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Yield potential improvement of upland red rice using gamma irradiation on local upland rice from southeast sulawesi indonesia

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The objective of the research obtained the genotypes of upland red rice which has the character of high yield potential. The research material is second generation upland rice mutant genotypes of gamma irradiation result from Landrace Pae Loilo and Pae Pongasi from Southeast Sulawesi. The research was conducted at the Indonesian Sweetener and Fiber Crops Research Institute, Karang Ploso Malang Regency. The research used the randomized block design method (Augmented Design) consists of five blocks. Genotype was planted in one block, not planted in the next block, except checks of the parents and superior varieties (Inpago 7 and Inpago Unram). Observational data were analyzed by SAS Program. Eight hundred and seventy one genotypes were selected with the selection criteria were based on yields on the average parents added 1.5 standard deviations. The results showed that 80 genotypes M2 had high production (> 81.66 g clump^{-1}), while yield checks were 64.56, 56.62, 67.33and 66.18 g clump^{-1}.

Keywords: gamma irradiation, upland rice, anthocyanin, red rice, functional food.

INTRODUCTION

Upland rice is one of the best-developed rice in Southeast Sulawesi considering the condition of the land which is mostly dry land. Upland rice is planted by farmers is local upland rice and among them is red rice. The upland red rice is excellent rice for health (Se et al.,2016). In 100 g red rice contained 77.6 g carbohydrates, 7.5 g protein, 0.9 g fat, 163 mg phosphorus, 0.3 g iron, 16 mg calcium, 0.1 mg vitamin B1, anthocyanin (Indriyani et al., 2013) and Zn (Swamy et al. 2016). The type of rice anthocyanin is from cyanidin (Reddy, 1996). The content of anthocyanin red rice is still very diverse and ranges from 0.34-93.5 μg in every gram (Damanhuri, 2005). High nutritional content and its function to prevent various types of diseases caused red rice is feasible as functional food. Red rice can function as a functional food because it contains anthocyanin as an antioxidant that prevents various types of diseases.

Although local upland rice has grown since a long time, now many are abandoned by farmers and switch to wet rice. Several cultivars of upland rice no found in farmers are cultivar PaebiuKolopoa and cultivar PaebiuTamalaki which have high anthocyanin content (Suliartini et al., 2011). This is due to, among others, relatively low production of upland rice compared to lowland rice. Wet rice yield is 4.24 tha^{-1} while upland rice is2.51 t ha^{-1} (Central Statistics of Southeast

Sulawesi, 2017).

Many efforts have been done to increase upland rice production (Kadidaa et al., 2017; Sutariati et al., 2017, 2018a, 2018b) and decrease level rice consumption while promoting local food (Muhidin et al., 2016) to reach fulfillment rice needs (Muhidin et al., 2013, 2018; Syaiful et al., 2013). One of them is through the breeding mutation (Suliartini et al., 2015; 2018) to increase upland rice production.

Mutation could increase genetic diversity that is very important in a breeding program. The population of upland rice that has a low genetic diversity in the character of production, genetic diversity needs to be improved. Genetic diversity can be increased through the introduction, crosses, and mutations. Mutations aim to provide basic populations with high genetic diversity (Wei et al., 2013) as a material of selection or crosses. Based on the mutation material, mutations are grouped into two: physical mutagen and chemical mutagen. Physical mutation is often performed in Indonesia is gamma irradiation. An individual from mutation is called mutant. Mutants are selected several generations to obtain the desired character by breeders. The pedigree selection is the main breeding method used to improve rice (Poli et al., 2013; Khan et al., 2015).

The mutation breeding is directed at increasing the production of local cultivars. Mutation induction has potential to increase upland rice production (Sobrizal, 2016). Also mutation breeding can be used to enhance the desired character of the crossed line. Sobrizal (2008) stated that increases the benefits of cross-breeding lines that have too high stems and late matured through mutation.

The research material was a second-generation mutant that is re-selected for high yield character. This mutant is the result of the first-generation selection for high production characters and harvest age. Selection for several generations is expected to obtain mutants with stable high production character.

MATERIALS AND METHODS

The research materials are the second generation of upland rice, PaeLoilo cultivar, PaePongasi cultivar. Inpago 7 and InpagoUnram used as control cultivar. The research design used Augmented Design which is divided into six blocks. The number of mutant genotypes planted was 171 genotypes. Genotypes that already exist in one block, not repeated in the next block except check test. Each genotype was planted as many as 50 plants. Observations were done to several parameters such as plant high, the number of productive tillers, the length of panicle, harvest age, the number of empty grains, the number of full grain, the weight of 1000 grains, and grain number per panicle. Observational data were analyzed by SAS Program. Eight hundred and seventy-one genotypes were selected with the selection criteria were based on yields on the average parents added 1.5 standard deviation (> X+1.5 SD).

RESULTSAND DISCUSSION

A total of 871 genotypes were observed in various character results and supporting results. The genotypes were analyzed and selected initially based on the average of the elderly plus 1.5 standard deviations. Mutant genotypes having yields above 90 g of clump^{-1} were selected to obtain potentially high-yield genotypes. Of the 30 selected mutant genotypes, the three genotypes SSJ21.185-35, SSJ21.72-11 and SSJ31.104-40 showed the highest production between 116.61 - 126.63 g clumps^{-1} (Table 1). This production is higher than the genotypes of the two elders (PaePongasi and PaeLoilo) and the two comparators (Inpago 7 and InpagoUnram).

The low yieldupland rice, especially in South eastSulawesi causes the fulfillment of food depends on wet rice. The development of upland rice is a key strategy in meeting the needs of rice in Southeast Sulawesi. The main purpose of plant breeding programs is to increase production including rice (Khan et al.,(2015). Rice line with higher yield potential is crucial to meet the needs of food in the world, including southeast Sulawesi. In addition, rice with high yield potential is important for reducing other external inputs that have an environmental impact, gaining a higher chance of getting the largest harvesting potential (Huang et al., 2017) and reducing forest land clearing for upland rice cultivation and utilization the land remaining due to industrialization and urbanization (Zhang et al., 2017).The results of previous generations (Mutant 2) obtained ten genotypes that have high production potential and a shorter harvest than their parents (Suliartini et al., 2016). The genotypes were further tested, numbered and coded into 817 re-selected genotypes to obtain more stable genotypes.~~T~~he eight hundred and sixty seven genotypes were selected based on the average production of elder plus 1.5 standard deviations. Based on these values are selected eighty genotypes of both PaeLoilo and PaePongasioffspring.

Tabel 1. Production of upland rice mutans and yield support character

No.	Genotype	Yield (g clump^{-1})	Group Letter	HarvestAge (day)	PlantHeight (cm)	Number of Tiller (tiller clump^{-1})	Grain Number	Long Panicle (cm)	Weight of 100 grain (g)
1	**SSJ21.185-35**	126.63	A	134	190.00	26	275	28.87	2.71
2	**SSJ21.72-11**	123.58	Ab	124	187.00	28	236	30.70	2.96
3	**SSJ31.104-40**	116.61	Abc	133	178.50	29	140	26.23	3.70
4	**SSJ21.185-1**	115.23	Bcd	134	160.00	34	165	25.17	2.91
5	**SSJ31.6-8**	111.90	Cde	135	195.20	29	161	25.93	3.55
6	**SSJ21.86-10**	111.37	c-f	148	192.60	23	259	28.07	2.88
7	**SSJ21.81-10**	111.01	c-f	137	198.30	23	258	28.03	2.86
8	**SSJ31.6-12**	110.61	c-h	135	180.00	30	162	30.30	4.84
9	**SSJ31.104-6**	109.83	c-j	133	185.20	30	137	27.70	3.81
10	**SSJ33.203-35**	109.49	c-i	142	146.30	27	160	25.17	4.09
11	**SSJ31.6-25**	107.77	c-k	135	183.20	24	211	27.20	3.78
12	**SSJ31.6-10**	106.73	c-m	135	190.40	24	192	29.83	4.01
13	**SSJ31.104-4**	106.68	c-n	133	180.90	26	165	26.50	3.73
14	**SSJ21.239-3**	105.56	d-p	137	171.20	25	253	27.90	3.18
15	**SSJ31.6-20**	105.41	c-q	135	183.00	30	154	26.43	3.91
16	**SSJ31.162-29**	103.59	e-r	139	155.40	19	158	27.20	3.62
17	**SSJ21.72-5**	103.58	e-s	130	182.00	27	156	27.63	2.78
18	**SSJ31.104-36**	102.60	e-t	133	183.40	20	149	29.03	3.81
19	**SSJ31.102-4**	101.08	f-v	134	176.10	23	186	27.10	3.61
20	**SSJ31.104-33**	101.04	e-w	133	180.50	21	184	27.93	3.63
21	**SSJ31.104-8**	100.24	f-x	133	180.50	24	145	26.77	4,00
22	**SSJ31.102-45**	100.19	f-x	134	160.90	22	192	27.73	3.72
23	**SSJ21.81-9**	99.28	g-z	137	191.50	22	271	31.17	2.93
24	**SSJ31.104-35**	99.26	h-z-a1	133	170.90	22	193	27.50	3.78
25	**SSJ21.72-31**	98.68	i-z-a1b2	130	173.00	34	120	28.87	3.17
26	**SSJ33.203-33**	98.45	j-y-a1c1	142	170.80	28	133	24.10	3.68
27	**SSJ21.72-6**	97.87	k-z-a1b1	130	181.30	33	173	27.20	2.57
28	**SSJ21.86-8**	97.82	k-z-a1b1c1	148	195.30	20	278	27.10	2.82
29	**SSJ21.167-21**	97.26	k-z-a1b1c1	132	187.60	12	206	27.80	3.04
30	**SSJ31.6-2**	97.14	l-z-a1b1c1	135	168.30	26	125	25.87	3.70
31	**Control**	**Production of PaePongasi 65.15 g clump^{-1}; Pae Loilo 54.93 g clump^{-1}; Inpago-7 67.62 g clump^{-1}and Inpago Unram 74.18 g clump^{-1};**							

Production of upland rice mutant was 92.075-126.629 g clump^{-1}. That production was much higher than two parents that of only 54.935 g clump^{-1}and 65.195 g clump^{-1}.The yield is higher than the yield of upland rice from crosses obtained by Sadimantara et al., (2016) is 35.92 - 61.61g clump^{-1}. It is also higher than the selection of some drought-resistant upland accession in Merangin District Jambi of 2.06 t ha^{-1} (Edi et al., 2015)

The high yield was obtained genotype SSJ21.185-35,SSJ21.72-11, and SSJ31.104-40. High yield of genotype SSJ21.185-35 and SSJ21.72-11 were supported by some supporting factors of production that is much of full grain and panicle length, while genotype SSJ31.104-40 was supported by the weight of 100 grains.All three genotypes are supported by a high number of productive tillers between 26-29 tillers. The same result obtained Edi et al.,(2015),upland rice accession from Tunggung supported by component result better than another accession, number of tiller productive (8.3 stems per clump) and panicle long (28 cm), the percentage of full grain (70.93%). Manurung and Ismunadji (1988) states that the yield of a crop is determined by the components of the crop, that the character of the components of one product to another has a close relationship, where the imbalance between the yield components will greatly affect the potential yield is obtained.

The best genotypes have a low number of empty grains between 6-11 grains per panicle.The percentage of low full rice indicates the inability of plants to fill the grain, empty grain causes low yield. Genetic or environmental factors are the cause of this (Horrie et al., 2006).

The acceptance of a superior variety (adoption of a superior variety by a farmer) is not always subject to yield. Some characters become the consideration of farmer preference to newly released superior varieties, such as harvest age, plant height and weight of 1000 grains. Hairmansis et al., (2015) showed that some rice lines have high preference values based on harvest age and plant height.

Grains weight is an important character in rice plant breeding programs, as one of the factors that determine the outcomes. According to Segami et al., (2016), seed size is determined by genes that control cell division and cell clearance. The results showed that 50 selected genotypes weighed of 100 grains between 2.57 - 4.84 g.The grains weight in this study is higher than that obtained by Ediet al., (2015) that is in the range of 20.4 to 24.4 g.

Higher plants tend to be a late harvest; lateharvest age leads to the process of filling the seeds longer so that the photosynthate that fills the grain becomes higher. It will affect the high yield.The result of Rohaeni and Permadi (2012), show that there is a close correlation between plant height and number of pithy rice with yield.The results showed that M2 genotype had plant height that ranged from 146.30-198.30 cm.These genotypes include high crops because they have a height above 125 cm (IRRI, 2002). The plant height of the three best genotypes is 178.50-190.00 cm.

CONCLUSION

There are three genotypes that can be developed further as a candidate of high yield lines consist of SSJ21.185-35, SSJ21.72-11 and SSJ31.104-40

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

NWSS designed and performleed the experiments and also wrote the manuscript. TW, AM, DB and MT performed plant treatments, field experiment and data analysis. MHD reviewed the manuscript. All authors read and approved the final version.

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