

Interaction between genotypes, environment and season (G x E x S) on anthocyanin corn in lowland zone of Indonesia

M Yasin H G, M Isnaeni, Faesal, and M Azrai

Indonesia Cereal Research Institute (ICERI), Jl. Dr. Ratulangi No. 274 Maros, South Sulawesi, Indonesia.

E-mail: hg_yasin@yahoo.co.id

Abstract. Interaction between genotypes (G), environment (E) and season (S) on anthocyanin corn has been studied under lowland zone in Indonesia. The experiment were conducted using Randomized Complete Block Design (RCBD) based on location namely Maros, Bajeng, and Polman with three replications. Ten populations of open pollinated variety (OPV) of anthocyanins purple corn included checks were used in two planting seasons (dry and rainy) in 2015/2016. The objective of the experiment is to determine which of the population is stable and has high yield to be promoted as candidate for new OPV varieties. Genotypes were planted in four rows of 5.0 m length, spacing of 75 cm x 20 cm, one plant per hill, and applied with Urea, Ponska (300 and 200 kg Ha⁻¹). Population was then selected by t test in model $Y_{ij} = \mu + \beta_i I_j + \delta_{ij}$, $i \neq j$ (Y: yield, μ : mean, β : regression coefficient, I: environmental index, δ : deviation from regression), and stability parameter $b_i = \sum Y_i I_j / I_j^2$. The results show that there was a significant interaction of GxExS on PMU(S1).Synth.F.C1 and PPU(S1).F.C1 with yield ranging between 6.70-8.48 t ha⁻¹ and grain potential found in the locations of Maros and Bajeng in the rainy season. Content of anthocyanins were between 37.15 and 51.92 µg per 100 g sample.

1. Introduction

Corn with purple coloured grain can be defined as a specialty corn which contains high content of nutritious anthocyanins. Originated from Mesoamerica, the corn with a pigment that gives colour of red, purple, and blue in the grain have health beneficial to prevent viral, cholesterol, heart disease, obesity, and cancer [1, 2]. Yasin *et al.* [3] reported that the corn has many excellent characters and higher economic value, that makes it as an importance raw material for food industries, textiles, paper making and feed. Germplasms had been selected to increase cycle of selection by self (S1, S2 to S4/S5). Anthocyanins corn is a recessive characteristic, production must be isolated from normal/dent to prevent losing the periculi starch and colour properties. The variety evaluation trial under some environments have been conducted and continued to provide guidance for selecting the best genotype and estimated yield. Several studies to test the yield stability of Quality Protein Maize (QPM) crops were conducted [3, 4] in seven environments under lowland tropical zone which resulted in 11 entries that found to be stable and had highly significant effect of GxExS.

The objective of the experiment is to evaluate the yield stability of ten anthocyanins corn under three environments during dry and rainy planting seasons in 2015/2016. The best population will be determined as the potential genotype for new open pollinated variety (OPV) of anthocyanins corn.



2. Methodology

The experiment was conducted in Maros (e1), Bajeng (e2) and Polman (e3) regencies in South Sulawesi Province of Indonesia. The locations are under lowland tropical zone <50 m above the sea level (asl). The genotypes (g) were 10 populations of anthocyanins corn with seed colours purple to black (table 1) based on Pixley *et al.* [5] that genetic population of specialty corn could be increase by initial selection of colour seeds. The experiment was set in Randomized Complete Block Design (RCBD) with three replications in dry and rainy season in 2015-2016. The genotypes were planted in four rows per se, spacing 75 x 20 cm, fertilized with Urea and Ponska with dosage of 300 and 200 kg Ha⁻¹, respectively.

Table 1. Seed texture, colour, origin and cycles population of anthocyanins corn planted in the two planting seasons in 2015/2016 in three locations under lowland of tropical zone condition.

Genotype (g)	Dry season, 2015		Rainy season, 2016	
	Seed texture	Seed colour	Seed origin	Cycles population
g1. PTU(S1)F.C0	flint	purple to black	China	C0
g2. PTU(S1)D.C0	flint	purple to black	China	C0
g3. PMU(S1)SYN.D.C1	semi dent	purple	Manado	Syntetik C1
g4. PMU(S1)SYN.F.C1	flint	purple	Manado	Syntetik C1
g5. PPH.FS.C1	flint	purple to black	Lembah Palu	C1
g6. PPH.(S1).C1	flint	purple to black	Lembah Palu	C1
g7. PVU.FS.C0	flint	purple	Vietnam	C0
Check				
g8. PLP.C0 (check 1)	semi flint	purple	Lembah Palu	C0
g9. PLM.C0 (check 2)	flint	White	Pulut Maros	C0
g10. URI1 (check 3)	flint	White	UPBS	C0
PTU : purple waxy of China URI : waxy corn 1(check, white) PLM : Local waxy of Maros				
PPH : black waxy of Palu PMU : purple waxy of Manado flint : pearl, dent:horse teeth				
PVU : purple waxy of Vietnam PLP : purple waxy of Palu				

The variable observed were yield, plant and ear height, period of tasseling and silking, weight of 1000 seeds, water content and shelling percentage. The data were analyzed by single effect of genotype (G), two factors interaction between genotype and environment (E) (GxE) by pooled analysis ei, i=1,2,3 on dry and rainy [3, 6], three factors interaction between genotype, environment and season (S) (GxEs) by simple regression analysis with xi as environmental index.

Coefficient of simple regression of Gi was calculated using: $Y = \beta_0 + \beta_1 x$. bi (i= 1,2, . . . ,10), bi = $(\sum \sum x_{ij} \cdot \bar{y}) / \sum \bar{y}^2$, where $\bar{y}$: grand mean of all population and x_{ij} : mean of each population gi [10].

The hypothesis of stability was $H_0: \beta_1=1$ vs $H_1: \beta_1 \neq 1$ by d.f : n-1. t.cal.: $(\beta_1-1)/sd$; sd : VS^2 ; S^2 : Varians : $1/n[\sum x_i^2 - (\sum x_i)^2/n]$.

Different of population in each location was compared to control with three checks by Least Significance Difference (LSD) test in level of significant of 95%. LSD: $t(18)\sqrt{(2s^2/3)}$, s^2 : error mean square. Yield of grain in 15% water content was predicted by: $Y: ((10000/7.5)*(100-wa)/85)*(shelling)*ear\ weight\ on\ harvested$. Genotype selected if hypotesis of $H_0: \beta_1 \neq 1$ was rejected, and average $Y_i > Y_t$ [2, 7].

3. Results and Discussion

3.1. GxE Interaction Analysis

The result analysis of variance and the mean square of observed variable and coefficient of variance value under dry and rainy season is shown in table 2. The analysis shows that under dry season there were significant interaction of GxE on variable of yield, tasseling, and weight of 1000 seeds. The single

effect of genotype (G) was significant on yield, plant height, silking period, and shelling percentage. In the rainy season, GxE was significant on plant height and water content of seeds only, and single effect of G shows that all variable were significant except of plant and ear height.

Table 2. The mean square and coefficient of variance (CV) of GxE interaction on anthocyanins corn in dry and rainy season in 2015/2016

Variable	E	U/E	G	GxE	Error	CV(%)
Dry season 2015						
Yield	10,544*	0,275	4,997*	1,530*	0,660	12,4
Plant height	4699,547*	135,890	156,044*	75,877	85,908	4,9
Ear height	2196,466*	1,805	28,173	42,730	54,802	8,1
Tasseling	12,878*	1,056	1,328	2,051*	1,228	2,3
Silking period	13,478*	0,256	1,888*	0,910	1,095	2,0
Water moisture	151,800*	26,455	3,084	5,290	5,026	8,3
Shelling percentage	14,042*	1,778	5,404*	3,845	4,418	2,7
Weight 1000 seeds	112,678	488,778	621,685	1330,715*	983,049	10,42
Rainy season 2016						
Yield	3,987	3,029	9,934*	0,584	0,750	12,9
Plant height	547,600*	69,433	89,723	157,205*	89,396	4,9
Ear height	26,678	41,956	42,326	62,011	82,412	9,6
Tasseling	0,900*	0,500	8,099*	1,147	1,290	2,3
Silking period	2,178*	0,900	9,723*	1,042	1,369	2,2
Water moisture	257,387*	19,709	24,792*	12,899*	11,072	10,3
Shelling percentage	0,289	1,349	4,760*	1,528	6,360	3,19
Weight 1000 seeds	578,011	638,344	2303,190*	371,838	919,005	10,02

* significant different on 95% level n : 90

3.2. GxExS Interaction Analysis

Table 3 shows analysis of three factors, GxExS, with significant variable were yield, plant height and water content of seeds. The results indicate that yield of all genotypes were different under three locations in Maros, Bajeng and Polman. The CV found for all variable was <20,0% and be assume that there are could be selected of Gi, i = 1, 2, 3, . . . , 10 for new corn varieties [3]. The experiment of QPM of yellow grain from CIMMYT showed that population could be adapted in Maros after selected by S1 families and genetically improved by one cycles of selection, yield was 8.0-10.0 t Ha⁻¹ [11]. The significant Interaction of GxExS on three variables could indicate that genotypes yield, plant height and water content of seeds at harvest were significantly different under three locations.

Table 3. The mean square, coefficient of variance (CV) and interaction GxExS on anthocyanins corn in 2015/2016.

Variable	E	R/E	G	ExG	S	ExS	GxS	GxExS	Error	CV (%)
Yield	12.542	1.901	12.040	0.967	0.591	1.990	2.890	1.147*	0.742	13.0
Plant height	1658.860	69.704	165.426	121.716	789.188	3588.287	79.340	111.366*	90.173	4.9
Ear height	983.382	27.138	27.277	54.614	268.156	1231.761	43.222	50.127	65.871	8.7
Tasseling	3.489	0.567	2.393	1.859	2.689	10.289	7.035	1.338	1.245	2.3
Silking period	2.617	0.428	4.388	0.907	1.606	13.039	7.223	1.045	1.206	2.1
Water moisture	222.913	9.937	10.468	7.739	460.160	186.275	17.409	10.450*	9.911	10.2
Shelling, %	8.434	1.757	4.046	3.058	11.300	5.879	6.119	2.316	5.178	2.8
1000 seeds	232.267	206.961	1578.154	731.730	107.339	458.422	1348.722	970.823	949.441	10.2

* Significant different on 95% level, n : 180

3.3. Yield Stability

The analysis of yield stability shown in table 4 shows significant differences were found in dry season and there are four candidate of genotypes (G1, G3, G4, and G7) that were significant by statistical t test, while three checks were not significant. However, in the rainy season, G1 and G3 were significant. The result indicates that population G1 (PTU(S1)F.C0 could become as a candidate for promising new OPV. The significant result indicates that the genotype yield was stable in the three locations under two seasons in rainy and dry seasons and assuming that the condition in the locations were favorable for plant growth, like well fertilized, no weeds and pest-disease resulted in maximum grain yield obtained. The statistical analysis of G1 shows that $b=1$, $H_1:b \neq 1.0$ was rejected and $R^2:99.2\%$.

Table 4. Parameters of yield stability of anthocyanins corn. 2015-2016

	R	R ²	B	Se.β	MSe	t.cal.
Dry 2015						
G1. PTU(S1)F.C0	0.996	0.992	3.050	0.340	0.001	6.029*
G2. PTU(S1)D.C0	-0.462	0.213	-1.397	2.677	5.037	0.894
G3. PMU(S1)SYN.D.C1	0.906	0.820	2.469	1.156	0.939	1.271*
G4. PMU(S1)SYN.F.C1	0.966	0.934	1.374	0.366	0.094	1.023*
G5. PPH.FS.C1	-0.559	0.313	-0.426	0.631	0.280	2.260
G6. PPH.(S1).C1	-0.474	0.225	-0.774	1.437	1.451	1.235
G7. PVU.FS.C0	0.973	0.946	1.915	0.457	0.147	2.003*
Check						
G8. PLP.C0 (check 1)	0.980	0.950	2.600	0.024	0.001	66.040
G9. PLM.C0 (check 2)	-0.961	0.923	-0.575	0.167	0.020	9.456
G10. URI1 (check 3)	0.813	0.661	0.828	0.597	0.243	0.300
Rainy 2016						
G1. PTU(S1)F.C0	0.961	0.924	2.549	0.731	0.142	2.119*
G2. PTU(S1)D.C0	0.281	0.079	0.815	2.780	2.054	0.066
G3. PMU(S1)SYN.D.C1	0.876	0.768	2.330	1.285	0.439	1.035*
G4. PMU(S1)SYN.F.C1	0.414	0.171	0.069	1.153	0.006	0.807
G5. PPH.FS.C1	-0.991	0.982	-1.347	0.101	0.009	23.237
G6. PPH.(S1).C1	0.546	0.290	0.772	1.184	0.373	0.193
G7. PVU.FS.C0	0.669	0.447	1.834	2.040	1.106	0.409
Check						
G8. PLP.C0 (check 1)	0.997	0.995	1.678	0.122	0.004	5.568
G9. PLM.C0 (check 2)	0.979	0.994	3.747	0.302	0.024	9.083
G10. URI1 (check 3)	0.848	0.719	1.273	0.796	0.160	1.275

*: significant different on 95% level

3.4. Agronomic and Yield Variables

Grain yield of the genotypes including checks and statistical test by LSD of all variable in the three environments are shown in table 5. Population of G1.PTU(S1)F.C0 and G2.PTU(S1)D.C0 found to be significant in E1, E2 and E3 in rainy season, the highest yield in Maros experimental farm was 8.48 t ha⁻¹ shown by G1.PTU(S1)F.C0 which differed by 50.3% than the best yield obtained by the check genotypes in rainy season and 21.3% in dry season. This indicates that G1 was the candidate for new OPV variety of anthocyanin corn. In the dry season the G1 candidate was significant in Maros experimental farm but not significant in Bajeng and Polman.

Observation on agronomic characters of the plant ie. plant and ear height, tasseling and flowering (table 6) shows that plant height was not significant but ear height was significant between genotypes. The position of ear height was found around middle from plant height. This position of ear plant was suitable for selection of corn. Shelling percentage of G1. PTU(S1)F.C0 was higher 8.4% than check. Variable of anthesis silking interval (ASI) shows that the range of flowering and tasseling periods was

2.0 to 4.0 days. The different value of flowering and tasseling defines ASI value. ASI value < 3.0 days was very suitable for maximal grain formation while ASI value > 6.0 days showed no grain formed. Experiment results of Djameluddin and Yasin [11] found that the ASI values of population MS-2 that ranged 5-6 days were associated with yield 2-3 t ha⁻¹. Gambin *et al.* [12] found that drought tolerant inbred line with ASI of 6.0 days experiencing decline in yield by 58-69%. Water content of seeds ranged between 27-34.0% and G1.PTU(S1)F.C0 found to be less than check 36.0%. The result is similar with shelling percentage of 79.3%.

Table 5. The yield potential and statistical test of LSD on anthocyanins corn

Genotype (G)	Dry 2015			Rainy 2016		
	E1	E2	E3	E1	E2	E3
G1. PTU(S1)F.C0	7.95abc	7.15	6.94	8.48abc	8.17abc	7.24bc
G2. PTU(S1)D.C0	7.69abc	7.21	6.76	7.65abc	7.86abc	6.35bc
G3. PMU(S1)SYN.D.C1	6.69	7.37	7.84bc	7.06abc	7.91abc	5.75bc
G4. PMU(S1)SYN.F.C1	7.96abc	6.28	7.80bc	7.46abc	7.76abc	7.91abc
G5. PPH.FS.C1	6.97	7.70b	6.17	6.95abc	7.57abc	5.60
G6. PPH.(S1).C1	6.86	5.77	6.67	7.40abc	7.92abc	6.66bc
G7. PVU.FS.C0	6.75	7.78b	6.71	6.64bc	6.62ac	6.94bc
Check						
G8. PLP.C0 (check 1)	6.56	6.76	7.13	5.64	5.60	6.57
G9. PLM.C0 (check 2)	5.80	6.17	5.93	4.86	5.97	4.99
G10. URI1 (check 3)	5.88	6.86	6.16	4.26	5.25	4.76
CV (%)	12.62	15.25	17.18	13.08	11.81	12.08
LSD 5%	1.06	1.28	1.42	1.05	1.01	0.92
LSD 1%	1.45	1.75	1.95	1.44	1.39	1.26

a,b,c : significant vs check 1, 2 and 3

E1 : Expm Farm of Maros,

E2 : Expm Farm of Bajeng,

E3 : Farmer's field of Polman-Sulbar

Table 6. The average of variable of anthocyanins corns planted in Maros (E1), Bajeng (E2) and Polman (E3) under two seasons in 2015/2016

E/G	Plant height (cm)	Ear height (cm)	Tasselling (days)	Flowering (days)	Water content (%)	Shelling (%)
E1. Maros						
G1. PTU(S1)F.C0	191.9	99.2	48.8	51.3	30.6	79.3
G2. PTU(S1)D.C0	194.3	94.4	48.5	51.3	29.9	73.6
G3. PMU(S1)SYN.D.C1	201.7	98.5	49.0	51.5	29.7	74.0
G4. PMU(S1)SYN.F.C1	196.4	91.9	48.2	51.0	31.0	76.7
G5. PPH.FS.C1	198.5	96.0	48.3	52.0	30.1	77.7
G6. PPH.(S1).C1	193.3	95.5	48.5	51.8	31.0	77.3
G7. PVU.FS.C0	195.3	95.4	48.5	51.5	31.1	75.7
G8. PLP.C0 (check 1)	193.5	92.9	48.8	52.2	31.1	77.3
G9. PLM.C0 (check 2)	197.6	96.8	48.3	51.5	30.6	75.7
G10. URI1 (check 3)	195.2	96.2	49.7	52.7	31.1	73.1
CV (%)	3.0	3.9	2.0	2.0	7.8	4.8
LSD (5%)	10.1	6.4	1.7	1.6	4.1	6.3

<u>E2. Bajeng</u>						
G1. PTU(S1)F.C0	194.2	97.9	49.3	52.0	29.5	79.7
G2. PTU(S1)D.C0	194.3	101.6	48.8	51.8	30.8	78.5
G3. PMU(S1)SYN.D.C1	193.5	91.0	49.5	52.7	29.5	78.5
G4. PMU(S1)SYN.F.C1	195.6	94.6	48.8	51.8	28.5	79.2
G5. PPH.FS.C1	187.6	91.6	49.8	52.8	29.3	78.0
G6. PPH.(S1).C1	189.3	95.1	48.7	51.7	27.7	78.7
G7. PVU.FS.C0	194.4	94.3	48.5	51.7	27.3	79.3
G8. PLP.C0 (check 1)	201.9	99.7	48.5	51.7	29.0	79.5
G9. PLM.C0 (check 2)	193.4	93.5	49.0	52.0	28.4	79.4
G10. URI1 (check 3)	191.8	91.9	49.7	52.8	28.6	79.7
CV (%)	3.3	6.3	1.7	1.4	7.8	1.8
LSD (5%)	11.0	10.3	1.4	1.2	3.9	2.4
<u>E3. Polman</u>						
G1. PTU(S1)F.C0	181.9	86.0	47.5	50.7	33.1	75.4
G2. PTU(S1)D.C0	179.4	87.6	47.7	50.3	33.0	78.6
G3. PMU(S1)SYN.D.C1	187.7	84.3	48.0	50.7	33.9	76.7
G4. PMU(S1)SYN.F.C1	191.8	84.4	48.8	51.8	32.9	76.7
G5. PPH.FS.C1	176.9	87.7	50.0	52.7	33.9	78.5
G6. PPH.(S1).C1	178.4	88.4	48.8	52.0	32.6	79.9
G7. PVU.FS.C0	181.8	85.1	48.7	51.8	33.5	76.1
G8. PLP.C0 (check 1)	182.4	86.9	49.3	52.2	34.4	77.2
G9. PLM.C0 (check 2)	175.9	86.9	49.5	52.5	34.2	78.0
G10. URI1 (check 3)	180.2	86.1	49.3	52.3	33.0	76.8
CV (%)	5.1	6.9	2.1	1.4	4.6	2.3
LSD (5%)	15.9	10.2	1.8	1.3	2.6	3.0

3.5. Nutrition

The result of ICERI Laboratorium shows that the three genotypes that contain anthocyanins $51.92 \mu\text{g g}^{-1}$ were PMU(S1).Synth.F.C1, PMU(S1).Synth.D.C1, and PPH.(S1).C1. Compared to content of this pigment in the check genotype ($12.10 \mu\text{g g}^{-1}$), there are difference of 329.1%. According to Widowati *et al.* [13] and Wong [14], the amylose content are $<10.0\%$ as long as that the anthocyanins population is assumed also as waxy corn.

4. Conclusion

Three factors significant interaction of genetic, environment and season (GxExS) was found on grain yield parameter with highest yield of 8.17 t ha^{-1} obtained by genotype G1. PMU(S1)SYN.D.C1 in Maros which was 21.3-50.3% higher than the three check genotypes. Two genotypes, G1.PTU(S1)F.C0 and G2.PMU (S1)SYN.D.C1, were found to be stable ($\beta=1$) and showed mean yield of $G_i:i:1,2$ higher than mean total G_{ij} and can be concluded as potential candidate for new superior variety of open pollinated variety of anthocyanins corn with anthocyanin content of $51.92 \mu\text{g g}^{-1}$ which is 329.1% higher than the check genotype.

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