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Obtaining Induced Mutations of Drought Tolerance in Sorghum

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Received August 9, 2002

Since sorghum plant (Sorghum bicolor L.) has a big potential to be cultivated in Indonesia especially in drought-prone areas, improvement of sorghum had been carried out through mutation breeding methods. The seeds of the sorghum plant was irradiated by gamma rays emitted from cobalt-60 source. The total dose was 0.4 kGy. Through selection process in the M2 generation, a number of promising mutant lines of sorghum have been obtained and registered in the M3 generation. In the M4, a number of 100 mutant lines were tested against drought in Gunung Kidul District during the dry season in 2000. Results of the test showed that mutant line DU/20/Psj/1, DU/20/Psj/4, DU/20/Psj/24, JA/30/Cty/21, ET/40/Psj/4 and DU/20/Psj/10 had relatively high grain yield compared to the control variety.

Key Words : sorghum, mutation breeding, radiation breeding, drought tolerance

1. Introduction

Gunung Kidul District of Yogyakarta Province is one of the well-known regions in Indonesia that are prone to drought year after year. But in this region, agricultural productions (crops and animals) are entirely dependent on the rain. Therefore, introduction of crops indicating high water efficiency and yield is very important for this region. A sorghum plant (*Sorghum bicolor* L.) has long known by farmers in the region but its improvement and development seem to be neglected if compared with those of the other food crops.

Sorghum's potential is primarily due to its high production, low-input crop (required less fertilizer), more tolerant to drought and other adverse conditions, and its high nutrition values. In many countries, sorghum has been

used as either food, feed, or industrial crops. As a food crop, sorghum has high nutrition values. Unfortunately, sorghum has so far been grown very limited by Indonesian farmers who are used to grow rice in their lands. This limitation may be due to some problems such as availability of qualified seeds of sorghum varieties.

From agronomic point of view, the local variety has some disadvantages as its characters of having high stature, late maturity, uninteresting seed color (brown), dropped head, and low production. For being used directly as food or in a food industry, white sorghum with low stature are usually more preferable.

Some improved sorghum mutant lines as results of breeding by using mutation techniques have been produced, released and listed as new varieties^{1), 2)}. Such results have also gained from sorghum mutation breeding

Table 1 Average of rainfall during the last 10 years in Gunung Kidul District, Yogyakarta Province (BPP Semanu, 1999)

Month	Average	
	Rainfall (mm)	Rain days
January	310.3	18
February	329.0	19
March	280.3	15
April	253.0	9
May	58.6	3
June	67.0	4
July	38.0	2
August	14.1	1
September	6.1	1
October	85.6	5
November	112.8	8
December	201.4	15
Total	1.756.2	100

Table 2 Survival rate of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Lines	Survival rate (%)
AM/20/Cty/2	21.62
AM/20/Cty/4	51.35
AM/20/Cty/9	47.30
AM CONTROL	45.95
ET/40/Psj/4	29.73
ET CONTROL	2.70
JA/30/Cty/21	18.92
JA/30/Cty/34	16.22
JA/30/Cty/37	35.14
JA CONTROL	24.33
DU/20/Psj/1	64.86
DU/30/Psj/4	37.84
DU/30/Psj/10	56.76
DU/20/Psj/11	64.86
DU/20/Psj/24	35.14
DU CONTROL	35.14

research carried out in BATAN which have identified some sorghum mutant lines. These lines need to be tested in drought prone areas such as that condition in Gunung Kidul District of Yogyakarta Province. Research objective was to search for drought-tolerant sorghum that might be possible to be grown and developed as an alternative food and feed in Gunung Kidul region.

2. Material and Method

Sorghum varieties Durra (DU), Jampang (JA), Amrik (AM) and mutant from Keris (ET) were used as plant materials in sorghum breeding by using mutation techniques. Seeds of DU were found from food crop research center in Bogor while JA and AM were collected from farmers in West Java. ET was a mutant selected by BATAN^{(3), (4)}. The seeds were then reproduced by BATAN and used as starting plant materials in the breeding research.

Sorghum seeds containing about 13% of water were irradiated by gamma rays emitted from ⁶⁰Co source. Gamma irradiator was available at the Center for Research and Development of Isotope and Radiation Technology, National Nuclear Energy Agency. The total dose was 0.4 kGy, which was found to provide the highest induced variation for plant height and harvest index, according to our previous study^{(3), (4)}.

Sorghum is self-pollinated crop so that all the M 1 plants (the first generation after gamma irradiation treatment) were harvested individually and then each plant was grown as single seed base in the M 2. Plant selections were started in the M 2 generation for those having agronomic characters phenotypically significant different from the control plants. These characters included plant height, plant age,

Table 3 Agronomic data of selected sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Lines	Plant Height (cm)		No. of Leaves		Seed Size (Relative)	Seed Color	Seed Form
	Av.	SD	Av.	SD			
AM/20/Cty/2	206.80	21.06	9.4	0.89	Medium	Yellow to gray	Oval
AM/20/Cty/4	224.80	23.08	9.2	0.84	Small	Yellow	Oval
AM/20/Cty/9	186.00	21.62	8.6	0.89	Small	Yellow to gray	Oval
ET/40/Psj/4	176.60	14.50	10.4	0.55	Big	White	Rough round
JA/30/Cty/21	95.00	17.32	4.2	0.45	Small	Black	Oval
JA/30/Cty/34	79.60	0.89	4.4	0.55	Small	Grey to black	Oval
JA/30/Cty/37	82.00	10.37	5.0	1.00	Small	Yellow to Black	Oval
DU/20/Psj/1	132.00	5.70	7.2	0.45	Big	White to gray	Round
DU/30/Psj/4	130.00	6.12	6.6	0.55	Medium	White to yellow	Round
DU/30/Psj/10	98.40	6.88	6.2	0.45	Big	White to gray	Round
DU/20/Psj/11	130.80	4.21	6.4	0.55	Big	White to yellow	Round
DU/20/Psj/24	129.00	6.52	6.4	0.55	Big	White	Round
DU CONTROL	127.80	9.31	7.0	1.00	Medium	Grey	Round

head size, seed color and yield. Dwarf or semi-dwarf, early maturing, big and condense head, and high yield were those among desirable agronomic characters for sorghum. Selected plants (mutant lines) were then grown in subsequent generations (M 3) for mutation identification and further selections.

Screening the promising mutant lines in the M 4 was carried out for their tolerance to drought. For this, field experiment was conducted in drought-prone areas of Gunung Kidul District, Yogyakarta Province during the dry season of 2 000. Sowing the seeds were done by the end of raining season and the sowing date was 10 June, 2 000. There was no rain at all during this sowing season and the drought condition at the time could be

classified as severe drought. Average of rainfall during the last 10 years in this District was shown in Table 1. Artificial irrigation, however, was given daily only up to 20 days after sowing the seeds, just to stimulate seed germination and seedling growth.

Agronomic observations were done at reproductive growth stage for survival rate, plant height and number of leaves. Evaluation on quality traits included seed size, seed color, seed form, and nutritive contents i.e. carbohydrate, protein, fat, ash, and water contents. Analysis of the nutritive contents was performed according to the standard method reported by Apriyantono et al. with two replications for each lines. Estimated yields were calculated by seed weight of individual

Table 4 Nutrition contents of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Lines	Contents (%)				
	Fat	Water	Ash.	Protein	Carbohyd
AM/20/Cty/2	1.22	9.45	0.76	6.20	79.32
AM/20/Cty/9	0.82	10.44	1.22	6.22	80.50
AM/20/Cty/4	1.47	10.44	0.59	6.58	80.92
ET/40/Psj/4	1.51	11.27	1.05	7.95	81.07
JA/30/Cty/21	1.25	9.85	0.82	6.46	81.59
JA/30/Cty/34	0.96	9.16	1.86	6.00	82.01
JA/30/Cty/37	0.66	9.17	0.44	6.23	80.55
DU/20/Psj/1	0.44	11.10	0.50	7.39	80.19
DU/30/Psj/4	1.15	10.02	0.77	6.49	80.44
DU/30/Psj/10	0.71	10.96	0.94	8.08	81.30
DU/20/Psj/11	0.49	12.47	1.99	6.98	78.59
DU/20/Psj/24	1.22	11.70	0.86	7.80	81.25
DU CONTROL	1.30	10.72	0.97	6.25	80.75

plant basis and converted to a hectare (ton/ha). Field experiments were conducted by randomized design and test of significance between treatments used the method of orthogonal contrast. Computer program MSTAT was used in analyzing the data⁵⁾.

3. Results and Discussion

Gamma irradiation treatments were reported to give a significant effect on the phenotypic performance of plant height and harvest index variables in the M2. For characters of plant height and harvest index, the dose treatment of 400 Gy was reported to give the highest variance^{3), 4)}. Following selection processes in the M2 and M3, a number of promising mutant lines had been registered in the M4. The selection was performed based on

qualitative, agronomical index, such as, plant size, seed size, seed color and seed form at an experimental farm in BATAN. Then the screening in the M4 was done for their tolerance to drought at drought-prone areas of Gunung Kidul district, Yogyakarta Province during the dry season of 2000. Out of 100 mutant lines tested in the district, 12 promising lines were selected. These tolerant sorghum lines consisted of 3 lines of AM, 1 line of ET, 3 lines of JA, and 5 lines of DU. The survival rates for drought of these sorghums were shown in Table 2 and were registered as those having good tolerance to drought. Some lines that could not grow at all in such condition were not written in the table.

Variation in plant height and number of leaves between sorghum lines as well as

Table 5 Estimated yield of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Line	Tillering	Days to mature	1000-seed weight (g)	Yield (ton/ha)
AM/20/Cty/2	2.5	105.5	15.432	2.7
AM/20/Cty/4	2.5	99.1	17.518	2.1
AM/20/Cty/9	3.3	103.6	18.355	2.8
ET/40/Psj/4	3.6	98.1	44.462	4.3
JA/30/Cty/21	3.3	90.4	27.105	3.0
JA/30/Cty/34	2.0	87.2	22.764	2.3
JA/30/Cty/37	4.1	92.5	23.147	2.5
DU/20/Psj/1	3.0	85.2	30.874	3.4
DU/30/Psj/4	3.6	86.1	30.056	4.1
DU/30/Psj/10	4.1	87.0	30.964	3.9
DU/20/Psj/11	4.3	86.3	34.870	3.4
DU/20/Psj/24	2.5	86.5	28.166	3.2
DU CONTROL	2.3	90.4	26.06	3.0

qualitative data i.e. seed size, seed color and seed form are presented in Table 3. Generally, short plants were accompanied with less leaves as shown by lines JA/30/Cty/21, JA/30/Cty/37 and JA/30/Cty/34. Seed size and seed color would determine quality of sorghum seeds either they were used directly as food or feed source. For being used as food source, white-seed sorghums were usually more preferable and the seeds were usually processed into different product such as milled grain, fine flour or rough flour. From the color of the seeds, utilization of the promising lines could be directed as food source (especially for lines of DU and ET) and as feed crops (for lines of JA and AM). This effort would help the local farmers produce either alternative food or feed during the dry season in their land.

The nutrition contents of sorghum lines are presented in Table 4. The nutrition contents of some sorghum lines were found relatively high

as it was shown in line ET/40/Psj/4 (7.95%), DU/20/Psj/1 (7.39%), DU/30/Psj/10 (8.08%), DU/20/Psj/11 (6.98%) and DU/20/Psj/24 (7.80%). These high-protein sorghum lines could be developed further in the region for helping overcome food crisis and human nutrition of the local inhabitants.

The short plants of JA, however, had relatively high tillering capacity (Table 5). These sorghum lines were suitable to be developed for feeding ruminant such as cow and cattle in the drought-prone region of Gunung Kidul. The plant stovers could be given to ruminant animals in form of green chop, pasture, hay or silage while the grain might be of useful to be used as a component of a poultry ransom.

Estimated economic yields (grain) of sorghum lines grown in dry conditions were presented in Table 5. Some lines had relatively high yield (more than 3 ton/ha) as it was shown by line

JA/30/Cty/21, ET/40/Psj/4, DU/20/Psj/1, DU/20/Psj/4, DU/20/Psj/10, DU/20/Psj/11 and DU/20/Psj/24. These promising lines had yield higher than the control DU variety. In reality, however, the yield might not be that high due to some constraints such as abnormal growth, disease and insect attacks etc. The other lines with low yield might also be of importance in producing biomass for supporting development of a sustainable agriculture in the area.

4. Conclusion

Sorghum is drought-tolerant crops. It could be grown in dry condition where other crops were not able to grow. Improvement of sorghum varieties by mutation breeding had resulted some promising mutant lines that could be developed further in Gunung Kidul District of Yogyakarta Province. Utilization of the promising lines could be directed as food source (especially for lines of DU and ET) and as feed crops (for lines of JA and AM). It is hoped that drought tolerant sorghum can help local farmers overcome food and feed crisis during dry season and also as an alternative plant in producing biomass for supporting development of a sustainable agriculture.

Acknowledgments

The work was supported and carried out

under the Cooperative Research Program, Graduate School of Agricultural and Life Sciences, The University of Tokyo. We would like to express our sincere and special gratitude to Mr. K. Ikushima, Musashi Engineering, Co., who was kind enough to provide us a research funding to perform this study.

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要 旨

耐乾性ソルガムの突然変異育種の試み

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インドネシアにおける乾燥地の食料不足ならびに米の代替品としての穀物品種を確保する目的のため、インドネシアでソルガム (*Sorghum bicolor* L.) の突然変異育種を行った。コバルト-60からの γ 線を0.4 kGy 照射し、第4世代(M4)まで育種実験を行った。M2とM3の選抜は研究所で行い、M4については実際の乾燥地 Yogyakarta Province で行った。種子の色から食糧および飼料に適する、耐乾性かつ蛋白総量が高い有望品種が得られた。