Research Article

www.ekinjournal.com

Ekin
Journal of Crop Breeding and Genetics

(2015) 1-2:26-31

Genotypes X environment interaction effect on nutritional quality of sorghum lines in Indonesia

Trikoesoemaningtyas[1*] **Desta Wirnas[1]** **Didy Sopandie[1]** **Tesfaye Tesso[2]**

[1] Department of Agronomy and Horticulture, Bogor Agricultural University,
Jl. Meranti Kampus IPB Darmaga, Bogor 16680, Indonesia,
[2] Department of Agronomy Kansas State University, USA
[*] Corresponding author e-mail: trikadytia@gmail.com

Citation:
Trikoesoemaningtyas, Wirnas D, Sopandie D, Tesso T 2015. Genotypes X environment interaction effect on nutritional quality of sorghum lines in Indonesia. Ekin J Crop Breed and Gen 1-2:26-31.

Received: 13.08.2014 ***Accepted: 18.11.2014*** ***Published Online: 30.07.2015*** ***Printed: 31.07.2015***

ABSTRACT

The adoption of sorghum as alternative souce of food in Indonesia depends on consummer acceptance of sorghum grain which is determine by the nutritional and anti-nutirtional values and the quality of sorghum grain. The objectives of this study were to obtain information on genetic variability of sorghum genotypes with diverse backgroud for nutritional values and the effect of genetic x environment on the variablity in sorghum grain nutritional values. The study was conducted on 24 sorghum lines consisted of breeding lines, introduced lines and a local variety. The lines were planted in a randomized complete block design with tree replications in two locations differing in soil fertility. The results showed that the protein, fat, amylose and tannin contents of the sorghum lines are effected by the genotype x environment interaction with different magnitutes. The presence of G X E interaction reduced the genetic variances and estimates of heritability of the characters.

Keywords: sorghum grain, protein content, tannin content, genetic variance, heritability

Introduction

Indonesia has a large areas of dryland with a total of 148 Million ha which are prone to drought, and a total of 102.8 million ha of the area are acid soils (Mulyani et al, 2011). In addition to the low nutrient content, acid soils are also characterized by high concentrations of Al, especially $Al3^{+}$, which is the form of Al considered to be most toxic to plants. Aside from Al stress, constraints on acid soils is P deficiency caused by binding of P by Al, which makes P unavailable (Marschner, 1995). A large areas of dryland are still under utilized with cropping index less than two. A crop with good adaptation to the condition, could improve the productivity of Indonesian dry lands and improve farmer income.

Sorghum is a drought tolerant crop and suitable for cultivation in dought prone areas in Indonesia. According to Assefa et al (2010) a medium-to-late maturing sorghum cultivar requires approximately 450 to 650 mm of water during a growing season. Water stress or drought reduces biomass, yield and harvest index more in maize than in sorghum, giving higher yields for sorghum under limited water. Sorghum has great ability to extract water from deep soil layers due to its deep root system (Farre & Faci, 2004). In addition, several sorghum varieties are tolerant to acid soil and able to maintain growth and yield under high Al toxicity and low P found in many acid soil in Indonesia (Agustina, et al, 2010).

Sorghum grains are important source of dietary proteins, carbohydrates, minerals, and B group vitamins with some values higher than rice. Sorghum is a good candidate to be promoted to improve human health and reduce rice consumption in Indonesia as a mean to sustain national food security. However, sorghum is still considered as a minor crop in Indonesia and still underutilized. To improve sorghum adoption by farmers, sorghum varieties should have good grain quality, high nutronal values and low in anti nutritional values.

There is variability for grain nutritional contents among sorghum genotypes as shown in the total protein, total starch and mineral contents among the South African sorghum accession (Ngu'ni et al, 2012) and in many cases also effected by the interaction of genotypes with the environment as shown in wheat (Kiliç and Yağbasanlar, 2010) and oats (Doehlert et al, 2001). The objectives of this study was to obtain information on genetic variability of sorghum germ plasm with diverse backgroud for nutritional and antinutritional values and the effect of genotype x environment on the variablity in sorghum grain nutritional values.

Materials and methods

This study was conducted in two locations (1) A farmer field in Jasinga, West Bogor District, Bogor Indonesia with soil pH of 4.1-4.4 and exchangable Al of 2.3-5.8 cmol/kg (2) The University Farm of Bogor Agricutlural University with soil pH of 5.5 and 0 cmol/kg of exchangeable Al. The grain analysis was conducted in the Laboratory of Post Harvest Research Center of the Ministry of Agriculture. The field experiments were conducted from April-July 2012 and the grain analysis was conducted in August 2012.

The genetic materials used in this study were 17 F_7 breeding lines from the cross of Numbu x UPCA-S1 developed by the Laboratory of Plant Breeding and Genetics, Department of Agronomy and Horticulture, Bogor Agricultural University, four introduced lines from ICRISAT and one local variety. Two national varieties UPCA-S1 and Numbu were used for comparison.

The experiment was conducted in a Randomized Complete Block Design with three replicates nested in location. The planting was conducted as direct seeding with 2 seeds per hole at 70 x 10 cm planting distance in a 4 m x 5 m plot. Fertilizers of Urea, SP36 and KCl were applied at the rate of 100 kg/ha, 100 kg/ha and 60 kg/ha, respectively. Two third of the urea was applied as base fertilizers at planting with SP-36 and KCl. The rest of the urea was applied at seven weeks after planting. Plot maintenance and pest and disease control was conducted accoring to standard practices.

After harvesting, the seeds were dehulled and analyzed for fat content, protein content, amylose content and tannin content The study was concuted at the Laboratory of Grain Quality of the Center for Postharvest Research the Ministry of Agriculture, in Bogor. The amylose content was determined using iodo-colorimetry method , protein content was analyzed by Kjeldahl method (AOAC, 2007) and tannin content was analyzed by the vanillin in acidic methanol method (Price et al, 1978).

Analysis of variance for randomized complete blocks design was carried out for each location using SAS version 9.2 (SAS Institutes, NC) where locations were considered as random and all genotypes were considered as fixed. Homogeny test of varinces was conducted by Bartlet's test and the combined analysis of variances was conducted for genotypes under two locations. The estimated variances of each components were partitioned into variace due to genotypes (σ^2_g), variance due to environment (σ^2_e) and the interation ($\sigma^2_{g\,x\,e}$) and broad sense heritablity was estimated for eah location and for the combined conditioned.

Results and discussion

Nutritional and anti-nutritional value of sorghum grains is important to accelarate consummers acceptance of sorghum in Indonesia. This study was conducted to evaluate nutritional values of grains of sorghum lines of diverse backgrounds. The lines consisted of introduced lines from ICRISAT, national varieties and breeding lines. The analysis of variance from each location showed that genotypes significantly effects the protein, fat, tannin and amylose content (Table 1 and Table 2). Genetic variability in nutritive content of sorghum grain has been reported among Southern African sorghum accessions (Ng'uni et al, 2012), and among Indian sorghum varieties used for Roti (Chavan et al, 2009).

The protein content of sorghum variety is important if the variety is to be designated as grain sorghum.The genotypic means showed that the protein content of the lines evaluated ranged from 8.0-11.41 % when grown in Jasinga and 8.83-9.83 % when grown in Leuwikopo. This is within the range for sorghum as reported in some inbred and hybrid lines of sorghum in Kansas, whrere the range was 10.3-16.5 % (Hicks et al, 2002). A local variety, Watar Hammu Puti (WHP) had the highest protein content (11.4%) compared to introduced lines and breeding lines when grown in acid soil of Jasinga with high Al content (Table 4). Aba et al (2005) reported that the protein content of ten African sorghum varieties ranged from 10 – 16.45%. The lines tested have different grain color from pearly white to pale red color. Ng'uni et al (2012) reported that there is no significant difference in protein content between red and white sorghum grains. The genotypic means for fat content of the evaluated lines ranged from 2.75-4.06%. The introduced lines PI-10-90-A has the highest fat content of 4.06%. This value is higher than reported by Hicks et al (2002) among sorghum inbred lines and hybrid which ranged from 3.17-3.63%. The fat content is important if sorghum grain is going to be used as feeds, because fat produces higher energy than carbohydrate.

The main storage carbohydrate in sorghum grain is starch, which consist of amylose and amylopectin. Sorghum is classified into three groups based on the amylose content, namely waxy (<1%), heterowaxy (10-20%) and normal (>20%) (Shelton et al, 2004). The amylose content of the sorghum lines evaluated ranged from 18.82-23.44% in Jasinga and 18.83-24.98% in Leuwikopo. Based on the amylose content, the sorghum lines were classified as normal sorghum. For food and industrial purposes, lower amylose content is needed, because lower amylose content increases carbohydrate digestibility (Lichtenwarner et al, 1978) and improve ethanol fermentation (Yan et al, 2011).

Sorghum grains contain tannin, a phenolic compound, which could reach up to 6%, the highest among grain cereals. Tannin can reduce protein and carbohydrate digestibility . Many consummers also prefer sorghum food with low tannin content because of the bitter taste of tannin. Our study showed that there is variability in tannin content among the sorghum lines. The introduced lines from ICRISAT have higher tannin content compared to IPB breeding lines and the national variety Numbu. Numbu has the lowest tannin content of only 0.11% (Table 1). Puspitasari et al (2011) reported that the the tannin content of sorghum mutant lines and national varieties grown in acid soil ranged from 0.38-3.66%, and national variety Mandau grown in acid soil has high tannin content of 3.66%. Ebadi et al (2005) classified sorghum varieties as low tannin (< 0.10%, LTS), medium tannin (0.10-0.3%, MTS), and high tannin (>0.3%, HTS). According to this classification, two IPB breeding lines were classified as high tannin content, and two lines, N/UP-48-2 and N/UP-156-8 were classified as medium tannin content with tannin content of 0.15% and 0.14%, respectively.

Environment conditions effect chemical composition, physical properties and food quality of sorghum. The nutritional content of sorghum grain is affected by environmental conditions such as drought, soil fertility, pest and diseseas (Roony and Murty, 1982). Pale et al (2010) reported that the both water management and fertilizer applications affected grain physicochemical characteristics and malting quality in two sorghum varieties. The results of the combined analysis of variances showed that sorghum genotypes differed significantly for protein, fat, amylose and tannin content, while locations were significant for fat and tannin content . Genotypes x Locations interaction was significant for all the traits (Table 3).

The combined analysis showed that the nutritional and anti-nutritional content of sorghum lines were effected by the genotype x locations with different magnitutes. The variances due to genotypes were higher for protein content and amylose content, but the variability observed for fat content and tannin content were mostly due to locations. The magnitute of variance due to genotype x locations was high for protein and amylose, but for fat and tannin content, the magnitutes of the genotype x location interaction were lower than variance due to genotype and environment alone.

The combined analysis showed that locations was the main source of variation in tannin content of sorghum lines (Table 3). Taleon et al (2012) reported that the total flavonoid content of black sorghum was effected strongly by environment, mainly due to the differential effect of abiotic factors such as light and temperature and also by the differential intensity of fungal infection.

The genetic x environment interaction qualitatively affect the protein content of sorghum genotypes causing a change in the ranking of genotypes. The intoduced lines PI-150-21-a which was ranked as the genotypes with the highest protein content in Jasinga was only third in Leuwikopo, and the local variety Watar Hamu Putih which produced second highest protein content in Jasinga was dropped to number thirteen in Leuwikopo. This type of interaction will complicate selection for protein content in sorghum.

The broad sense hertability estimates for a single environment were high for fat and tannin content. However, presence of genotype x environment interaction reduced the magnitutes of the genetic variances and the estimate of heritability as compared to the estimates of a single environment (Table 5). The reduction of the heritability estimates are propotional to the magnitute of the variace of genotypes x environment interaction. This findings indicated that for nutritional content, estimation of heritability should include variablity due to genotype x invironment interaction to avoid upward bias of the estimate for one or the other environment.

Genotype by environment interaction effects sorghum grain nutritional and anti nutritional content. The presence of genotypes x environemntal interaction resulted in differential nutritional values of a genotypes over environments. The result indicated that while conducting yield stability trials, breeders should not only focused on agronomic characters and yield potential. Observation should be made on important nutritional content of sorghum grain over environments in order to select for superior sorghum genotypes with good grain quality.

Acknowledgement

This study was funded by a grant from the Ministry of National Education and Culture the Republic of Indonesia, under the International Colaboration and Publication Research Grant Contract no 203/SP2H/PL/Dit. Litababmas/IV/2012 for Trikoesoemaningtyas.

Table 1. Mean Squares (MS) for seed content of sorghum introduced and breeding lines grown in acid soil in Jasinga

	Mean Squares				
Source	**df**	**Protein**	**Fat**	**Amylose**	**Tannin**
Replicaate	2	0.0459	0.0568	1.7123	0.0352
Genotypes	16	2.3954*	0.4888*	6.4912*	0.0773*
Error	32	0.6670	0.0520	3.3005	0.0167
Total	50				

Table 2. Mean Squares (MS) of seed content of introduced and breeding lines of sorghum grown in non acid soil in Leuwikopo

Source	**df**	**Mean Squares**			
		Protein	**Fat**	**Amylose**	**Tannin**
Replicaate	2	0.1246	0.1274	0.3544	0.0329
Genotypes	16	0.3149*	0.3288*	10.7089*	0.0293*
Error	32	0.2045	0.1100	4.1850	0.0122
Total	50				

Table 3. Combined Analysis of Variances for grain nutrition and anti nutritional content of introduced and breeding lines of sorghum over two environment.

Source	**df**	**Mean Squares**			
		Protein	**Fat**	**Amylose**	**Tannin**
Replicates	4	0.04348	0.00753	0.36281	0.02149
Location	1	0.39221	0.55663*	0.46812	3.29042**
Genotypes	16	1.44126*	0.52815*	9.86565*	0.05323*
Genotypes x Locations	16	1.26897*	0.28940*	7.33445*	0.05342*
Error	64	0.43833	0.08629	3.78463	0.01519
Total	101				

Table 4. Nutritional and anti-nutritional content of sorghum lines in two locations in Indonesia

No	Genotypes	Protein (%)		Fat (%)		Amylose (%)		Tannins	
		JSG	LEU	JSG	LEU	JSG	LEU	JSG	LEU
1	PI-150 21 a	11.22	9.74	2.68	2.87	20.57	20.68	0.80	0.75
2	PI-5 193 C	9.88	9.33	2.61	2.99	20.30	19.51	0.42	0.75
3	PI-10 90 A	10.33	9.50	4.06	2.99	18.82	18.83	0.32	0.81
4	PI-150 20 A	9.38	9.58	2.97	2.65	21.48	21.70	0.29	0.78
5	WHP	10.82	9.22	2.91	2.43	23.90	21.74	0.14	0.77
6	N/UP-166-6	10.65	9.59	2.76	3.14	23.44	19.48	0.25	0.41
7	N/UP-48-2	10.32	9.56	2.85	2.69	21.05	24.98	0.15	0.72
8	N/UP-82-3	9.20	9.83	2.45	2.49	23.76	18.62	0.25	0.66
9	N/UP-118-3	8.86	9.20	2.61	3.05	22.85	21.17	0.40	0.66
10	N/UP-156-8	9.56	9.55	2.83	2.24	21.80	22.63	0.14	0.65
11	N/UP-89-3	9.36	8.92	2.85	2.21	22.97	24.61	0.20	0.75
12	N/UP-39-10	9.51	8.83	2.65	2.30	20.99	22.63	0.21	0.73
13	N/UP-118-7	8.68	9.98	2.19	2.28	21.59	20.70	0.28	0.71
14	N/UP-139-1	9.19	9.23	2.60	2.62	22.82	24.17	0.41	0.56
15	N/UP-124-7	8.04	9.04	2.61	2.85	21.34	21.10	0.38	0.64
16	Numbu	8.20	9.74	2.89	2.17	19.60	21.02	0.45	0.62
17	UPCA-S1	9.11	9.31	2.23	2.26	20.56	21.95	0.40	0.60

JSG = Location 1 (Jasinga pH 4.1-4.4, 2.3-5.8 cmol/kg Al), LEU = Location 2 (Leuwikopo, pH 5.5, 0 cmol/kg Al), WHP = Watar Hamu Puti

Table 5. Partition of variances and estimates of heritability for nutritional content of sorghum in each location and over two environemnts

Characters	Jasinga		Leuwikopo		Combined		
	σ^2_g	h^2	σ^2_g	h^2	σ^2_g	$\sigma^2_{g \times e}$	h^2
Protein	0.576	46.346	0.037	15.257	0.167	0.277	18.944
Fat	0.146	73.677	0.073	39.867	0.074	0.068	32.351
Amylose	1.064	24.371	2.175	0.006	1.014	1.183	16.944
Tannin	0.020	54.812	34.195	32.022	0.006	0.013	18.498

References

[AOAC] Official Methods of Analysis of AOAC International. 2007. 18th ed, AOAC International, Maryland .

Aba D A, E. Abu, P S Chindo, P S Marle, D N Maigida, A O Ogungbile. 2005. Characterization of Some Released Sorghum Varieties for Food and Industrial Utilization In Nigeria. Agricultura. Tropica Et Subtropica Vol. 38(2): 1-6

Agustina K, D Sopandie, Trikoesoemaningtyas, D Wirnas. 2010. Physiological Response of Sorghum (*Sorghum bicolor* L. Moench) Roots to Aluminium Toxicity and Phosphorous Deficiency. (in Indonesian). Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy) Vol 38, No 2.

Assefa Y, A Scott, Staggenborg, V P V Prasad. 2010. Grain Sorghum Water Requirement and Responses to Drought Stress: A Review. Plant Management Network. Crop Management doi:10.1094/CM-2010-1109-01-RV

Chavan V D, J V Patil, M S Shinde. 2009. Nutritional and Roti Quality of Sorghum Genotypes. Indonesian Journal of Agriculture Sciences 10 (2): 80-85.

Doehlert D C, M S McMullen, J J Hammond. 2001. Genotypic and Environmental Effects on Grain Yield and Quality of Oat Grown in North Dakota Crop Sci. 41:1066-1072.

Ebadi M R, J Pourreza, J Jamalian, M A Edriss, A H Samie, S A Mirhadi. 2005. Amino Acid Content and Availability in Low, Medium and High Tannin Sorghum Grain for Poultry. International Journal of Poultry Science 4 (1): 27-31, 2005

Farre I and J M Faci. 2004. Comparative response of maize (*Zea mays* L.) and sorghum (S*orghum bicolour* L. Moench) to irrigation deficit in a Mediterranean climate. Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep-1 Oct 2004 | ISBN 1 920842 20 9 | www.cropscience.org.au

Hicks C, M R Tuinsra, J F Pederssen, K D Kofoid. 2002. Genetic analysis of feed quality and seed weight of sorghu inbred lines and hybrids using analytical methods and NIRS. Euphytica 127: 31-40.

Kiliç H, T Yağbasanlar. 2010. Genotype x Environment Interaction and Phenotypic Stability Analysis for Grain Yield and several Quality Traits of Durum Wheat in the South-Eastern Anatolia Region. Not. Bot. Hort. Agrobot. Cluj 38 (3) 2010, 253-258.

Lichtenwalner E, B Ellis, L W. Rooney. 1978. Effect of incremental dosage of waxy genes of sorghum on digestibility. Journal of Animal Sciences 46: 1113-1119.

Marschner H. 1995. Mineral Nutrition in Higher Plant. San Diego: Acad Press.

Mulyani, A, S Ritung, I. Las. 2011. Potential and availability of land resources to support food security. (In Indonesian). Journal Litbang Pertanian (3) 2: 73-80.

Ng'uni D, M Geleta, P Hofvander, M Fatih, T Bryngelsson. 2012. Comparative genetic diversity and nutritional quality variation among some important Southern African sorghum accessions [*Sorghum bicolor* (L.) Moench]. Australian Journal of Crop Science 6(1): 56-64

Palé S, S J B. Taonda, B Bougouma S C Mason. 2010. Water and fertilizer influence on sorghum grain quality for traditional beer (*dolo*) production in Burkina Faso. African Journal of Food Science Vol. 4(11) : 723-734. http://www.academicjournals.org/ajfs

Price, ML, S Van Scoyoc, L G Butler. 1978. A critical evaluation of vanillin reaction as an assay for tannin in sorghum. Journal of Agricultural and Food Chemistry 26, 1214-1218.

Puspitasari W, S Human, D Wirnas and Trikoesoemaningtyas. 2011. Evaluating Genetic Variability of Sorghum Mutant Lines Tolerant To Acid Soil. Atom Indonesia Vol. 38 No. 2

Rooney , L W, D S Murty. 1982. Evaluation of Sorghum Food Quality. Sorghum in the Eighties: Proceedings Symposium on Sorghum, 2-7 Nov 81, Patancheru, India: ICRISAT.

Shelton J L, J O Mattews, L L Southern, A D Higbie, T D Bidner, J M Fernandez and J E Pontit. 2004. Effect of non-waxy and waxy sorghum on growth, carcass traits and glucose and insulin kinetics of growing and finishing barrows and gilts. J. Animal Sciences 82: 1699-1706.

Taleon V, L Dykes, W L Rooney , L W Rooney., Effect of genotype and environment on flavonoid concentration and profile of black sorghum grains, *Journal of Cereal Science* (2012), doi: 10.1016/j.jcs.2012.05. 001.

Yan S, X Wu, S R. Bean, J F. Pedersen, T Tesso, Y R. Chen, D Wang. 2011. Evaluation of waxy grain sorghum for ethanol production. Cereal Chemistry 88 (6) : 589-595