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Glucomannan Content Stability of Eddoe Taro Tuber Based on Parametric, Non-Parametric, and Ammi Analysis

(Kestabilan Kandungan Glukomanan Ubi Taro Eddoe Berdasarkan Analisis Parametrik, Bukan Parametrik dan Ammi)

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ABSTRACT

The consumption of taro tuber as an energy source is widespread due to its composition of complex carbohydrates, including starch and non-starch polysaccharides. Glucomannan is one of the non-starch polysaccharides found in taro tuber and has been shown to be a dietary fiber with positive effects on health and beauty. The development of new varieties of taro tuber with high glucomannan content is challenging and requires significant effort in order to produce high-quality food. Therefore, this study aimed to investigate the stability of glucomannan content among 14 eddoe taro tuber genotypes using parametric, non-parametric, and AMMI methods, and to determine genotypes with high glucomannan stability. The experiments were conducted in three different agro-climatic locations using a randomized full-block design. Glucomannan content of taro tuber was analyzed from a mixture of corms and cormlets harvested 5 months after planting following the gravimetric method. The combined analysis of variance for glucomannan content showed significant effects of the environment, genotypes, and G×E interaction. Genotypes S7, S35, S15, S18, S17, S34, and S24 produced glucomannan levels higher than the overall average, but genotypes S7, S17, S18, and S34 consistently displayed higher glucomannan content than the average in each experimental site. Parametric and non-parametric measurements provided comparable results. Based on parametric stability analysis, genotype S34 showed high-rank stability (W_i^2, σ^2_i, CVi value). Additionally, genotypes S34 and S18 demonstrated high stability according to b_i, and genotypes S17 exhibited stability according to the s^2d_i value. Non-parametric stability analysis showed that S34 was the most stable genotypes base on Nassar Huehn, Kang-Rangksum, and Thennarasu theories. Genotypes S7 was also identified as stable, according to Kang-Rangksum. The AMMI analysis indicated that genotypes S34, S17, and S7 were high glucomannan yielders, with S34 displaying wide adaptation and S17 and S7 having specific location adaptation.

Keywords: Adaptation; environment; *non-starch polysaccharides; selection; superior genotype*

ABSTRAK

Penggunaan ubi keladi sebagai punca tenaga semakin meluas kerana komposisi karbohidrat kompleks yang terkandung meliputi kanji dan bukan-kanji polisakarida. Glucomannan termasuk kelas bukan-kanji-polisakarida yang terdapat dalam ubi keladi dan mempunyai bukti sebagai serat makanan yang mempunyai kesan positif terhadap kesihatan dan kecantikan. Penciptaan varieti baru tanaman keladi dengan kandungan glukomanan yang tinggi adalah mencabar dan memerlukan usaha yang besar untuk menghasilkan makanan yang berkualiti tinggi. Oleh itu, penyelidikan ini bertujuan untuk mengkaji kestabilan kandungan glukomanan dalam kalangan 14 genotip ubi keladi eddoe menggunakan kaedah parametrik, tak-parametrik dan AMMI serta untuk menentukan genotip dengan kestabilan glukomanan yang tinggi. Percubaan telah dijalankan di tiga lokasi dengan agro-iklim berbeza menggunakan reka bentuk blok rawak lengkap. Kandungan glukomanan ubi keladi dianalisis daripada campuran *corm* dan *cormlet* yang dituai 5 bulan selepas

di tanam mengikut kaedah gravimetrik. Gabungan analisis varians bagi kandungan glukomanan menunjukkan kesan ketara terhadap sekitaran, genotip dan interaksi G×E. Genotip S7, S35, S15, S18, S17, S34 dan S24 menghasilkan tahap glukomanan lebih tinggi daripada purata keseluruhan, tetapi genotip S7, S17, S18 dan S34 secara tekal menunjukkan kandungan glukomanan yang lebih tinggi daripada purata di setiap tapak percubaan. Pengukuran parametrik dan tak-parametrik memberikan hasil yang setanding. Berdasarkan analisis kestabilan parametrik, genotip S34 menunjukkan kestabilan peringkat tinggi (W_i^2, σ^2_i, CVi-value). Selain itu, genotip S34 dan S18 menunjukkan kestabilan yang tinggi mengikut nilai b_i dan genotip S17 menunjukkan kestabilan mengikut nilai s^2d_i. Analisis kestabilan tak-parametrik menunjukkan bahawa S34 adalah genotip paling stabil berdasarkan teori Nassar Huehn, Kang-Rangksum dan Thennarasu. Genotip S7 juga dikenal pasti sebagai stabil mengikuti Kang-Rangksum. Analisis AMMI menunjukkan bahawa genotip S34, S17 dan S7 adalah hasil glukomanan yang tinggi, dengan S34 memiliki kemampuan penyesuaian sekitaran yang luas sedangkan S17 dan S7 mempunyai penyesuaian khusus.

Kata kunci: Genotip unggul; pemilihan; penyesuaian; sekitaran; tak-berkanji polisakarida

Introduction

Eddoe taro tuber (*Colocasia esculenta* var antiquorrum) is a staple food in tropical and sub-tropical countries worldwide. Taro tuber is the most widely consumed part of the plant because of its high energy content. Meanwhile, the nutritional composition of taro tuber is low in protein and fat but high in carbohydrates (Temesgen & Retta 2015). Taro tuber is a source of complex carbohydrates, including starch and non-starch polysaccharides, which have received attention for their potential positive health effects and use in functional foods (Li et al. 2018; Saeed et al. 2021). Non-starch polysaccharides found in taro tuber is glucomannan (Maretta et al. 2020), which is widely used and explored in the health, beauty, and cosmetic industries (Bateni et al. 2013; Tester & Al-Ghazzewi 2016). Glucomannan has been shown to aid in weight loss because it is a neutral, fermentable, and viscous dietary fiber (Zalewski, Chmielewska & Szajewska 2015). It can also relieve physiological disorders such as diabetes and cardiovascular diseases, as well as reduce blood lipid and cholesterol levels (Behera & Ray 2016; Shah et al. 2015).

The improvement of taro tuber quality could be achieved by enhancement of it's glucomannan content. The high content can potentially supply high-quality food and a cheap energy source. Taro tuber breeding efforts should focus on traits important for producers and consumers, such as nutritional quality (Oladimeji et al. 2022).

Developing new varieties in a breeding program needs the availability of genetic diversity for further selection. It is highly feasible to obtain in Indonesia since this country is one of the centers of diversity in the world (Chaïr et al. 2016). In the procedure of superior genotypes selection, multi-location trials are required for testing adaptation and investigating the stability performance of the genotypes to the change of growth environment (Ganança et al. 2015). The existence of genotypes and environment interaction (G×E) caused selection process to become complicated. The stability analysis is the technique for understanding the interaction G×E to identify the stable and consistent genotypes. Various approaches have been suggested to appraise selected genotypes, including parametric, non-parametric, and multivariate methods. Therefore, this study aimed to investigate the stability of glucomannan content among 14 genotypes of eddoe taro tuber using parametric, non-parametric, and AMMI methods and determine the genotypes with high glucomannan stability.

Materials and Methods

Study Site

The experiments were conducted in three different agroclimatic locations. The first location was South Tangerang District, Banten Province, with an altitude of 60 m above sea level (masl), clay soil, medium C/N ratio (C/N=13), and pH of 6.1. It was carried out from September 2018 to January 2019 during the wet season, with a total rainfall of 819.6 mm and a humidity of 75.81%. The second location was Bogor District, West Java Province, with an altitude of 222 masl, silty clay-type soil, medium C/N ratio (C/N=13), and pH of 4.8. Furthermore, the experiment was conducted from March to July 2019, during the rainy season, with a total rainfall of 1404 mm and humidity of 81.81%. The most recent experiment was in Subang District, West Java Province, from April to August 2019, during the dry season, with a

total rainfall of 493.3 mm and humidity of 73.33%. The field featured clay soil, a low C/N ratio of 10, a pH of 4.4, and an altitude of 582 masl.

PLANT MATERIAL AND CULTIVATION

The study utilized plant materials from 14 accessions comprising 8 Indonesian landraces and 6 introduced cultivars (Maretta et al. 2020). The genotypes were procured from various provinces in Indonesia, and some were introduced cultivars grown by local farmers. Furthermore, the experiment followed a randomized full-block design with two replications at each site. In each block, five seeds of each genotypes were planted. The soil was plowed and harrowed twice before planting and was created using a raised bed. The planting bed was elevated approximately 20 cm above the soil and had a single line of plants. A cormlet was planted in each hole, weighing 30-50 g and with a diameter of 2.5-3.5 cm. The planting distance between the genotypes lines was 100 cm but was 60 cm within the line of plants. Moreover, glucomannan content of taro tuber was evaluated from a mixture of cormus and cormlets, harvested five months after planting, and prepared as taro tuber flour. The procedure for taro tuber preparation adhered to Chairul and Chairul (2006), while glucomannan compound investigation adopted the gravimetric method assigned to Widjanarko and Megawati (2015).

STABILITY ANALYSIS

Glucomannan data of each genotypes were subjected to a combined analysis of variance. Furthermore, Bartlet's test of homogeneity variances and the normality test for data were conducted using STAR software. Utilizing SAS software, a combined analysis of variance (ANOVA) was carried out to examine the effects of genotypes, environment, and G×E interaction. Stability analysis was performed using an online tool, namely *Stabilitysoft,* accessed at https://manzik.com/stabilitysoft/ (Aboughadareh et al. 2019). This tool was used for estimating several parametric and non-parametric stability parameters. The parametric stability parameters include Wricke's ecovalence (W_i^2), regression coefficient (Eberhart & Russell 1966; Finlay & Wilkinson 1963), and Shukla's stability variance (σ^2_i). The non-parametric stability includes parameters from Nassar and Hühn (1987), Kang's yield, and stability index (YSi) from Kang (1988) and Thennarasu. Additionally, main component-based stability studies, including AMMI, were carried out using PBTools software downloaded from http://bbi.irri.org/ products and correlation analysis among the parameters stability used *Stabilitysoft*.

RESULTS AND DISCUSSION

ANALYSIS OF VARIANCE

The combined analysis of variance for glucomannan content showed significant effects of the environment, genotypes, and G×E interaction (Table 1). This result showed the variation of glucomannan in taro tuber performance of different genotypes in different locations. It suggests that glucomannan is a quantitative character, and increasing glucomannan levels in taro tuber can also be achieved by improving agronomic techniques in the field (Pramadio, Saptadi & Soegianto 2018). Interaction between G×E explained 32.32% of the total variation in taro tuber yields of glucomannan, while the genotypes accounted lower for 23.73%. Therefore, there were substantial differences in the response across the location (Etminan et al. 2019). Additionally, the G×E interaction was higher than the genotypic effect, indicating a loss of genetic potential. The potential of genotypes was more exploited when identified for the specific environments (Kang, Aggarwal & Chirwa 2006; Kebede & Getahun 2017). General average of glucomannan content for all experimental sites was 4.86% dry weight. Meanwhile, the general average of glucomannan content of seven genotypes produced higher than 4.86%, namely S7, S35, S15, S18, S17, S34, and S24, with each glucomannan content of 5.91, 5.89, 5.82, 5.67, 5.64, 5.43, 4.99 % dry weight. Four of the seven genotypes (S7, S17, S18, and S34) consistently had higher glucomannan content than average in each experimental location, that were 5.7% in the Tangerang, 4.76% in the Bogor and 4.10% in the Subang (Table 2). The highest glucomannan production was in the Tangerang and significantly different to the two other locations according to Duncan's multiple range test. It indicates that the agroclimatic in the Tangerang during expreriment was the most appropriate for glucomannan biosynthesis in the taro plant (Pramadio, Saptadi & Soegianto 2018).

PARAMETRIC AND NON-PARAMETRIC STABILITY ANALYSIS

According to the substantial G×E interaction for glucomannan characters, certain genotypes were unstable while others were stable. This interaction makes it difficult to plant breeders in genotypes selection that consistently produce a high yield in diverse

environmental conditions unless stability analysis is undertaken (Adugna & Labuschagne 2003). There are two main methods for examining G×E interaction and adaptation. The first one is parametric, which relates observed genotypic responses to a sample of environmental factors. The second method specifies habitats and phenotypes concerning biotic as well as abiotic components and is known as the non-parametric approach (Syukur, Sujiprihati & Yunianti 2015).

TABLE 1. Combined analysis of variance for glucomannan content of taro tuber

Source	df	SS	MS	F-test	PR>F	% of total
Enviroment (E)	2	36.15	18.08	10.64	0.0002 **	14.56
Replication/E	3	6.80	2.27	1.33	0.2774	2.74
Genotypes (G)	13	58.94	4.53	2.67	0.0089 **	23.73
G×E	26	80.29	3.09	1.82	0.0444 *	32.32
Error	39	66.25	1.70			26.67
Total	83	248.42				
Coefficients of variance = 26.84%						

*=significantly different at α 5%; **=significantly different at α 1%

TABLE 2. Effect of genotype and environment interaction on glucomannan content

Genotypes	Environments			General average
	Bogor	Tangerang	Subang	
	Average (% of dry weight)			
S6	6.24 ± 0.98 ^{abc}	1.64 ± 2.32 ^{fg}	4.71 ± 1.34 ^{abcdef}	4.20 ± 2.45 ^{abcd}
S7	6.68 ±0.44 ^{abc}	6.69 ± 2.19 ^{ab}	4.35 ± 0.04 ^{bcdefg}	5.91 ± 1.56 ^{a}
S15	4.34 ± 0.88 ^{bcdefg}	7.04 ± 0.20 ^{ab}	6.08 ± 0.25 ^{abcd}	5.82 ± 1.29 ^{ab}
S17	7.17 ± 3.07 ^{ab}	5.38 ± 0.70 ^{abcd}	4.36 ± 0.17 ^{bcdefg}	5.64 ± 1.90 ^{abc}
S18	6.98 ± 1.30 ^{ab}	5.92 ± 1.07 ^{abcd}	4.13 ± 0.83 ^{bcdefg}	5.67 ± 1.54 ^{abc}
S20	4.88 ± 1.02 ^{abcde}	4.57 ± 0.10 ^{bcdef}	4.11 ± 0.34 ^{bcdefg}	4.52 ± 0.59 ^{abcd}
S24	6.05 ± 0.88 ^{abcd}	3.96 ± 0.59 ^{bcdefg}	4.97 ± 0.72 ^{abcde}	4.99 ± 1.09 ^{abcd}
S26	5.17 ± 0.31 ^{abcde}	4.93 ± 2.11 ^{abcde}	2.14 ± 1.55 ^{efg}	4.08 ± 2.24 ^{bcd}
S28	4.76 ± 0.70 ^{abcdef}	4.40 ± 1.10 ^{bcdefg}	4.33 ± 1.37 ^{bcdefg}	4.50 ± 1.50 ^{abcd}
S30	3.46 ± 0.17 ^{cdefg}	4.30 ± 0.42 ^{bcdefg}	2.12 ± 3.00 ^{efg}	3.29 ± 1.68 ^{d}
S33	5.44 ± 1.11 ^{abcd}	5.26 ± 2.57 ^{abcde}	1.33 ± 1.88 ^{g}	4.01 ± 2.57 ^{cd}
S34	5.98 ± 0.87 ^{abcd}	5.64 ± 1.10 ^{abcd}	4.67 ± 0.67 ^{bcdef}	5.43 ± 0.92 ^{abc}
S35	7.90 ± 0.08 ^{a}	4.02 ± 0.96 ^{bcdefg}	5.76 ± 0.40 ^{abcd}	5.89 ± 1.80 ^{a}
S36	4.79 ± 0.66 ^{abcdef}	2.98 ± 1.12 ^{defg}	4.37 ± 0.86 ^{bcdefg}	4.05 ± 1.00 ^{bcd}
Averages	5.70 ± 1.46 ^{a}	4.76 ± 1.71 ^{b}	4.10 ± 1.67 ^{b}	4.86 ± 1.73

Mean values followed by similar letter are not significantly different ($p<0.05$) according to Duncan's multiple range test

Parametric stability statistics tested were Wricke (W_i^2), Finlay-Wilkinson (b_i), Eberhart-Russel (s^2d_i), Shukla (σ^2_i), and Francis-Kannenberg (CVi) methods. The genotypes with high-rank stability and high glucomannan content was S34 based on Wricke (W_i^2), Shukla (σ^2_i), and Francis-Kannenberg (CVi) theories, genotypes S7, S18, and S34 according to Finlay-Wilkinson method (b_i) and genotypes S17 based on the Eberhart-Russel method (s^2d_i). Genotypes S28 and S20 had s^2d_i values closer to zero, and the lowest CVi index indicated that high stability belongs to Eberhart-Russel and Francis-Kannenberg theories. However, glucomannan content of these two genotypes was lower than the average yield among genotypes, as shown in Table 3.

Table 4 presents the results of non-parametric stability statistics used to rank genotypes across environments, including Nassar Hühn ($S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$), Thennarasu ($NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$ and $NP^{(4)}$), and Kang-Rangksum methods. According to Nassar Hühn and Thennarasu, genotypes S34 was the most stable for taro tuber glucomannan content. Utilizing these two measurement theories to select genotypes across environments can help recommend genotypes that able to adaptation with high yield to reduce biases caused by outliers and do not require assumptions about the distribution of observed values (Sabaghnia, Dehghani & Sabaghpour 2006). Furthermore, univariate non-parametric methods rely on the rank order of genotypes to determine stability, and a genotypes is considered stable when its ranking is relatively constant across environments (Temesgen et al. 2015). Using the Kang-Rangksum method, S7 was also identified as a stable genotypes in addition to S34. These two genotypes produced glucomannan yields above the average in each experimental field and had no significant difference among S7, S34 and S18. The study found that both parametric and non-parametric measurements yielded similar results. According to parametric analysis, three out of four genotypes that produced high yields were stable, with S7, S18, and S34 being stable in environmental changes. The non-parametric methods found S7 and S34 stable while S18 was unstable.

TABLE 3. Mean values (Y), parametric stability and stability rank for glucomannan content of 14 genotypes eddoe taro tuber

Genotypes	Y (% of dry weight)	Wricke (W_i^2)	Finlay-Wilkinson (b_i)	Eberhart-Russel (s^2d_i)	Shukla (σ^2_i)	Francis-Kannenberg (CVi)
S6	4.20	9.11^{14}	1.21	1.2933^{14}	5.19^{14}	55.79^{13}
S7	5.91	1.40^{6}	1.36	0.1766^{6}	0.69^{6}	22.81^{5}
S15	5.82	8.14^{13}	-1.21	0.2653^{11}	4.62^{13}	23.48^{7}
S17	5.64	0.78^{4}	1.77^{18}	0.0021^{3}	0.32^{4}	25.25^{8}
S18	5.67	0.94^{5}	1.74	0.0345^{5}	0.42^{5}	25.34^{9}
S20	4.52	0.37^{2}	0.47	0.0019^{2}	0.09^{2}	8.63^{2}
S24	4.99	1.46^{7}	0.78	0.1992^{7}	0.72^{7}	20.90^{4}
S26	4.08	2.35^{10}	1.79	0.2216^{8}	1.24^{10}	41.28^{12}
S28	4.50	0.69^{3}	0.27	0.0011^{1}	0.27^{3}	5.07^{1}
S30	3.29	1.85^{8}	0.72	0.2494^{10}	0.95^{8}	33.39^{11}
S33	4.01	5.84^{12}	2.41	0.4677^{12}	3.28^{12}	57.91^{14}
S34	5.43	0.18^{1}	0.79	0.0172^{4}	-0.03^{1}	12.53^{3}
S35	5.89	4.91^{11}	1.52	0.6514^{13}	2.74^{11}	32.98^{10}
S36	4.05	2.12^{9}	0.37	0.2308^{9}	1.11^{9}	23.41^{6}

Y=mean value of glucomannan content; W_i^2=Wricke *ecovalence value;* bi=regression coefficient, *= significantly differ from 1; s^2d_i=deviation from regression ; σ^2_i=Shukla's stability variance; CVi=environmental coefficient of variance. The number following stability index is genotype stability ranking, the lower number shows the more stable of genotypes

TABLE 4. Mean values (Y), non-parametric stability and stability rank for glucomannan content of 14 genotypes eddoe taro tuber

Genotypes	Y (% of dry weight)	Nassar Hühn				Thennarasu				Kang
		$S^{(1)}$	$S^{(2)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(1)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	*K*R
S6	4.20	6.67^{12}	30.33^{13}	8.27^{13}	1.73^{13}	4.33^{8}	0.61^{9}	0.84^{11}	0.91^{11}	24^{13}
S7	5.91	4.00^{7}	9.33^{7}	1.81^{5}	0.65^{4}	3.33^{5}	0.18^{2}	0.28^{3}	0.39^{4}	7^{1}
S15	5.82	8.00^{14}	48.00^{14}	9.60^{14}	1.60^{10}	4.33^{8}	0.31^{7}	0.54^{9}	0.80^{10}	16^{9}
S17	5.64	3.33^{5}	6.33^{6}	1.23^{4}	0.52^{2}	4.67^{10}	0.18^{2}	0.32^{5}	0.32^{2}	9^{3}
S18	5.67	4.67^{8}	16.33^{9}	3.38^{8}	0.97^{7}	2.33^{3}	0.25^{5}	0.27^{2}	0.48^{6}	9^{3}
S20	4.52	2.00^{1}	2.33^{1}	0.88^{2}	0.63^{3}	1.67^{2}	0.38^{8}	0.32^{4}	0.38^{3}	10^{5}
S24	4.99	6.00^{11}	21.00^{11}	5.25^{10}	1.25^{9}	3.33^{5}	0.31^{6}	0.36^{6}	0.75^{9}	14^{8}
S26	4.08	3.33^{5}	6.33^{5}	2.24^{6}	0.94^{6}	3.67^{7}	0.67^{10}	0.68^{10}	0.59^{7}	21^{10}
S28	4.50	2.00^{1}	3.00^{3}	1.20^{3}	0.80^{5}	3.00^{4}	0.67^{10}	0.49^{8}	0.40^{5}	12^{6}
S30	3.29	2.67^{4}	4.33^{4}	3.25^{7}	1.75^{14}	5.33^{12}	1.87^{14}	1.54^{14}	1.00^{14}	22^{12}
S33	4.01	5.33^{10}	17.33^{10}	6.12^{12}	1.65^{12}	5.33^{12}	0.93^{13}	0.98^{13}	0.94^{13}	25^{14}
S34	5.43	2.00^{1}	2.33^{2}	0.48^{1}	0.34^{1}	1.33^{1}	0.15^{1}	0.13^{1}	0.21^{1}	7^{1}
S35	5.89	6.67^{12}	30.331^{2}	5.87^{11}	1.23^{8}	4.67^{10}	0.24^{4}	0.45^{7}	0.65^{8}	13^{7}
S36	4.05	4.67^{8}	13.00^{8}	5.20^{9}	1.60^{10}	5.67^{14}	0.89^{12}	0.84^{12}	0.93^{12}	21^{10}

Y=mean value of glucomannan content; $S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$=Nassar Hühn stability index; $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$=Thennarasu stability index; *KR*=Kang ranksum stability index. The number following stability index is genotype stability ranking, the lower number shows the more stable of genotypes

CORRELATION RELATIONSHIP AMONG DIFFERENT STABILITY STATISTICS

Pearson's correlation coefficients demonstrate the relationship between stability statistics and yield of glucomannan in Table 5. The table shows that the yield is negatively correlated with $NPi^{(2)}$, $NPi^{(3)}$, $NPi^{(4)}$, and *K*R. Negative values indicate that the higher the genotype's glucomannan content, the more unstable the character (Nassar & Hühn 1987). Furthermore, the parametric $S^{(6)}$, and *K*R. Parameter stability b_i is not correlated with stability measures of W_i^2, σ^2_i, s^2d_i, and CVi are positively correlated with each other and with $S^{(1)}$, $S^{(2)}$, any other parameters. Fasahat et al. (2015) recommended using W_i^2, σ^2_i, s^2d_i, and CVi concurrently to estimate phenotypic stability effects since W_i^2 and σ^2_i are equivalent and b_i indicates genotypes adaptation rather than stability. The *K*R parameter positively correlates with other parametric and non-parametric stability measures, including $S^{(3)}$, $S^{(6)}$, $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$, W_i^2, σ^2_i, s^2d_i. The $NP^{(2)}$ parameter is significantly positively correlated with $S^{(6)}$, $NP^{(1)}$, $NP^{(3)}$, $NP^{(4)}$, *K*R, and $NP^{(3)}$ with $S^{(6)}$, $NP^{(1)}$, $NP^{(2)}$, *K*R, and CVi. The significant positive correlation suggests that these parameters play similar roles in the stability ranking of genotypes (Temesgen et al. 2015). This finding showed the top ranking in stability measurements demonstrated by the identical genotypes. Meanwhile, knowledge of the correlation between yield value and stability coefficients is needed to further investigate the interrelationships among different stability statistics. This can help breeders select the appropriate method for obtaining superior genotypes (Aboughadareh et al. 2019; Fasahat et al. 2015). However, finding the appropriate stability method for glucomannan content study remains challenging, as indicated by the stability parameter association analysis. Temesgen et al. (2015) stated that the strong negative correlation between yield and stability parameters would be less useful when a high-yield genotypes is the primary target of selection.

TABLE 5. Pearson's correlation coefficients between parametric and non-parametric stability parameters for glucomannan content of 14 taro tuber genotypes

	Y	$S^{(1)}$	$S^{(2)}$	$S^{(3)}$	$S^{(6)}$	$NP^{(1)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	W_i^2	σ^2_i	s^2d_i	b_i	CVi
Y														
$S^{(1)}$	0.29													
$S^{(2)}$	0.33	0.96**												
$S^{(3)}$	-0.01	0.93**	0.93**											
$S^{(6)}$	-0.50	0.63*	0.59*	0.83**										
$NP^{(1)}$	-0.36	0.45	0.34	0.55*	0.74**									
$NP^{(2)}$	-0.86**	-0.19	-0.22	0.09	0.62*	0.55*								
$NP^{(3)}$	-0.81**	0.07	0.04	0.35	0.78**	0.72**	0.95**							
$NP^{(4)}$	-0.58*	0.56*	0.48	0.76**	0.98**	0.77**	0.67**	0.82**						
W_i^2	-0.05	0.81**	0.84**	0.90**	0.71**	0.49	0.08	0.35	0.63*					
σ^2_i	-0.05	0.81**	0.84**	0.90**	0.71**	0.49	0.08	0.35	0.63*	1.00**				
s^2d_i	-0.21	0.62*	0.56*	0.69	0.62*	0.43	0.14	0.38	0.58*	0.83**	0.83**			
b_i	-0.07	-0.14	-0.33	-0.26	-0.15	0.10	-0.01	0.02	-0.09	-0.13	-0.13	0.17		
CVi	-0.36	0.49	0.36	0.56*	0.63*	0.60*	0.34	0.56*	0.64*	0.69**	0.69**	0.75**	0.54*	
*K*R	-0.77**	0.35	0.27	0.59*	0.85**	0.71**	0.71**	0.85**	0.89**	0.61*	0.61*	0.61*	0.09	0.76**

Y=mean value of glucomannan content; W_i^2=Wricke *ecovalence value;* bi=regression coefficient; s^2d_i=deviation from regression ; σ^2_i=Shukla's stability variance; CVi=environmental coefficient of variance; $S^{(1)}$, $S^{(2)}$, $S^{(3)}$, $S^{(6)}$=Nassar Hühn stability index; $NP^{(1)}$, $NP^{(2)}$, $NP^{(3)}$, $NP^{(4)}$=Thennarasu stability index; *KR*=Kang ranksum stability index; **=significant correlation at t=0.01; *=significant correlation at t=0.05

AMMI ANALYSIS

The AMMI approach clarified the genotypes stability and presented a biplot diagram of AMMI1 and AMMI2, as shown in Figures 1 & 2. In the biplot AMMI1, the vertical line was the grand mean of the experiment. Novianti, Mattjik and Sumertajaya (2010) stated that the AMMI1 graphic showed the summarized information of genotypes and environment on the vertical axis and G×E interaction on the horizontal axis (PC1). The genotypes on the right side of the vertical axis have a higher yield than the mean average (Kılıç 2014). Accordingly, S17, S20, S28, and S34 were the most stable, marked by the position close to the PC1 axis, which suggested a low contribution to G×E interaction. The genotypes S17 and S34 had higher glucomannan content than the grand average and were ideal for selected genotype, conversely S20 and S28. Other genotypes with high yield and values close to the PC1 axis were S7, S15, and S17, so the three genotypes can be also considered as the preferred genotypes.

Finding genotypes with specific or wide adaptation may be conducted using AMMI1 analysis (Figure 1). The genotypes close to the ordinate and environment imaginer showed general and more specific site adaptions (Hebbache et al. 2021; Mortazavian et al. 2014). Based on the AMMI1 and AMMI2 analysis, genotypes S34 was found to have a high glucomannan yield and wide adaptation. Meanwhile, S17 and S7 have specific adaptation to ENV1 (Tangerang) and ENV2 (Bogor), respectively. Genotypes S15 and S18 based on AMMII1 have high glucomannan content and are relatively stable. However, they are laid far from the ordinate and environment axis based on AMMI2 analysis (Figure 2). Oliveira, Freitas and Jesus (2014) stated that perfect variety was difficult to identify, and obtaining a genotypes for regional adaptation would be beneficial.

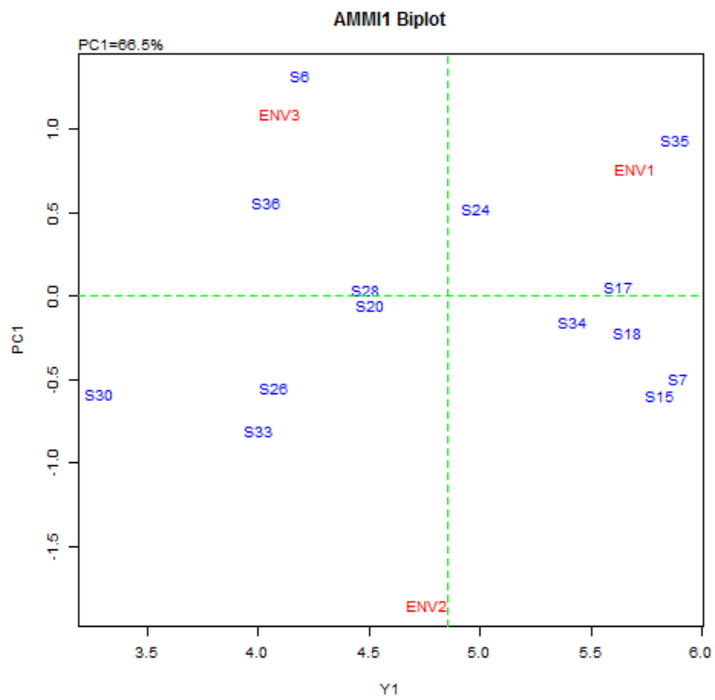

FIGURE 1. Biplot of AMMI1 model for glucomannan content showing the plotting of mean yield and PC1 of genotypes. Y1=mean of glucomannan content; ENV1=Tangerang; ENV2=Bogor; ENV3=Subang

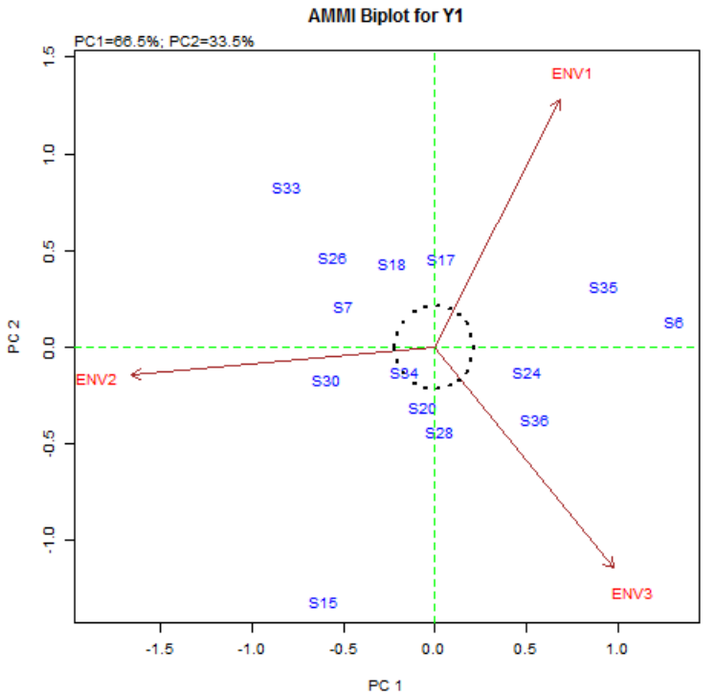

FIGURE 2. Biplot of AMMI2 model for glucomannan content showing the PC1 and PC2 of genotypes. Y1=mean of glucomannan content; ENV1=Tangerang; ENV2=Bogor; ENV3=Subang

CONCLUSIONS

This study reported that the interaction of genotypes and environment influences glucomannan production in Eddoe taro tuber. Accessions S7, S17, and S34 showed a high stability genotypes for glucomannan character. In addition, S34 was identified as a wide adaptation genotypes, while S7 and S17 as genotypes for specific environments.

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