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Yield Components of Some Sesame Mutant Populations Induced by Gamma Irradiation

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ABSTRACT

Sesame is an producing seed whose oil is commercially needed. Breeding attempts to improve the productivity of sesame and yield components are induction of gamma ray irradiation mutations (Co-60). This study was aimed to identify effects of induced mutation by gamma rays irradiation in quantitative characteristics and yield of sesame in M_4 generation originated from local cultivars. Two types of sesame (black and white) are irradiated with eight doses (100-800 Gy) of Co-60. The result showed a high variation in almost all morphological characters and modified the character of stem height from base to first branch, number of capsules per plant, biomass yield per plant, and seed yield per plant. Sesame irradiated with 600 Gy Co-60 doses has a beneficial effect on the number of capsules (black:120.23; white: 255.23, respectively) and the weight of 1000 seeds (black:3.63 g; white: 4.55 g, respectively). Genotypic Coefficient of Variation in M_4 generation were recorded for high value for characters number of primary branches (30.16%), stem height from base to the first branch (30.96%), stem height from base to first capsule (14.82%), number of secondary branches (53.64%), number of nodes to first flower (72.66%), number of capsules/plant (44.90%), biomass yield/plant (28.37%), and seed yield/plant (36.68%). Genetic variability of plant population is very important for plant breeding program and to sustain level of high productivity.

Keywords: *Sesamum indicum* L., yield components, gamma irradiation.

Komponen Hasil Beberapa Populasi Mutan Wijen yang Diinduksi oleh Iradiasi Gamma

ABSTRAK

Wijen adalah tanaman penghasil biji yang minyaknya dibutuhkan secara komersial. Upaya pemuliaan untuk meningkatkan produktivitas wijen dan komponen hasil adalah dengan induksi mutasi iradiasi sinar gamma (Co-60). Penelitian ini bertujuan mengidentifikasi pengaruh induksi mutasi iradiasi sinar gamma pada karakter kuantitatif dan hasil pada generasi M_4 wijen yang berasal dari kultivar lokal. Dua jenis wijen (hitam dan putih) diiradiasi dengan delapan dosis (100-800 Gy) Co-60. Sejumlah pengaruh mutasi wijen berhasil menunjukkan variasi yang tinggi pada hampir semua ciri morfologi dan memodifikasi karakter tinggi batang dari pangkal ke cabang pertama, jumlah kapsul/tanaman, hasil biomassa/tanaman dan hasil biji/tanaman. Wijen yang diiradiasi dengan dosis 600 Gy Co-60 memiliki efek menguntungkan pada jumlah kapsul (hitam:120,23; putih: 255,23) dan berat karakter 1000 biji (hitam:3,63 g; putih: 4,55 g). Koefisien Keragaman Genotipik pada generasi M_4 dicatat nilai tertinggi pada karakter jumlah cabang primer (30,16%), tinggi batang dari pangkal ke cabang pertama (30,96%), tinggi batang ke kapsul pertama (14,82%), jumlah cabang sekunder (53,64%), jumlah ruas ke bunga pertama (72,66%), jumlah kapsul/tanaman (44,90%), hasil biomassa/tanaman

(28,37%), dan hasil biji/tanaman (36,68%). Keragaman genetik dari populasi tanaman sangat penting untuk program pemuliaan tanaman dan mempertahankan produktivitas yang tinggi.

Kata kunci: *Sesamum indicum* L., komponen hasil, iradiasi gamma.

INTRODUCTION

Sesame (*Sesamum indicum* is a crop that produce high nutritive quality and quantity of oil ranging from 40 to 63% (Uzun et al., 2008). This oil is rich in antioxidants and has a significant amount of oleic and linoleic acids. Sesame especially grows well and gives high yields in both tropical and temperate climates (Morris, 2009). Sesame populations often exist as a composite of various homozygous individuals (Furat & Uzun, 2010). Despite its long history and nutritional value, the crop has low yielding capacity compared to other oilseed crops, mainly due to its low harvest index, susceptibility to diseases, seed shattering and indeterminate growth habit (Yol & Uzun, 2012). Assembling of varieties to obtain new improved varieties with desirable traits, needs to be supported by germplasm with high genetic diversity (Purwati et al., 2015).

Induced mutation both in seeds and vegetative propagated crops is one of the techniques employed in the improvement of traits of economic plants. It facilitates the isolation and identification which would ultimately help in designing crops with improved yield, increased stress tolerance and longer life span as well as reduced agronomic inputs usage (Ahloowali & Maluszynski, 2001)). Mutation breeding has been perceived as an important tool to foster additional variability in qualitatively and quantitatively inherited traits in a number of crop plants (Ahloowali & Maluszynski, 2001).

An effort to increase sesame production through breeding with selection is made possible by irradiation induced polygenic characteristics with a Co-60 source. Several studies of sesame irradiation have been performed using several dosages gamma ray. Pathirana (1992) reported that gamma ray teretmens of 450 Gy and 600 Gy produced more M4 lines tolerant to the disease. Research of Pathirana & Subasinghe (1993) also proved that the most suitable doses of gamma rays for seed irradiation in mutation breeding experiment using locally recommended sesame cultivars line were in the range of 100–750 Gy to produce weight of fresh seedlings and dry weight of roots or shoots with higher coefficient of variation. Cagirgan (2001) states that M3 irradiated sesame cultivars in the gamma dose range 150–750 Gy are able to produce unique induction mutants, such as closed capsules. Boureima et al., (2016) reported that induction of 300 and 400 Gy in 19 sesame strains was able to produce cultivars with plant height and stem length characteristics for the first capsule properties as an indirect criterion for dry resistant sesame crop.

Mutation in gene level causes alterations in the structure and position of gene on chromosome called point mutation. This results in the alteration of phenotype of an organism. Changes in basic chromosome number either any addition of loss of any set or parts of them cause appearance of new characteristics disappearance. Once the mutation in gene or chromosomal level is firmly established in populations, they are subjected to natural or artificial selection. Mutation breeding is the tool to create variability in crop population and to make selection in the population easier to bring about further improvement in crop. In general mutation plant breeding has been playing a key role in self-pollinated crop with limit variability (Ambavane et al., 2015). The effect of induced mutation by gamma rays irradiation on sesame local population would improve sesame breeding materials. Therefore, the present study was aimed to identify effects of induced mutation by gamma rays irradiation in quantitative characteristics and yield of M_4 sesame generation originated from local cultivars.

MATERIALS AND METHODS

A field experiment was conducted in Sleman, Yogyakarta, Indonesia (7°16′ N; 110°21′ E; altitude 193 m above sea level), in March-August 2015. The soil of the experimental site was an inceptisol which contained of 9.73% clay, 33.63% silt and 56.64% sand with the Soil pH is about 6.34.

This study used 18 local black and white types of M_4 sesame lines. The M_4 generations were originally selected from M_2 generations that were screened on 6 g/l NaCl for salinity tolerance. This study aims to determine a dose of sesame screening to salinity stress and performance of some sesame M_3 generations from the screening using the selected screening dose. The result of this study showed that the performance of observed characteristics from M_3 generation was not significantly different from the original population, both in white and black sesames. Survival individual plants were harvested together for each dose to produce M_3 seed materials. The M_4 generations was than exploited to identify effect of induced mutation in quantitative characteristics.

Treatments applied were eight doses (100–800 Gy) of gamma rays (Co-60) and the effects were were evaluated using completely randomized design. Each line was grown in four row of 5 m length at a distance of 50 cm between the rows and 25 cm between the plants within the rows. Sesame was sown at two seeds per hole to ensure adequate crop stand. A doze of nitrogen, phosphorus, and potassium was applied as composite fertilizers at sowing (100 kg/ha respectively). Weeds were controlled manually every three weeks and pesticides were not used in the experiments. Harvesting is done after the plants showed yellowing pods as much as 80 % and leaf fall over already.

Quantitative observations were recorded on yield related components of sesame (plant height, number of primary branches, number of secondary branches, number of nodes/plant, number of nodes to first flower, stem height from base to first branch, stem height from base to first capsule, number of capsules/plant, biomass yield/plant, 1000-seed weight and seed yield/plant) according to (IPGRI & NBPGR, 2004). Data obtained on growth, yield components and yield were subjected for statistical analysis and interpretation. Statistical parameters such as mean and standard deviation were analyzed according to the method described by Steel & Torrie (1980) and Gomez & Gomez (1984). All data obtained were subjected to analysis of variance using SAS statistical software (9.1) (Littell et al., 2006). Duncan's multiple range tests was used to compare the means. Considering that all tested lines were genetically uniform, variance error (σ_e^2) will be purely a random environmental variance (MSe). The mean of squares among lines will consist of the variances which are attributable to lines differences (i.e. genotypic differences) and due to environmental variation among individuals of each line. Thus variance genotypes would be (Singh & Chaudhary, 1977):

$$\sigma_g^2 = \frac{\mathrm{MSv} - \mathrm{MSe}}{r}$$

The phenotypic variance, i.e. σ^2_p will be equal to $\sigma_g^2 + \sigma_e^2$. Genetic variability for all properties is calculated from the phenotypic and genotypic coefficient of variation (Singh & Chaudhary, 1977). Phenotypic coefficient of variation (PCV):

$$\mathrm{PCV} = \frac{\sqrt{\sigma_p^2}}{\bar{x}} \text{ x } 100$$

Genotypic coefficient of variation (GCV):

$$\mathrm{GCV} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \text{ x } 100$$

The PCV and GCV were than classified for high, moderate and small based on Johnson et al., (1955). The phenotypic coefficient of variation is divided into three major categories: high (PCV>50%), moderate (25%<PCV≤50%) and small (PCV≤25%). The genotypic coefficient of variation is classified into three major categories: high (GCV>14.5%), moderate (5%<GCV≤14.5%) and small (GCV≤5%).

RESULTS AND DISCUSSION

The mutagenic effect of gamma rays irradiation to improve seed yield in seventeen genotype of sesame was investigated. The genotype effect on the expression of morphological traits following irradiation is given in Table 1.

Table 1. Mean squares from analysis of variance for morphological traits in M_4 generation sesame

Characteristics		MSe
Plant height (cm)	Genotype	10933.09**
	Error	684.99
Number of primary branches	Genotype	192.99**
	Error	2.51
Number of secondary branches	Genotype	640.79**
	Error	11.03
Number of nodes/plant	Genotype	513.88**
	Error	24.34
Number of nodes to first flower	Genotype	441.00**
	Error	1.45
Stem height from base to first branch (cm)	Genotype	1355.66**
	Error	22.03
Stem height from base to first capsule (cm)	Genotype	7417.62**
	Error	131.45
Number of capsules/ plant	Genotype	259001.86**
	Error	6665.61
Biomass yield/plant (g)	Genotype	67660.11**
	Error	3910.69
1000-seed weight (g)	Genotype	7.35**
	Error	0.32
Seed yield/plant (g)	Genotype	4410.27**
	Error	182.71

** Highly significant difference (p≤00.1); MSe=the mean squares within lines; Degree of Freedom Genotype=16; Error=1228; Corrected total=1244.

The result Table 1 obtained from the M_4 generation analysis of variance indicated a highly significant improvement (p≤00.1) in the effect of the mutagen on all the selected traits of sesame. The analysis of variance revealed significant difference among the genotypes for each character, indicating the presence of considerable variability among the genotypes for the character studied.

The variation observed among the seventeen sesame mutant lines for all quantitative descriptors are presented in Table 2. The quantitative observations were recorded on plant height at 120 days after sowing, the lowest plant height of M_4 was observed on treatment gamma rays 300 Gy on black sesame type (178.05 cm), while the highest was on treatment gamma rays 400 Gy on the white type (225.71 cm) compared to control (194.35 cm). The gamma rays treatments, in general, induced a shift in the mean value important characters. both in the lower and higher direction. The magnitude of variation was not the same for all the characters. Plant height are identified as important yield components leads (Begum & Dasgupta, 2014) to a higher significant direction on black sesame type (600 and 700 Gy treatments) and on the white type (300, 400 and 800 Gy treatments). This was in agreement with the findings reported by Hoballah (1999), that the increased in plant height of sesame is due to irradiation mutagenesis. But at the same time, the results in an decrease in treatment 300 Gy on black sesame type. In negative directions, reduction was conspicuous in plant height due to induced mutation also reported by MaluszynskiI et al., (2001).secondary branches after mutation treatments showed decrease value compared to control.

The variation observed among tested sesame mutant lines for all quantitative descriptors are presented in Table 2. The quantitative observations were recorded on plant height at 120 days after sowing, the

Table 2. The morphological variation of M_4 generation sesame traits following gamma irradiation

Type	Treat ments	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of nodes per plant	Number of nodes to first flower	Stem height from base to first branch (cm)	Stem height from base to first capsule (cm)	Number of capsules per plant	Biomass yield per plant (g)	1000-seed weight (g)	Seed yield per plant (g)
Black	Control	194.35 def	5.57 abc	9.21 a	25.51 b	4.86 e-h	6.80 fg	47.60 def	219.18b	155.43abc	3.68cd	25.05 ef
	100 Gy	204.75 bcd	5.28 bcd	7.11 cd	23.96 bc	5.21 c-f	7.32 efg	53.60 bc	179.21cde	165.83ab	3.63cde	51.71 a
	200 Gy	200.77 b-e	5.96 ab	7.87 abc	24.46 b	4.60 h	7.52 efg	51.61 bcd	178.73cde	115.61de	3.53def	24.58 ef
	300 Gy	178.05 g	5.73 ab	8.82 ab	22.32 cd	5.32 cde	7.05 efg	46.18efg	267.27a	180.82a	3.67cd	34.18 cd
	400 Gy	195.03 def	4.66 d	5.86 de	20.83 d	4.57 h	7.86 d-g	52.29bcd	274.57a	137.31cd	3.97b	30.08 de
	500 Gy	200.69 b-e	2.63 e	0.72 h	24.90 b	4.77f gh	9.20 cde	45.54efg	74.95g	101.83efg	3.74bcd	21.45 fg
	600 Gy	222.05 a	2.87 e	2.32 g	25.38 b	4.75 fgh	12.66 b	52.26bcd	120.23f	100.39efg	3.63cde	17.54g
	700 Gy	207.06 bc	1.22 f	0.17 h	27.84 a	4.35 h	8.75 def	42.50g	68.81g	90.98efg	3.82bc	20.32fg
	800 Gy	190.65 ef	5.24 bcd	5.41 ef	24.81 b	4.74 gh	10.81 bc	50.44cde	149.98ef	112.46def	3.72cd	22.29fg
White	100 Gy	199.47 cde	4.74 d	5.47 ef	21.65 d	4.65 gh	7.39 efg	50.32cde	167.60de	149.61bc	3.62cde	30.95cd
	200 Gy	192.61 ef	5.82 ab	7.61 bc	21.81 d	5.18 d-g	7.56d-g	49.00cde	189.43bcd	103.18efg	3.83bc	22.89fg
	300 Gy	211.80 b	4.94 cd	4.56 ef	21.03 d	6.11 b	19.60a	69.04a	84.40g	80.64g	3.40ef	17.83g
	400 Gy	225.71 a	5.95 ab	4.76 ef	21.94 cd	5.72 bc	11.72b	72.43a	120.91f	80.60g	3.40ef	24.28f
	500 Gy	186.07f g	5.86 ab	8.76 ab	21.72 d	5.44 cd	9.15cde	43.24fg	152.55ef	86.98fg	2.83h	20.53fg
	600 Gy	184.04f g	5.85 ab	8.31 abc	14.96 e	21.27 a	6.31g	49.31cde	255.23a	156.58abc	4.55a	36.09c
	700 Gy	193.94 def	6.20 a	4.16 f	20.75 d	4.81 e-h	9.64cd	55.86b	122.96f	137.04cd	3.15g	31.68cd
	800 Gy	208.77 bc	6.12 a	5.76 de	25.18 b	5.59 cd	6.24g	52.71bcd	207.53bc	164.59abc	3.29fg	43.17b
	Mean	202.83	4.68	5.07	23.26	5.44	10.50	53.52	140.34	111.26	3.56	24.53
	SD	28.58	2.23	4.37	5.54	2.67	6.26	15.01	99.55	68.78	0.64	15.40
	PCV (%)	14.23	45.34	**84.60**	24.34	**75.97**	**54.40**	26.05	**73.49**	**62.96**	18.53	**66.19**
		(small)	(moderate)	(high)	(small)	(high)	(high)	(moderate)	(high)	(high)	(small)	(high)
	GCV (%)	5.99	**30.16**	**53.64**	11.91	**72.66**	**30.96**	**14.82**	**44.90**	**28.37**	9.83	**36.68**
		(moderate)	(high)	(high)	(moderate)	(high)	(high)	(high)	(high)	(high)	(moderate)	(high)

Means within the columns with the same letter(s) are not significantly different at p≤0.05 (Duncan test); Highlighted values are those significantly different with control (decrease: yellow for black type; green for white type; increase: purple for both types); SD=standard deviation; PCV=phenotypic coefficient of variation; GCV=genotypic coefficient of variation.

lowest plant height of M_4 was observed on treatment gamma rays 300 Gy on black sesame type (178.05 cm), while the highest was on treatment gamma rays 400 Gy on the white type (225.71 cm) compared to control (194.35 cm). The gamma rays treatments, in general, induced a shift in the mean value important characters. both in the lower and higher direction. The magnitude of variation was not the same for all the characters. Plant height are identified as important yield components leads (Begum & Dasgupta, 2014) to a higher significant direction on black sesame type (600 and 700 Gy treatments) and on the white type (300, 400 and 800 Gy treatments). This was in agreement with the findings reported by Hoballah (1999), that the increased in plant height of sesame is due to irradiation mutagenesis. However, at the same time, the results also showed that there were a decrease in treatment 300 Gy on black sesame type. In negative directions, reduction was conspicuous in plant height due to induced mutation also reported by MaluszynskiI et al., (2001).

Based on the overall average values, the different values from the controls were observed for sesame black type treated by gamma rays 700 Gy. This treatment resulted the lowest value on the number of primary branches (1.22) and number of secondary branches (0.17) compared to control (5.57 and 9.21). Sesame white types irradiated with dose 100 Gy of Co-60 showed a negative effect on the number of primary branches (4.74) and number of secondary branches (5.47). These values were significantly lower than those of control.

Number of nodes per plant had the highest value on sesame black type treated by gamma rays 700 Gy (27.84) compared to control (25.51). Number of nodes to first flower had the highest value on the 600 Gy treated (21.27) on sesame white types. The effect of mutation on the character of the stem height from the base to the first branch should be known to know the strength of the plant, the best result obtained from 600 Gy irradiation on sesame black types (12.66 cm) and 300 gy irradiation on sesame white types (19.60 cm) compared to control (6.80 cm).

One of the important goals in sesame breeding is to improve varieties with high seed yield. Sesame black types irradiated with dose 400 Gy of gamma rays had beneficial effect on the number of capsules per plant (274.57) and 1000-seed weight (3.97 g). While, sesame white types irradiated with dose 600 Gy of Co-60 had beneficial effect on the number of capsules per plant (255.23), 1000-seed weight (4.55 g), and seed yield per plant (g) (36.09 g). Yol et al., (2010) and Nura et al., (2013) also reported that among the most important traits were number of capsules per plant and 1000-seed weight which positively correlated to seed yield per plant.

Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) in M_4 generation were recorded for high value for stem height from base to the first branch (30.96% and 54.40%, respectively), number of capsules/plant (44.90% and 73.49%), biomass yield/plant (28.37% and 62.96%), and seed yield/plant (36.68% and 66.19%) (Tabel 2). The genotype with a wide range of variation for quantitative traits and extensive genetic variation showed as potential genotypes. High genetic variability of plant population is very important for plant breeding program and developing new varieties to sustain level of high productivity. Large value of GCV on characters number of capsules/plant and seed yield/plant in sesame, potentially used as the basis of selection to improve the nature of sesame in an effort to improve the sesame yield. The importance to create new mutants is potentially improve the nature of sesame is similar with the results of Sumanthi & Muralidharan (2010); Narayanan & Murugan (2013), and Adikadarsih et al., (2015).

CONCLUSION

Gamma rays irradiation induced mutation with a high genetic level on sesame yield and its yield components. The induction provided a huge scope for selection of promising genotypes with different agronomic traits from the present collection pool. A high variation as novel recombinant was observed in almost all traits except stem height from base to first branch and it to first capsule. Induced mutagenesis could be used as a successfully method to develop new mutant varieties of sesame with superior morphological retention and high seed yield. Induced mutagenesis of sesame seeds by irradiation with 600 Gy Co-60 resulted a potential superior lines.

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