93	8.58**±2.79	4.3	1.7
8	19.57**±4.24	2.73**±1.16	10.55**±5.28	14.45±1.63	12.20±1.98
9	18.07**±4.89	3.40**±1.47	10.7**±4.66	5.68**±0.76	4.17**±0.71

Note: * and ** = significantly different from the control population (0 Gy) at 5% and 1% level by t test

ent from untreated population (Fig. 1). Plants irradiated with dose 7 Gy only a plant succeeds in yielding very small bulbs in M_1V_2 generation (Fig. 2), so it could not be incorporated into the data processing and cannot be included anymore for subsequent cultivation.

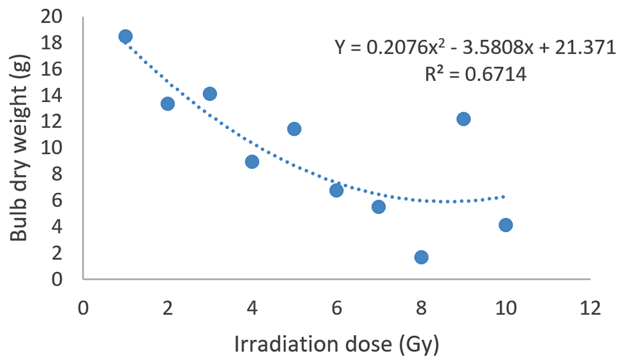

Fig. 1. Bulb dry weight of shallot irradiated by different doses of γ-irradiation

The decrease in all quantitative characters observed might occurred as a result of the ongoing physiological damage transferred from M_1V_1 to M_1V_2 generation, therefore selection has not been performed on this generation. Akpaniwo et al. (2015) reported similar results obtained in their research in Pumpkin (*Telfairia Occidentalis*, Hook. F.) irradiated by X rays, where in M_1V_2 generation almost all mean values of irradiated plant characters observed were lower than the mean value of untreated plant. Similar results are reported by Ahmad and Qureshi (1992) in corn (*Zea mays* L) and Din *et al*. (2003) in *Triticum aestivum* L.

The results of the plant length, tiller number, leaf number, and bulb weight in Table 1 showed that M_1V_2 generation was undergoing segregation, characterized by the high standard deviation of each genotype. The highest standard deviation values for plant length characters were obtained in 9 Gy genotype population, also obtained on the tiller number, leaf number, and bulb fresh weight of genotype populations irradiated with 1 Gy, and the bulb dry weight of population irra-

Fig. 2. Performance of bulbs yielded in M_1V_2 generation: a – control; b – bulbs yielded in 7 Gy

diated with 2 Gy. Higher standard deviation values indicate the presence of variations due to the effects of gamma-ray radiation, otherwise the near-zero standard deviation value shows more uniform data. Due to the diversity it is possible to select the desired mutant genotypes according to the purpose of breeding (Arwin et al., 2012).

Heritability estimates value in the broad sense and genetic variation of M_1V_2 generation were presented in Table 2. One of the genetic parameters considered for selecting the characters in selection is heritability value (Barmawi et al., 2013). Heritability estimated value plays an important role to determine the selection to be performed on a character. High heritability estimates indicate that the genetic influence is higher when compared to environmental factors, so it is expected that the emerging phenotype diversity is an expression of genetic factors contained in it, otherwise the herita-

Table 2. Genetic variation of M_1V_2 plants at different gamma irradiation dose

Irradiation doses	Characters	σ^2p	σ^2g	h^2	h^2 criteria	CVG	CGV criteria
1 Gy	Plant length	15.59	4.36	0.28	moderate	7.03	narrow
	Tiller number	5.07	3.58	0.71	high	29.84	wide
	Leaf number	62.22	49.76	0.80	high	34.76	wide
	Bulb fresh weight	78.57	59.46	0.76	high	47.999	wide
	Dried bulb weight	65.12	53.29	0.82	high	60.40	wide
2 Gy	Plant length	12.30	1.07	0.09	low	4.11	narrow
	Tiller number	2.16	0.67	0.31	moderate	19.30	moderate
	Leaf number	26.43	13.97	0.53	high	26.03	wide
	Bulb fresh weight	65.70	46.60	0.71	high	38.27	wide
	Dried bulb weight	64.23	52.40	0.82	high	56.77	wide
3 Gy	Plant length	17.59	6.36	0.36	moderate	10.90	moderate
	Tiller number	2.65	1.16	0.44	moderate	26.37	wide
	Leaf number	36.25	23.79	0.66	high	36.32	wide
	Bulb fresh weight	38.43	19.32	0.50	high	40.22	wide
	Dried bulb weight	33.22	21.39	0.64	high	64.23	wide
4 Gy	Plant length	22.93	11.71	0.51	high	14.80	wide
	Tiller number	1.50	0.01	0.01	low	2.57	narrow
	Leaf number	31.39	18.94	0.60	high	32.55	wide
	Bulb fresh weight	33.15	14.05	0.42	moderate	27.08	moderate
	Dried bulb weight	26.93	15.10	0.56	high	33.86	moderate
5 Gy	Bulb fresh weight	21.32	2.22	0.10	low	16.34	narrow
	Dried bulb weight	16.70	4.87	0.29	moderate	60.64	wide
6 Gy	Plant length	16.32	5.10	0.31	moderate	10.52	moderate
	Tiller number	1.57	0.09	0.06	low	7.56	narrow
	Leaf number	13.73	1.27	0.09	low	10.60	narrow
	Bulb fresh weight	10.85	-8.25	0	low	0	narrow
	Dried bulb weight	13.28	1.45	0.11	low	66.27	wide
8 Gy	Plant length	17.98	6.76	0.38	moderate	13.29	moderate
	Tiller number	1.35	-0.13	0	low	0	narrow
	Leaf number	27.88	15.42	0.55	high	37.24	wide
	Bulb fresh weight	2.65	-11.46	0	low	0	narrow
	Dried bulb weight	3.92	-7.91	0	low	0	narrow
9 Gy	Plant length	23.94	12.72	0.53	high	19.74	wide
	Tiller number	2.15	0.66	0.31	moderate	23.91	wide
	Leaf number	17.00	4.54	0.27	moderate	22.44	moderate
	Bulb fresh weight	0.58	-18.42	0	low	0	narrow
	Dried bulb weight	0.50	-11.33	0	low	0	narrow

Note: σ^2p = phenotype variance; σ^2g = genotype variance; h^2 = heritability value; CGV = coefficient genetic variation bility value low to medium indicates that the influence of environmental factors is higher than the genetic factors, so that the diversity that appears more influenced by environmental factors.

Based on the results of the study, high heritability estimate values were obtained on tiller number character in 1 Gy population, leaf number character in 1 Gy to 4 Gy and 8 Gy populations, bulb fresh weight in 1 Gy to 3 Gy populations, and bulb dry weight in 1 Gy to 4 Gy populations. The population of M_1V_2 was a segregated population after being irradiated by gamma rays, where each individual of the randomly irradiated population probably has a mutated gene so that each of the irradiated population genotypes has a different character. Pavadai et al., (2010) stated that the diversity of quantitative characters in the 2nd generation is due to the segregation of irradiated populations.

Genetic variation was determined based on the coefficient genetic variation (CGV). Genotypic coefficient of variation (CGV) values obtained in M_1V_2, ranged from 0 to 66.27 with narrow to wide criteria. Wide CGV values were obtained on the plant length in 4 Gy (14.8) and 9 Gy (19.74) populations, tiller number in 1 Gy (29.84) and 3 Gy (26.37) populations, leaf number in 1 Gy, 2 Gy, 3 Gy, 4 Gy, and 8 Gy populations which range value was 26.03 to 37.24, bulb fresh weight in 1 Gy, 2 Gy, and 3 Gy populations which range CGV value was 38.27 to 47.99, and bulb dry weight in 1 Gy, 2 Gy and 3 Gy population which range value was 56.77 to 64.23.

According to Sa'diyah (2011), wide genotypic coefficient of variation values followed by high heritability estimate values, indicate that characters performed are more determined by genetic factors. In addition, Syukur et al. (2010) also stated that selection will be effective if the population has wide genetic diversity and high heritability. The results of this study indicated that wide genotypic coefficient of variation (GCV) and high heritability values were obtained in the plant length character on 4 Gy and 9 Gy populations, tiller number on 1 Gy population, leaves number on 1 Gy until 4 Gy and 8 Gy populations, bulb fresh weight on 1 Gy to 3 Gy populations, and dry weight on 1 Gy to 4 Gy populations.

Conclusions

Almost all mean values of agronomic characters observed of irradiated shallot in M_1V_2 generation were lower than those of control plant, and it was considered as a result of the ongoing physiological damage transferred from M_1V_1 to M_1V_2 generation. The higher doses of gamma rays, the lower mean values of character observed.

Low doses of gamma rays irradiation could increase genetic variation with high heritability estimate values on several characters of samosir shallot. Wide genetic variation with high heritability estimate values were obtained in the range of irradiation doses from 1 Gy to 4 Gy.

Acknowledgments

This research was supported by the Ministry of Research, Technology and Higher Education (Kemenristek DIKTI), Indonesia. We respectfully thank Kemenristek DIKTI for the provided financial assistance.

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Received: July, 13, 2018; *Accepted:* October, 22, 2018; *Published:* October, 31, 2019