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Morphological Characteristics and Productivity of Guinea Grass (*Panicum maximum* CV Purple Guinea) Irradiated with Gamma-Ray

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ABSTRACT

Mutation breeding using gamma irradiation is one of the alternative ways to increase the variability and productivity of Guinea grass (*Panicum maximum* cv Purple guinea). The aimed of the study was to determine the dosage of gamma irradiation and morphological characters for high-yielding of the putative mutant of guinea grass. The Guinea grass seeds was irradiated by gamma-ray. The treatment was 8 doses of gamma irradiation and control (non-irradiated). The treatment was arranged in a randomized complete block design (RCBD) with 3 replications. The study was conducted for 3 generations, which were mutants 1 (M1), mutant 1 vegetative 1 (M1V1), and mutant 1 vegetative 2 (M1V2). The results showed that the gamma irradiation dose affected variables observed. The variables affected in M1 were fresh and dry weights of shoot, the number of tillers, and the length of the leaves. Whereas in the populations of M1V1 and M1V2, almost all characters were influenced by gamma irradiation, except stem diameter, length of internode, and leaf length. Gamma irradiation doses of 175 x 2 Gy, 250 Gy and 350 Gy in M1V1 and 100 x 2 Gy, 150x2 Gy and 175 x 2 Gy in M1V2 produced the high number of tillers, fresh and dry shoot weights. Heritability value and GCV of number of tillers, fresh and dry weight of shoot were high for M1V1 and M1V2 populations. These results indicated that gamma-ray irradiation can be applied to increase productivity and genetic variability of Guinea grass. The highest forage production was obtained at a dose of 100 x 2 Gy, which was 625 g/plant.

Keywords: Panicum maximum, gamma rays, breeding, mutation

INTRODUCTION

The productivity of forage crop can be improved by combining plant cultivation technology and plant breeding. Guinea grass (*Panicum maximum* cv Purple Guinea) is widely used by farmers in Indonesia. The crude protein of Guinea grass is higher than elephant grass, although the dry matter production is lower (Ukanwoko & Igwe, 2012). Crude protein content of Guinea grass is 14.1% in hay and 13.6% in silage (Santoso & Hariadi, 2008). The range of average productivity is 9.59-12.43 tons DM/ha/year with a 60-day cutting interval (Hare *et al*., 2013). As pasture, carrying capacity of Guinea grass was 8.8 animal units with an increase in body weight of 1200 kg/ha/year (Vicente-Chandler, 2001). This grass is also considered a high-quality grass, adapting well to soils with medium fertility and rainfall of more than 600 mm (Jank *et al*., 2010).

Mutation induction using gamma irradiation has been widely used to increase the variability and productivity of a plant (Saha & Paul, 2019). Gamma-ray are the most efficient ionizing irradiation to create mutants in plants because they can induce a high number of mutations. In addition, it can modify physiological characteristics to develop varieties that are agriculturally and economically significant and contain high productivity potential (Eroglu *et al*., 2007). The use of gamma-ray to increase plant productivity was carried out on rice (Sobrizal, 2016), Soybean (Asadi, 2013), *Psoralea corylifolia* (Jan *et al*., 2011), *Brachiaria brizantha* cv. MG5 (Respati *et al*., 2018), wild ginseng (Le *et al*., 2019), fenugreek (*Trigonella foenum-graecum* L) (Hanafy & Akladious, 2018), and other plants. A mutation study on Guinea grass using gamma-ray was carried out to produce the putative mutants which had higher productivity than a non mutant. The aimed of the study was to determine the dosage of gamma-ray and morphological characters for high-yielding of putative mutant of guinea grass cv Purple guinea.

MATERIALS AND METHODS

The study was conducted at the Technical Implementing Service Unit (Agriculture Service, Bogor District) dry land, Tenjo Sub-district, Bogor District, West Java for 12 months. Soil pH was 5.7, C concentration was 1.42%, N concentration was 0.17%, and P concentration was 30.05 ppm. The treatment was arranged in a randomized complete block design (RCBD) and replicated 3 times. The treatments were a dose of gamma irradiation consisted of 4 acute doses and 4 fractionated doses plus controls. The treatment dosages were acute doses i.e., 200 Gy, 250 Gy, 300 Gy, 350 Gy, and Fractionted doses i.e., 100 x 2 Gy, 125 x 2 Gy, 150 x 2 Gy, 175 x 2 Gy, and control. These doses were based on the range of LD_{20} - LD_{50} of Guinea grass (Fanindi *et al*., 2016). The fractionated dose is done by giving ½ dose of the acute dose on the first day and ½ dose on the second day. The irradiation treatment was performed at the National Nuclear Energy Agency of Indonesia. The gamma-ray source was Cobalt ^{60} delivered through *irradiator gamma chamber* 4000A.

Seeds of Guinea grass were gamma irradiated and grown in the nursery for 1 month before transplanting into the field. Each dose consisted of 100 plants. The plant population of this stage was as mutant 1 (MI), each treatment dose consisted of 100 plants. Fertilizers applied were urea at a dose of 75 kg/ha, SP36 at a dose of 100 kg/ha and KCl at a dose of 100 kg/ha, lime at a dose of 1ton/ha and added manure at a dose of 5 tons/ha.

Each plant of M1 was sampled 3 tillers. Therefore, plant materials for the population of mutant 1 vegetative 1 (M1V1) consisted of 2700-3000 plants. The population of mutant 1 vegetative 2 (M1V2) consisted of tillers derived from 10% of the selected population of M1V1 plants. Plant parameters observed of 3 generations were: (1) plant height, (2) the number of tillers, (4) leaf length and width, (5) stem diameter, (6) stem length (7), internode length, and (8) shoot weight. Observation of the plant parameters were conducted at the age of 3 months.

The collected data were analyzed by calculating the average of the characters. Furthermore, the F test was conducted to compare the control and the irirradiated plant, and if there were significantly differences it will be followed by Duncan test.

Heritability value was counted based on the Kalton *et al*. (1952):

$$h^2= (\sigma^2S1- \sigma^2S0) / \sigma^2S1$$

where h^2 is heritability; σ^2S0 is variant between clon; and σ^2S1 is variant of mutant.

Genetic variability was determined by the basis of genetic variability coefficient (GCV) using the method by Singh & Chaudhari (1977).

$$GVC= (\sigma g/x) \times 100\%$$

where σg is squared root of genotype variant; x is means.

Heritability value is categorized low when $h^2<20\%$, moderate when $20\% \leq h^2<50\%$, and high when $h^2 \geq 50\%$. While the value of the GCV was calculated based on the relative GCV of its absolute value, the criteria for the relative GCV were low when the range of relative GCV was 0%-25%, quite low when the range of relative GCV was 25%-50%, quite high when the range of relative GCV was 50%-75%, and high when the range of relative GCV was 75%-100% (Moedjiono & Mejaya, 1994)

RESULTS

Identification of Morphological Characters of M1 Population

Plant height, width, and length of leaves of Guinea grass are shown in Table 1. The plant height and the length of Guinea grass leave were affected by the dose of gamma-ray. Plant height in the control was higher compared to the other treatments. Plant height was in a range of 116.57-165.79 cm. The highest leaf length was found in Guinea grass irradiated at a dose of 200 Gy which was 57.28 cm, and the lowest was found in Guinea grass irradiated at a dose of 150 x 2 Gy. However,the leaf width was not affected by the doses of gamma irradiation. The highest number of tillers was foundin Guinea grass irradiated at a dose of 350 G (66.60 tillers), while the lowest number of tillers was found in Guinea grass irradiated at a dose of 100 x 2 Gy (33.48 tillers) (Table 1). Stem diameter did not show any differences between treatments. The range of stem diameter was 0.36-0.44 cm.

Shoot fresh and dry weights were affected by the irradiation doses (Table 1), where the highest weight was found in Guinea grass irradiated at a dose of 350 Gy. Almost all the above parts of Guinea grass can be consumed by livestock.

Table 1. The average of plant height, leaf width, leaf length, number of tiller, stem diameter, shoot weight, and leaf length of Guinea grass (M1) irradiated with gamma-ray

Gamma ray dose (Gy)	Variables						
	Plant height (cm)	Leaf width (cm)	Leaf length (cm)	Number of tillers	Stem diameter (mm)	Shoot fresh weigh (kg/plant)	Shoot dry weight (g/plant)
Control	165.79± 8.03[a]	1.76±0.12	52.33±5.98[ab]	30.59±1.62[d]	0.44±0.05	0.80±0.01[c]	172.80±15.29[ab]
200	128.90±21.87[efg]	2.21±0.04	57.28±9.01[a]	42.41±9.03[c]	0.42±0.04	0.70±0.15[c]	144.17±29.48[abc]
250	124.29± 7.31[fg]	1.80±0.01	47.60±3.39[b]	42.60±6.04[c]	0.39±0.01	0.81±0.16[c]	172.01±48.56[ab]
300	141.77±21.69[cde]	1.94±0.16	47.37±2.77[b]	34.11±5.67[cd]	0.43±0.04	0.65±0.08[c]	133.24±29.65[bc]
350	145.27±36.11[bcd]	1.83±0.63	53.26±5.88[ab]	66.60±3.34[a]	0.36±0.11	1.03±0.04[a]	202.72±18.95[a]
100x2	116.57±13.50[g]	1.79±0.11	50.37±4.84[ab]	33.48±6.20[d]	0.36±0.06	0.49±0.08[d]	96.60± 5.41[c]
125x2	158.21±16.58[ab]	2.16±0.16	49.00±4.18[ab]	43.19±3.35[c]	0.44±0.02	0.84±0.22[bc]	147.89±63.19[abc]
150x2	134.43±20.66[def]	1.84±0.23	46.76±1.54[b]	42.76±3.40[c]	0.41±0.07	0.78±0.22[c]	147.58±40.11[abc]
175x2	149.03±13.22[bc]	2.17±1.41	50.41±2.26[ab]	52.87±8.81[b]	0.42±0.06	0.98±0.15[ab]	190.76±24.72[ab]

Note: Means in the same column with different superscripts differ significantly (p<0.05).

Identification of Morphological Character of M1V1 Population

Morphological characters of M1V1 plants are presented in Table 2. Morphological characters influenced by the dose of gamma-ray were plant height, tillers number, stem length, leaf width, shoot fresh, and dry weight.

The significantly highest plant height ($p<0.05$) was found in Guinea grass irradiated at a dose of 175 Gy x 2. However, gamma irradiation did not affect the number of the tiller. The significantly highest shoot weight ($p<0.05$) was found in Guinea grass irradiated at doses of 250 Gy and 175 x 2 Gy compared to control and the other treatments.

The values of heritability and GVC of M1V1 of Guinea grass are presented in Table 3. The heritability of plant height was low to moderate, while the value of genetic coefficient variation (GCV) was low. Moderate heritability was found in Guinea grass irradiated at doses of 200 Gy, 350 Gy, 125 x 2 Gy, and 150 x 2 Gy. The GCV of stem length was low, while the range of heritability was low to moderate. The heritabilities of internode, leaf length and width were low to moderate and the heritability of GCV was low. Fresh weight of shoot is one of indicators in determining the productivity of forage. The heritabilities of fresh weight of shoot were low to high (Table 5), and high heritability values were found in Guinea grass irradiated at doses of 200 Gy, 350 Gy, and 175 x 2 Gy. The GCV of these characters were also low to high. The high heritability and GCV values in dry weight of shoot were found in Guinea grass irradiated at a dose of 200 Gy, 350 Gy, and 175 Gy x 2. The values of heritability of tillers were moderate to high, which were found in Guinea grass irradiated at doses of 250 Gy and 350 Gy, while the GCV values were between low to quite high.

Identification of Morphological Character of M1V2 Population

The variables observed in the population of M1V2 are presented in Table 4. The results showed that the gamma-ray dose affected ($p<0.05$) plant height, stem length, and internode length. Plant height and stem length of Guinea grass irradiated with gamma-ray at a dose of 175 x 2 Gy were significantly the highest compared to control. The highest internode length (23.16 cm) was found in Guinea grass irradiated with gamma-ray at a dose of 100 x 2 Gy.

Shoot productivity expressed in fresh and dry weights is shown in Table 6. Fresh and dry weights of the shoot were affected by the dose of gamma-ray, and the highest shoot fresh weight was found in Guinea grass irradiated at a dose of 100 x 2 Gy and the lowest was found in control. The fresh weight of shoot in Guinea grass irradiated at a dose of 100 x 2 Gy was not significantly different when compared with the fresh weight of shoot in Guinea grass irradiated at doses of 125 x 2 Gy, 150 x 2 Gy, and 175 x 2 Gy. The highest dry weight (625.63 g) was also found in Guinea grass irradiated at a dose of 100 x 2 Gy, and this dry weight was significantly different when compared to the control.

The dose of gamma-ray irradiation also significantly affected the number of tillers ($p<0.05$). The highest number of tillers was found in Guinea grass irradiated at a dose of 100 x 2 Gy and the lowest was found in Guinea grass irradiated at the control dose. Leaf width, leaf length, root length, and root weight are shown in Table 4. Leaf width and root length were affected by the dose of gamma-ray. The gamma-ray irradiation at a dose of 200 Gy resulted in the highest leaf width and was not different when compared to Guinea grass irradiated at doses of 100 x2 Gy and 175 x 2 Gy. The highest root length was found in Guinea grass irradiated at doses of 100 x 2 Gy and 150 x 2 Gy.

The heritability and GCV values are presented in Table 5. The heritability and GCV value of each variable ranges from low to high. The GCV value of plant height in the M1V2 population was low at each dose of treatment, while the heritabilities were high in Guinea grass irradiated at doses of 125 x 2 Gy, 150 x 2 Gy, and 175 x 2 Gy. GCV values for stem length were low to rather low and high heritability values were found in Guinea grass irradiated at doses of 100 x 2 Gy, 125 x 2 Gy, 150 x 2 Gy, and 175 x 2 Gy. Stem diameter, internode length, leaf width, and leaf length were low in GCV, and heritability ranged from low to high. The GCV values and

Table 2. The average of plant height (cm), tiller number, stem diameter (cm), stem length (cm), internode length (cm), leaf length (cm), width leaf (cm), shoot fresh, and dry weight (g/plant) in M1V1 population of Guinea grass

Variables	Dose (Gy)								
	0	200	250	300	350	100x2	125x2	150x2	175x2
H.plant	151.11[b]	174.02[ab]	176.9[ab]	155.33[b]	150.11[b]	169.59[ab]	175.5[ab]	150.42[b]	188.03[a]
N.tiller	10.15[b]	13.50[ab]	15.92[a]	12.87[ab]	11.94[ab]	12.56[ab]	11.74[ab]	15.65[a]	13.98[ab]
D.stems	4.91[a]	5.70[a]	5.78[a]	5.09[a]	5.20[a]	4.69[a]	5.14[a]	5.02[a]	5.78[a]
H.stem	144.9[ab]	159.23[ab]	159.9[ab]	142.5[b]	138.2[b]	154.6[ab]	159.9[ab]	134.09[b]	172.63[a]
L.internode	25.19[a]	26.96[a]	25.22[a]	25.28[a]	25.99[a]	26.63[a]	26.41[a]	24.73[a]	24.65[a]
L.leaf	54.09[a]	62.94[a]	61.61[a]	56.54[a]	52.84[a]	56.36[a]	60.87[a]	53.65[a]	63.32[a]
W.fresh	369.92[b]	594.7[a]	608.5[a]	405.48[b]	423.73[b]	470.20[b]	437.30[b]	468.84[b]	638.50[a]
W.dry	74.4[c]	141.9[a]	151.3[a]	84.5[c]	89.9[bc]	106.9[abc]	96.2[bc]	119.2[abc]	131.7[ab]

Note: Means in the same row with different superscripts differ significantly ($p<0.05$).
*H.Plant = plant height; N.tiller=tiller number; D. stem= stem diameter; H.stem= length stem; L.internode=length internode; L.leaf= leaf length; W.leaf= leaf width; W.fresh= shoot fresh weight; W.dry= shoot dry weight.

Table 3. Phenotypes variance (σ^2p) and genetics variance (σ^2g), heritability (h^2) and GCV height of plant, length of stem, diameter of stem, length of internode, leaf length and leaf width, shoot fresh and dry weight, and number of tiller in Guinea grass in the population of M1V1

Variables	Dose (Gy)							
	200	250	300	350	100 x 2	125 x 2	150 x 2	175 x 2
H.Plants*								
σ2p	1415.57	1007.82	1117.13	1347.81	1231.45	1330.98	1295.52	1013.81
σ2g	344.98	29.16	138.48	369.15	252.80	352.32	316.86	35.16
h2	0.24	0.029	0.12	0.27	0.20	0.26	0.24	0.035
GCV (%)	10.67	3.05	7.58	12.80	9.37	10.69	11.83	3.15
GCV	low	low	low	low	low	low	low	low
L.Stem								
σ2p	1122.06	1030.91	1006.32	1116.94	955.88	1266.70	1348.11	1029.06
σ2g	319.05	227.90	203.31	313.93	152.87	463.69	545.10	226.05
h2	0.28	0.22	0.20	0.28	0.16	0.37	0.40	0.22
GCV (%)	11.22	9.44	10.01	12.82	8.00	13.47	17.41	8.71
GCV	low	low	low	low	low	low	low	low
D.Stem								
σ2p	1.43	1.36	1.83	3.60	1.00	1.15	1.08	1.40
σ2g	0.59	0.52	1.00	2.77	0.17	0.32	0.24	0.56
h2	0.42	0.39	0.55	0.77	0.17	0.27	0.22	0.40
GCV (%)	13.51	12.52	19.64	31.97	8.68	10.94	9.78	13.00
GCV	low	low	low	quite low	low	low	low	low
L.internode								
σ2p	28.08	19.53	24.48	21.17	19.46	20.89	15.01	19.15
σ2g	9.96	1.40	6.36	3.04	1.33	2.77	0.00	1.03
h2	0.35	0.072	0.26	0.14	0.068	0.13	0.00	0.053
GCV (%)	11.71	4.70	9.97	6.71	4.34	6.30	7.14	4.11
GCV	low	low	low	low	low	low	low	low
L.Leaf								
σ2p	109.28	125.23	112.67	131.30	89.12	147.95	159.81	117.82
σ2g	22.41	38.36	25.80	44.43	2.25	61.08	72.94	30.95
h2	0.20	0.30	0.23	0.34	0.025	0.41	0.46	0.26
GCV (%)	7.52	10.05	8.98	12.61	2.66	12.84	15.92	8.79
GCV	low	low	low	low	low	low	low	low
W.Leaf								
σ2p	0.17	0.13	0.11	0.18	0.19	0.16	0.12	0.15
σ2g	0.04	0.00	0.00	0.05	0.06	0.03	0.00	0.02
h2	0.24	0.17	0.00	0.27	0.32	0.20	0.00	0.12
GCV (%)	8.62	2.17	0.00	10.21	11.34	8.17	0.00	6.04
GCV	low	low	low	low	low	low	low	low
W.fresh*								
σ2p	270954	193498	78829	235464	121535	98198	174347	284066
σ2g	172925	95468	19199	137434	23506	168.53	76318	186037
h2	0.64	0.49	0.00	0.58	0.19	0.017	0.44	0.65
GCV (%)	69.92	50.78	0.00	87.49	32.60	2.96	60.06	67.55
GCV	q. high	q. high	low	high	quite low	low	q. high	q. high
W.dry								
σ2p	51474	16767	8252	24216	13091	8511	15051	27851
σ2g	41783	7076	1437	14526	3400	1179	5361	18160
h2	0.81	0.42	0.00	0.60	0.26	0.00	0.36	0.65
GCV (%)	95.88	43.01	0.00	93.75	36.39	0.00	48.00	74.18
GCV	high	q. low	low	high	quite low	low	q. low	high
N.Tiller								
σ2p	58.84	101.83	48.96	87.64	39.50	39.47	77.41	68.44
σ2g	25.98	68.69	16.10	54.77	6.63	6.61	44.55	35.58
h2	0.44	0.68	0.33	0.63	0.17	0.17	0.58	0.52
GCV (%)	37.74	52.14	31.18	61.97	20.50	21.91	42.64	42.66
GCV	q. low	q. high	q.low	q. high	Low	low	q. low	q.low

Note: *H.Plant = plant height; N.tiller=tiller number; D. stem= stem diameter; H.stem= length stem; L.internode=length internode; L.leaf= leaf length; W.leaf= leaf width; W.fresh= shoot fresh weight; W.dry= shoot dry weight.

Table 4. The average of plant height, stem length, internode length, diameter of stem shoot weights, leaf width, leaf length, root length, and root weights of Guinea grass in M1V2 population

Variables	Dose (Gy)								
	0	200	250	300	350	100x2	125x2	150x2	175x2
*PH	139.4±10.4^{b}	138.2±13.9^{b}	143.4±4.1^{ab}	144.9±6.8^{ab}	135.6±10.9^{b}	151.5±9.5^{ab}	147.3±13.9^{ab}	151.4±15.4^{ab}	157.5±11.7^{a}
SL	61.2±4.3^{c}	65.4±12.2^{bc}	66.8±6.9^{bc}	65.1±3.5^{bc}	58.1±2.2^{d}	78.1±11.7^{ab}	68.9±16.8^{bc}	72.7±16.1^{abc}	82.9±15.7^{a}
IL	20.5±2.0^{b}	19.8±2.3^{b}	22.0±2.6^{ab}	21.8±2.3^{ab}	21.3±1.9^{ab}	23.2±1.4^{a}	20.5±1.8^{b}	20.6±1.3^{ab}	20.1±1.6^{b}
SD	6.7±0.3	6.7±0.7	6.9±0.3	6.5±0.1	6.6±0.4	6.8±0.5	6.4±0.4	6.4±0.4	6.5±0.5
SF	347.6±79^{d}	465.9±177^{bc}	489.7±104^{b}	480.0±123^{bc}	370.3±57^{d}	625.6±100^{a}	549.7±128^{ab}	544.5±36^{ab}	533.1±106^{ab}
SD	75.7±13.9^{c}	82.4±37.1^{bc}	100.1±18.7^{bc}	100.3±28.3^{bc}	78.4±15.1^{c}	126.4±19.4^{a}	109.9±25.7^{ab}	106.9±8.9^{ab}	109.0±21.0^{ab}
NT	18.2±2.5^{d}	20.3±4.7^{cd}	26.6±5.7^{ab}	24.4±4.1^{abc}	21.3±1.9^{bcd}	28.7±5.8^{a}	26.0±4.5^{abc}	24.1±4.3^{abc}	24.1±1.6^{abc}
LW	2.2±0.2^{c}	2.7±0.2^{a}	2.3±0.1^{bc}	2.2±0.3^{c}	2.2±0.2^{c}	2.6±0.2^{ab}	2.3±0.2^{c}	2.3±0.1^{c}	2.5±0.2^{abc}
LL	71.3±1.5^{ab}	73.4±1.3^{ab}	71.3±1.4^{ab}	74.3±3.5^{a}	72.4±2.0^{ab}	71.5±4.6^{ab}	71.1±1.6^{ab}	69.1±3.9^{b}	72.5±1.9^{ab}
RL	34.6±3.5^{d}	37.0±3.9^{bcd}	39.9±2.5^{abc}	41.9±6.1^{ab}	35.6±3.3^{cd}	43.5±3.2^{a}	40.5±3.9^{abc}	42.4±6.7^{a}	39.4±2.0^{abcd}
RW	8.5±0.7^{a}	8.3±4.1^{a}	7.8±0.9^{a}	9.0±4.6^{a}	6.9±1.9^{a}	11.9±5.2^{a}	11.9±6.7^{a}	11.8±6.9^{a}	8.9±2.5^{a}

Note: Means in the same row with different superscripts differ significantly ($p<0.05$).
PH = plant height (cm);SL=stem length (cm); IL=internode length (cm); SD= stem diameter (mm); SF= shoot fresh weight (g); SD= shoot dry weight (g) NT=tiller number; LW= leaf width (cm);LL= leaf length (cm);RL= root length (cm); RW= root weight.

Table 5. Phenotypes variance (σ2p) and genetics variance (σ2g), heritability (h2) and GCV of plant height, stem length, stem diameter, internode length, leaf length, and leaf width in M1V2 population

Variables	Dose (Gy)							
	200	250	300	350	100 x 2	125 x 2	150 x 2	175 x 2
H.Plant*								
σ2p	406.39	160.35	269.84	191.79	470.63	575.58	697.66	780.42
σ2g	157.49	0	20.94	0	221.73	326.68	448.76	531.52
h2	0.39	0	0.08	0	0.47	0.57	0.64	0.68
GCV (%)	9.02	0	3.16	0	9.89	12.33	14.07	14.8
GCV	low	low	low	low	low	low	low	low
L.Stem								
σ2p	368.59	284.68	180.84	173.56	504.15	473.45	547.09	838.38
σ2g	186.75	102.84	0	0	322.31	291.61	365.25	656.54
h2	0.51	0.36	0	0	0.64	0.62	0.67	0.78
GCV (%)	20.41	15.02	0	0	23.3	24.27	26.1	30.2
GCV	low	low	low	low	low	quite low	quite low	quite low
D.Stem								
σ2p	1.2	0.63	0.9	0.35	0.86	0.48	1.41	0.6
σ2g	0.52	0	0.21	0	0.17	0	0.72	0
h2	0.43	0	0.23	0	0.2	0	0.51	0
GCV (%)	10.55	0	7.04	0	6.01	0	13.16	0
GCV	low	low	low	low	low	low	low	low
L.Internode								
σ2p	15.39	21.12	44.7	12.97	16.26	11.72	14.61	27.24
σ2g	3.42	9.15	32.72	0.99	4.29	0	2.64	15.26
h2	0.22	0.43	0.73	0.08	0.26	0	0.18	0.56
GCV (%)	9.3	14.01	26.65	4.67	8.93	0	7.84	19.43
GCV	low	low	quite low	low	low	low	low	low
W.Leaf								
σ2p	0.17	0.2	0.17	0.23	0.13	0.14	0.14	0.2
σ2g	0.04	0.07	0.04	0.1	0	0.01	0.01	0.07
h2	0.22	0.35	0.22	0.44	0.02	0.08	0.05	0.34
GCV (%)	7.23	11.02	8.66	14.14	1.88	4.61	3.75	10.48
GCV	low	low	low	low	low	low	low	low
L. Leaf								
σ2p	34.95	24.75	30.4	16.2	45.64	38.33	68.79	13.03
σ2g	16.51	6.31	11.96	0	27.2	19.89	50.35	0
h2	0.47	0.26	0.39	0	0.6	0.52	0.73	0
GCV (%)	5.54	3.51	4.65	0	7.37	6.29	10.27	0
GCV	low	low	low	low	low	low	low	Low

Note: *H.Plant = plant height; N.tiller=tiller number; D. stem= stem diameter; H.stem= length stem; L.internode=length internode; L.leaf= leaf length; W.leaf= leaf width; W.fresh= shoot fresh weight; W.dry= shoot dry weight.

Table 6. Phenotypes variance (σ2p), genetic variance (σ2g), heritability (h2) and genetic coefficient variation (GCV) of shoot fresh weight and dry weight, tiller, leaf weight, length of root and weight of roots in M1V2 population

Variables	Dose (Gy)							
	200	250	300	350	100x2	125x2	150x2	175x2
*W.fresh								
σ2p	70430.04	20307.1	41871.4	20345.5	173564.8	189926.7	184408.7	28350.7
σ2g	55251.8	5128.8	26693.2	5167.19	158386.5	174748.4	169230.4	13172.5
h2	0.78	0.25	0.64	0.25	0.91	0.92	0.92	0.46
GCV (%)	48.1	14.65	34.04	19.43	64.66	70.55	72.29	21.94
GCV	quite high	Low	quite low	low	quite high	quite high	high	low
W.Dry								
σ2p	3123.2	910.6	1944.2	1104.6	10205.2	8300.9	7061.2	1446.2
σ2g	2703.8	491.2	1524.7	685.3	9785.9	7881.5	6641.8	1026.8
h2	0.87	0.54	0.78	0.62	0.96	0.95	0.94	0.71
GCV (%)	86.57	53.95	78.43	62.04	95.89	94.95	94.06	71
GCV	high	quite high	high	quite high	high	high	high	quite high
N.Tiller								
σ2p	53.64	105.24	89.87	99.82	99.3	147.24	113.78	43.51
σ2g	6.13	57.73	42.35	52.3	51.79	99.73	66.27	0
h2	0.11	0.55	0.47	0.52	0.52	0.68	0.58	0
GCV (%)	12.03	29.53	26.72	34.44	27.46	37.48	34.42	0
GCV	low	quite low	quite low	quite low	quite low	quite low	quite low	low
W.Leaf								
σ2p	254.97	136.17	126.69	171.66	33.22	142.36	267.86	204.42
σ2g	146.55	27.75	18.26	63.24	0	33.93	159.44	95.99
h2	0.57	0.2	0.14	0.37	0	0.24	0.6	0.47
GCV (%)	17.51	7.96	6.24	11.7	0	8.83	18.07	15.05
GCV	low	low	low	low	low	low	low	low
W.Root								
σ2p	34.31	5.12	40.87	20.35	67.48	79.27	59.43	20.17
σ2g	25.77	0	32.33	11.81	58.94	70.73	50.89	11.63
h2	0.75	0	0.79	0.58	0.87	0.89	0.86	0.58
GCV (%)	63.62	0	68.89	49.41	66.29	66.15	64.23	39.76
GCV	quite high	Low	quite high	quite low	quite high	quite high	quite high	quite high
L.Root								
σ2p	99.9	31.3	79.78	37.36	36.96	49.33	71.03	29.14
σ2g	21.83	0	43.45	1.02	0.63	13	34.7	0
h2	0.64	0	0.54	0.03	0.02	0.26	0.49	0
GCV (%)	63.57	0	15.6	2.82	1.81	8.79	13.81	0
GCV	quite high	Low	low	low	low	low	low	low

Note: *W.fresh = shoot fresh weight (g); W.Dry= shoot dry weight (g) NT=tiller number; W. leaf= leaf width (cm); W. Root. root weight (g);L. Root= root length (cm).

heritability of shoot fresh weights, tillers, root weights, and root lengths are shown in Table 6. The value of GCV shoot fresh weight was low to high, as well as the value of heritability was low to high. The high GCV values were found in Guinea grass irradiated at doses of 150 x 2 Gy, 100 x 2 Gy, 125 x 2 Gy and 200 Gy. The heritability and the GCV of dry weight of Guinea grass irradiated at all doses of treatment were high. The value of GCV of tillers ranged from low to quite low, while the value of heritability ranges from low to moderate. The heritability of root weight and root length were low to high, while the GCV value was low to high.

DISCUSSION

The results of the study on the M1 population showed that the dose of gamma-ray affected the number of tillers, shoot fresh weight, and dry weight. While the other parameters were not affected by the dose of gamma-ray. The control plant height in the M1 population was higher than the Gamma irradiated plant. The decreased plant height due to gamma-ray irradiation on M1 was also reported to occur in maize (Marcu *et al*., 2013), soybeans (Alikamanoglu *et al*., 2011), *Curcuma alismatifolia* (Taheri *et al*., 2014), *Arabidopsis thaliana* (Kim *et al*., 2014), *Phaseolus vulgaris* (Ulukapi & Ozmen, 2018), ryegrass (Chen *et al*., 2016), Okra (Amir *et al*., 2018), *Brasica napus* (Khan *et al*., 2015) and *Cynodon dactylon* (Mutlu *et al*., 2015). The decreased growth in irradiated plants is thought to be due to several factors, including being associated with metabolic disturbances in seeds after irradiation (Chaudhuri, 2002), chromosome damage with the increasing doses of irradiation (Mohajer *et al*., 2014) or processes such as changes in ascorbic acid content, destruction of auxin and physiological and biochemical disorders that interfere with the process of plant development (Hanafy *et al*., 2018, Kitano *et al*., 2015).

Fresh weight of shoot is an important parameter in the productivity of forage crops. The fresh weight of the shoot in the M1 population was affected by the dose of irradiation. The increased production in the M1 population that was irradiated by gamma-ray was reported in cowpea (Badr *et al*., 2014), *Nigella sativa* L. (Amin *et al*., 2019) and soybean (Hanafiah *et al*., 2010). The selection was not done in M1 population, because the mutations caused by gamma irradiation are mostly recessive and cannot be selected to multiply until the second population (Singh, 2005). M1 population was also a population that has physiological influence and damage to biological material due to direct or indirect irradiation. Direct damage can be caused by the direct effects of irradiation on ionization sequence of DNA itself (Parman *et al*., 1999). However, the plant characters in M1 can be a preliminary reference for the next population selection (M1V1), because the propagation of Guinea grass is vegetatively material.

M1V1 population is a segregated population so that each individual randomly allows to have genes that undergo mutations and that cause genetic variability in each character in the irradiated population genotype (Tah, 2006). In this population, selection usually starts to identify the desired plant characters. The population of M1V1 Guinea grass was affected by gamma irradiation. The increased production due to gamma irradiation in M1V1/ M2 was also reported in ryegrass (Chen *et al*., 2016), peas (Khan, 2018), lentil beans (Tabti *et al*., 2018), *Sesamum indicum* L (Muhammad *et al*., 2018), and wheat (Ahmed, 2017). Each type of plant has a certain dose of irradiation in increasing its productivity. In millet, the right dose to increase its production is 400-500 Gy (Ambavane *et al*., 2015), 45 Krad (450 Gy) in wheat Batoor varieties and 15 Krad (150 Gy) for Janbaz varieties (Ahmed, 2017), 440.15 Gy in *Sesamum indicum* L(Saha & Paul, 2019), while in Cynodon grass the right dose is 70-100 Gy. This dose was the dosage between LD_{20}-LD_{50} for Guinea grass cv Purple Guinea where at those doses more diversity appeared. Doses of LD_{20} and LD_{50} on Guinea grass cv purple Guinea were 358.23 Gy and 176.83 Gy, respectively (Fanindi *et al*., 2016).

The coefficient of genotype, phenotype, heritability, and GCV are useful tools for measuring genetic variability (Aditya *et al*., 2011). Heritability and GCV for M1V1 were in a range of low to high. High heritability and GVC values were obtained only in the characters of shoot and tillers weights. The value of heritability due to gamma irradiation was also reported in other studies such as *Vigna ,mungo* (Sri Devi, 2012), lentils (Laskar & Khan, 2017), sorghum (Anand & Kajjidoni, 2014), chickpea (Amri-Tiliouine *et al*., 2018), mungbean (*Vigna radiata*) (Dhole & Reddy, 2018), pinger millet (Umeshkumar *et al*., 2015), and rice (Islam *et al*., 2015).

High heritability helps to choose certain desired traits in plants. Heritability also helps breeders to choose plants based on their performances and phenotypic reliabilities (Islam *et al*., 2015). High heritability values in tillers, fresh and dry shoot, suggest that most total variations are in genetic control and selection based on phenotypic levels will be useful in improving these traits. High heritability followed by a high GCV allows the opportunity to choose a good genotype (Akram *et al*., 2016). These results also show that it is likely that most additive genetic effects regulate these characters so that selection pressure can be applied to select these characters in Guinea grass breeding.

Some characters observed in the M1V2 population was affected by gamma-ray irradiation. The characters that were influenced by gamma-ray in the population of M1V2 relatively the same as M1V1, this due to that the population of M1V2 was the result of selection from the population of M1V1. In the M1V2 population it was indicated that the important character for the productivity of Guinea grass, such as tillers, root length, fresh weight, and dry forage were influenced by gamma irradiation.

Population of M1V2 produced the high number of tillers, fresh and dry weight of shoot at fractionated irradiation (100 x 2 Gy and 175 x 2 Gy) compared to control and acute dose. Walther & Sauer (1990) stated that fractionated irradiation explants of Gerbera resulted in a higher percentage of shoot growth than the acute technique. In addition, Guedea *et al.* (2013) showed that irradiation with a single dose inhibited the growth of chili plants, compared with fractionated irradiation. Although there are still different opinions regarding mutants produced using acute or fractionated doses.

The high heritability and GCV on the population of M1V2 were achieved for fresh and dry weight of shoot, the number of tillers and root weights. Therefore, those characters can be selected for improving productivity of Guinea grass.

CONCLUSION

Gamma-ray irradiation affected morphological characters of Guinea grass in the populations M1, M1V1, and M1V2 and can improve productivity. The dose of gamma-ray irradiation could also provide a high heritability and genetic character coefficient on the character of shoot fresh and dry weight as well as the number of tillers. Those characters can be applied as characters for selecting putative mutant. The gamma irradiation at doses of 100 x 2 Gy and 175 x 2 Gy improved the productivity of Guinea grass cv Purple guinea. The highest production (625 g/plan) was obtained in Guinea grass irradiated at a dose of 100 x 2 Gy.

CONFLICT OF INTEREST

There is no conflict of interest with any financial, personal, or other relationship with other people or organization related to the material discussed in the manuscript.

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