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SORGHUM BREEDING BY MUTATION TECHNIQUES FOR ALTERNATIVE ANIMAL FEED

Soeranto, H., Suharyono, Carkum, Sihono, Parno[1]

Abstract

Drought problem is one of limiting factors in agriculture development in Indonesia. One of the well-known drought prone areas is found in Gunung Kidul Region of Yogyakarta Province. In this hilly District, agriculture and livestock are mainly the basic income for the people living there. The problem is that annual dry season goes quite long namely for about 6 months, starting from May up to October. During dry season most arable land becomes barren, and farmers attempt to import corn leaves (plant stovers) in a big amount from other Regions or Provinces in order to suffice their cattle feeds. Sorghum plant (*Sorghum bicolor*) is thought of having high tolerance to drought. Breeding sorghum for improved its yield in drought prone areas can be of importance for animal husbandry in the region. Research on sorghum breeding by using mutation techniques has been conducted at BATAN. Induction of mutation was made by gamma irradiation emitted from Cobalt-60 source. The breeding objective was to improve sorghum production (seeds and stovers) in drought prone areas to be used as alternative animal feeds especially during dry season. Some promising mutant lines of sorghum had been identified and registered. These lines were tested against drought in Gunung Kidul region in 2001. Research collaboration with national and international institutions was made to support the development of sorghum germplasm collection and mutant stock repository.

Key words: Sorghum, Mutation breeding, Mutant lines, Drought tolerance, Animal feed

Introduction

Drought problem is one of limiting factors in agriculture development in Indonesia. One of the well-known drought prone areas is found in Gunung Kidul District of Yogyakarta Province. In this hilly District, agriculture and livestock are mainly the basic income for the people living there. The problem is that annual dry season goes quite long i.e. for about 6 months, starting from May up to October (BPP Semanu, 1999). During dry season most arable land becomes barren, and

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[1] Centre for Research and Development of Isotope and Radiation Technology, National Nuclear Energy Agency (BATAN), Jl. Cinere Pasar Jumat, Jakarta, Tel: (021) 7690709, Fax: (021) 7691607, E-mail: Soeranto@batan.go.id

farmers attempt to import corn leaves (plant stovers) in a big amount from other Districts or Provinces in order to suffice their cattle feeds.

Sorghum plant (*Sorghum bicolor*) is thought of having high tolerance to drought (ICRISAT/FAO, 1996). Breeding sorghum for improved its yield in drought prone areas can be of importance for increasing the overall agricultural production. The Indonesian farmers have long known sorghum but its improvement and development seem to be neglected if compared to the other food crops. Sorghum is usually used as an alternative food or feed source. As a food source sorghum has been reported to have good nutrition values (Depkes RI, 1992). The nutrition content of sorghum grain and other crop products is presented at Table 1.

Table 1. Nutrition content of sorghum grain compared to other crops

Components	Content/100 g				
	Rice	Corn	Cassava	Sorghum	Soybean
Calorie (cal)	360	361	146	332	286
Protein (g)	6.8	8.7	1.2	11.0	30.2
Fat (g)	0.7	4.5	0.3	3.3	15.6
Carbohydrate (g)	78.9	72.4	34.7	73.0	30.1
Calcium (mg)	6.0	9.0	33.0	28.0	196.0
Ferro (mg)	0.8	4.6	0.7	4.4	6.9
Phosphate (mg)	140	380	40	287	506
Vitamin B1 (mg)	0.12	0.27	0.06	0.38	0.93

About 48 percent of world sorghum grain production is fed to livestock (human food use constitutes about 42 percent). In contrast to food utilization, which is relatively stable, utilization for feed sorghum changes significantly in response to two factors: rising incomes, which stimulate the consumption of livestock products, and the price competitiveness of sorghum compared to the other cereals, especially maize. While sorghum is generally regarded as an inferior cereal when consumed as food, the income elasticity for livestock products (and hence the derived demand for feed) is generally positive and high.

Demand for animal feed is concentrated in the developed countries and in middle-income countries in Latin America and Asia, where demand for meat is high and the livestock industry is correspondingly intensive. Over 85 percent of sorghum feed use occurs in the developed countries. Three countries (United States, Mexico and Japan) together absorb nearly 70 percent of the world total (Table 2).

World feed use rose from 16 million tons at the beginning of the 1960s to about 35 million tons by the mid 1980s, an average growth of 4 percent per annum. This demand was the main driving force in raising global production and international trade during that period. One major factor was increased use of sorghum feed in the United States during the 1960s and early 1970s, largely because the cattle-feeding industry shifted from the northern maize belt to the southern plains, where most

United States sorghum is grown. Another factor was sharply raising demand for livestock products in Latin America, particularly in Mexico. In addition, government policies in some Latin American countries (e.g., Venezuela) restricted maize imports.

Table 2. Feed sorghum utilization in selected countries (FAO/ICRISAT, 1996)

Countries	Average (million tons)			
	1979-1981	1984-1986	1989-1991	1992-1994
United States	10.5	14.7	10.9	11.1
Mexico	6.7	6.6	8.1	7.1
Japan	4.1	4.2	3.5	2.6
China	2.4	2.1	1.5	1.9
Argentina	2.1	2.5	0.9	1.5
EC	1.8	0.5	0.8	0.9
Australia	0.4	0.3	0.8	0.8
Colombia	0.5	0.5	0.7	0.7
Venezuela	0.7	1.3	0.6	0.4
USSR	2.5	0.9	0.3	0.1
Others	3.4	3.1	3.2	3.2
World	35.1	36.7	31.3	30.6

Trends since then were shaped by two events-responses by the former USSR to the United States grain embargo on sales in the early 1980s, and policy changes in the United States that favoured maize over sorghum. These factors led to an increase in maize production; maize became cheaper than sorghum, and sorghum trade and utilization for animal feed declined. Feed utilization has gradually increased in Africa and remained relatively unchanged in the lower-income countries in Asia. Roughly 5-10 percent of the sorghum produced in India - and a considerably higher proportion in China - is used for livestock and poultry feed. However, both these regions are relatively minor users of feed; changes in utilization trends are driven largely by the developed countries, particularly the United States.

Competition between sorghum and maize is a key factor in feed utilization. The feed characteristics of sorghum are very similar to those of other cereals with which it competes. It provides about as much metabolisable energy as maize, has a higher crude protein content (trough of lower quality), and is relatively rich in niacin, an essential vitamin. However, large investments in maize research have helped increase yields and reduce growing cycles for this competing energy source. This has improved the competitiveness of maize prices in many countries.

Feed industries in most countries apply least-cost formulations to produce compound feeds, in which sorghum/maize is mixed with non-grain ingredients. The quantity of sorghum used in feed depends primarily on the relative prices of sorghum and maize, and on relative feed value.

Another important factor is consumer preferences for meat colour. Maize contains higher carotene levels than sorghum, so meat from maize-fed animals tends to be more yellow than meat from sorghum-fed animals. In Japan for example, consumers generally prefer white-coloured meat. Therefore, sorghum is a valued ingredient in some compound feed rations (for poultry, pigs and some breeds of beef cattle). In contrast, sorghum is discounted by producers in India because consumers there generally prefer poultry meat and egg yolks with a deeper yellow colour.

In addition, farmers in Asia have shown a growing interest in the sale and purchase of sorghum fodder. While the use of sorghum crop residues in Africa remains largely restricted to the farm, there is a large and growing market in Asia for traded sorghum residues to meet both rural feed shortfalls and urban agriculture demand, the letter largely for maintenance of dairy animals.

Material and Methods

Sorghum varieties Durra (DU), Jampang (JA), Ethio-95 (ET) and Amrik (AM) were used as plant materials in sorghum breeding by using mutation techniques. Seeds of Durra and ET-95 were found from food crop research centre in Bogor while Jampang and Amrik were collected from farmers in West Java. The seeds were then reproduced by BATAN and used as starting plant materials in the breeding research. These varieties could grow well in Indonesia but some improvements were required in order to increase their production in marginal conditions. Most marginal lands found in Indonesia are characterized by soil acidity and prone to drought. Therefore, sorghum breeding was aimed at improving plant adaptability in such adverse conditions.

Early experiment on sorghum breeding was made to increase genetic variability of sorghum plant by mutation techniques. For this, sorghum seeds with water content of about 13% were treated by mutagenic agents (gamma rays) emitted from Cobalt-60 source. Gamma irradiator is available at the Centre for Research and Development of Isotope and Radiation Technology, National Nuclear Energy Agency.

Sorghum is self-pollinated crop (House, 1984) so that breeding this crop will follow rules as for that of rice, soybean etc. All the M1 plants (the first generation after gamma irradiation treatment) were harvested individually and then each plant was grown as single seed base in the M2. Plant selections were started in the M2 generation for those having agronomic characters phenotypically significant different from the control plants. These characters included plant height, plant age, head size, seed colour 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 generation (M3) for further selections if they were still segregating. From the selection process, a number of mutant lines had been obtained and registered in the M3 and they were described as promising mutant lines.

Screening the promising mutant lines in the M4 was done 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 2000. Sowing the seeds was done by the end of raining season and the sowing date was 10 June 2000. 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 3 (BPP Semanu, 1999). 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 colour, seed form, and nutritive contents i.e. carbohydrate, protein, fat, ash, and water contents. Analysis of the nutritive contents used the standard method (Apriyantono *et al.*, 1989), with two replications for each line. Estimated yields were calculated by seed weight of individual plant basis and converted to a hectare (ton/ha). Field experiments were conducted by randomised design and test of significance between treatments used the method of orthogonal contrast. Computer program MSTAT was used in analysing the data (Bricker, 1989).

Table 3.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

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

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reported to give the highest variance (Soeranto *et al.*, 1998). Following selection process in the M2 and M3, a number of promising mutant lines had been registered in the M4. Results of testing some of the promising mutant lines in drought-prone areas of Gunung Kidul district during the dry season of 2000 were presented in Table 4 for the survival rates and Table 5 for the agronomic data. Qualitative data of the promising mutant lines i.e. seed size, seed colour and seed form are presented in Table 6. The quality data i.e. nutrition contents of sorghum lines are presented in Table 7. The estimated yield of sorghum lines is presented in Table 8.

Table 4. Survival rate of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Plot No.	Sorghum Lines	Survival rate (%)	Plot No.	Sorghum Lines	Survival rate (%)
2	AM/20/Cty/1	21.63	53	JA/30/Cty/57	2.70
3	AM/20/Cty/2	21.62	54	JA/30/Cty/60	8.11
4	AM/20/Cty/12	13.51	56	JA/30/Cty/36	48.65
6	AM/20/Cty/9	47.30	57	JA/30/Cty/37	35.14
8	AM/20/Cty/10	13.51	58	JA/30/Cty/35	24.32
9	AM/20/Cty/14	13.51	59	JA CONTROL	24.33
10	AM/20/Cty/18	21.62	60	JA/30/Cty/53	75.68
12	AM/20/Cty/3	27.03	61	JA/30/Cty/27	18.92
13	AM/20/Cty/4	51.35	62	JA/30/Cty/71	5.41
14	AM CONTROL	45.95	63	JA/30/Cty/33	13.51
15	AM/20/Cty/5	51.35	64	JA/30/Cty/39	14.87
17	ET/40/Psj/5	20.27	65	JA/30/Cty/34	16.22
27	ET/40/Psj/4	29.73	66	JA/30/Cty/17	9.46
30	ET/30/Psj/5	2.70	67	JA/30/Cty/69	16.22
31	ET CONTROL	2.70	68	DU/20/Psj/14	10.81
33	JA/30/Cty/47	6.76	69	DU/20/Psj/11	64.86
35	JA/30/Cty/43	27.03	70	DU/20/Psj/5	13.51
37	JA/30/Cty/41	10.81	72	DU/20/Psj/2	13.51
39	JA/30/Cty/19	21.62	73	DU/20/Psj/16	8.11
40	JA/30/Cty/50	35.14	75	DU/20/Psj/1	64.86
41	JA/30/Cty/77	27.03	76	DU/20/Psj/24	35.14
44	JA/30/Cty/41	5.41	78	DU/20/Psj/7	2.70
45	JA/30/Cty/23	16.22	83	DU/30/Psj/10	56.76
46	JA/30/Cty/70	5.41	86	DU/30/Psj/6	2.70
47	JA/30/Cty/21	18.92	90	DU CONTROL	35.14
48	JA/30/Cty/45	5.41	92	DU/30/Psj/22	2.70
49	JA/30/Cty/52	9.46	94	DU/30/Psj/4	37.84
50	JA/30/Cty/31	13.51	95	DU/30/Psj/27	2.70
51	JA/30/Cty/28	27.03	97	DU/30/Psj/1	8.11
52	JA/30/Cty/38	13.51	100	DU/40/Psj/1	40.54

Table 5. Agronomic data of selected sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Plot No.	Sorghum Lines	Plant Height (cm)		Number of Leaves	
		Average	SD	Average	SD
75	DU/20/Psj/1	132.00	5.70	7.2	0.45
94	DU/30/Psj/4	130.00	6.12	6.6	0.55
76	DU/20/Psj/24	129.00	6.52	6.4	0.55
47	JA/30/Cty/21	95.00	17.32	4.2	0.45
57	JA/30/Cty/37	82.00	10.37	5.0	1.00
27	ET/40/Psj/4	176.60	14.50	10.4	0.55
3	AM/20/Cty/2	206.80	21.06	9.4	0.89
6	AM/20/Cty/9	186.00	21.62	8.6	0.89
65	JA/30/Cty/34	79.60	0.89	4.4	0.55
69	DU/20/Psj/11	130.80	4.21	6.4	0.55
90	DU CONTROL	127.80	9.31	7.0	1.00
13	AM/20/Cty/4	224.80	23.08	9.2	0.84
83	DU/30/Psj/10	98.40	6.88	6.2	0.45

Table 6. Qualitative data i.e. seed size, seed colour and seed form of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Lines	Relative Seed Size	Seed Colour	Seed Form
DU/20/Psj/1	Big	White to grey	Round
DU/30/Psj/4	Medium	White to yellow	Round
DU/20/Psj/24	Big	White	Round
JA/30/Cty/21	Small	Black	Oval
JA/30/Cty/37	Small	Yellow to Black	Oval
ET/40/Psj/4	Big	White	Rough round
AM/20/Cty/2	Medium	Yellow to grey	Oval
AM/20/Cty/9	Small	Yellow to grey	Oval
JA/30/Cty/34	Small	Grey to black	Oval
DU/20/Psj/11	Big	White to yellow	Round
DU CONTROL	Medium	Grey	Round
AM/20/Cty/4	Small	Yellow	Oval
DU/30/Psj/10	Big	White to grey	Round

Table 3 gave information that survival rates between sorghum lines varied in condition of severe drought. Some lines that could not grow at all in such condition were called unadaptable lines and they were not written in the table. The sorghum lines having survival rate as shown in Table 3 were then registered as those having good tolerance to drought. These tolerant sorghum lines consisted of 11 lines of AM, 3 lines of ET, 29 lines of JA, and 16 lines of DU. These lines were promising to be developed further in Gunung Kidul District of Yogyakarta Province in order to support development of a sustainable agriculture in the region. 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.

Table 7. Nutrition contents of sorghum lines grown in drought-prone areas of Gunung Kidul, Yogyakarta Province

Sorghum Lines	Contents (%)				
	Fat	Water	Ash	Protein	Carbohydrate
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/20/Psj/24	1.22	11.70	0.86	7.80*	81.25
JA/30/Cty/21	1.25	9.85	0.82	6.46	81.59
JA/30/Cty/37	0.66*	9.17	0.44*	6.23	80.55
ET/40/Psj/4	1.51*	11.27	1.05	7.95*	81.07
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
JA/30/Cty/34	0.96	9.16	1.86*	6.00	82.01
DU CONTROL	1.30	10.72	0.97	6.25	80.75
DU/20/Psj/11	0.49*	12.47*	1.99*	6.98*	78.59
AM/20/Cty/4	1.47	10.44	0.59*	6.58	80.92
DU/30/Psj/10	0.71	10.96	0.94	8.08*	81.30

* Significant compared to control ($P<0.05$)

Table 8. 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)
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/20/Psj/24	2.5	86.5	28.166	3.2
JA/30/Cty/21	3.3	90.4	27.105	3.0
JA/30/Cty/37	4.1	92.5	23.147	2.5
ET/40/Psj/4	3.6	98.1	44.462	4.3
AM/20/Cty/2	2.5	105.5	15.432	2.7
AM/20/Cty/9	3.3	103.6	18.355	2.8
JA/30/Cty/34	2.0	87.2	22.764	2.3
DU CONTROL	2.3	90.4	26.06	3.0
DU/20/Psj/11	4.3	86.3	34.870	3.4
AM/20/Cty/4	2.5	99.1	17.518	2.1
DU/30/Psj/10	4.1	87.0	30.964	3.9

Variation in plant height and number of leaves between sorghum lines in severe drought conditions could be seen in Table 5. Generally, short plants were accompanied with less leaf as shown by lines JA/30/Cty/21, JA/30/Cty/37, JA/30/Cty/34 and JA/30/Cty/10. These short plants, however, had relatively high tillering capacity (Table 8). 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.

Variations were also observed in relative seed size, seed colour and seed form of the sorghum lines (Table 6). These variation 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. The nutrition contents of some sorghum lines were found relatively high (Table 7) as it was shown in protein content of the mutant line DU/20/Psj/1 (7.39 %), DU/20/Psj/24 (7.80 %), ET/40/Psj/4 (7.95 %), DU/20/Psj/11 (6.98 %) and DU/30/Psj/10 (8.08 %). These high-protein sorghum lines could be developed further in the region for helping overcome food crisis and human nutrition of the local inhabitants, and also for improving the quality of animal feed.

Estimated economic yields (grain) of sorghum lines grown in dry conditions were presented in Table 8. Some lines had relatively high yield (more than 3 ton/ha) as it was shown by 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. These promising lines had yield higher than the control DU variety. In reality, however, the yield might not be that high due to some constrains such as abnormal growth, disease and insect attacks etc. The other lines with low yield might also be of importance in producing biomass for being used as animal feed (green forage), and it can also be recycled in the soil in order to support the development of a sustainable agriculture in the region.

Conclusion

Sorghum is drought-tolerant crops. It could be grown in dry condition where other crops may not be able to grow. Improvement of sorghum varieties by mutation breeding had resulted some promising mutant lines that could be grown and developed further in Gunung Kidul District of Yogyakarta Province. Utilization of the promising lines could be directed either as food or feed source for the local farmers. Sorghum cultivation would help the local farmers produce either alternative food or feed during the dry season in their land. Some sorghum lines were suitable to be developed for feeding ruminant animals such as cow and cattle in the drought-prone region of Gunung Kidul District. The stovers might be given to the animals in forms of green chop, pasture, hay or silage while the grain might be of useful to be used as a component of a poultry ransom. Some high-protein sorghum lines could be developed further in the region for helping local inhabitants overcome food crisis and human nutrition. Moreover, sorghum was an alternative plant in producing biomass during dry season. Recycling this biomass to the soil will help farmers maintain soil fertility for future development of sustainable agriculture in the region.

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