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AGRONOMIC CHARACTERS AND SEED PROTEIN CONTENT OF SOYBEAN (*GLYCINE MAX* [L.] MERR.) LINES ACROSS ENVIRONMENTS

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SUMMARY

Agronomic performance and seed nutritional content are influenced by genetic, environmental, and genotype × environmental factors. The objective of this research was to study the agronomic performance and seed protein contents of 49 soybean lines in two environments. This research was conducted in vertisols located in Ngale Research Station (RS) and associated alfisol with inceptisol located in Jambegede RS with different chemical soil properties and weather conditions. The plant materials were 49 soybean lines that originated from soybean crossing. Agronomic characteristics, such as days to maturity, plant height, branches plant^{-1}, productive nodes plant^{-1}, filled pods plant^{-1}, 100-seed weight, and seed yield were influenced by location, genotype, and genotype × environment interactions. Location had no effect on plant height and the number of filled pods. However, the number of filled pods was influenced by genotype × environmental interactions. The agronomic characteristics and protein content of 49 soybean lines in Ngale RS were higher than those of the lines in Jambegede RS. The agronomic performance of the tested lines was inconsistent in the two locations. G-15 had the highest yield in Ngale with 3.36 t ha^{-1}, whereas the highest seed yield in Jambegede was shown by G-49 with 3.88 t ha^{-1}. Lines G-4, G-5, G-20, G-22, G-25, G-38, G-39, and G-49 had the highest protein contents, which ranged from 39.97% to 40.97%. The methionine contents of these eight lines ranged from 5080.61 ppm to 6018.20 ppm. The highest methionine content was achieved by G-5, whereas the lowest methionine content was achieved by G-37.

Keywords: Methionine, protein, protein digestibility value, digested protein

Key findings: Agronomic characters and protein content are important for soybean yields. A genotype with stable agronomic characteristics and protein content is expected to be significant in the development of a new superior soybean variety with high yield and protein content.

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INTRODUCTION

In Indonesia, soybean (*Glycine max*) is the third strategic food commodity after rice and maize. Soybean is rich in the macro- and micronutrients needed to fulfill the nutrient needs of humans, livestock, and health (Akparobi, 2009; Hasan *et al*., 2015). It is also the main source of vegetable protein in the world (Gurmu *et al*., 2009) with protein contents of up to 30%–50% (Mannan, 2014). Its protein content is the highest among those of other food crops, such as rice, maize, and mungbean, which have protein contents of only between 5% and 25% (Kemekes, 2018; Mujic *et al*., 2011; Okonmah, 2012). In Indonesia, two varieties (i.e., Detam 1 and Detam 2) have high protein contents of up to >45% dry weight (Balitkabi, 2016). Therefore, Indonesian soybean is widely used as raw materials for various food products, mainly tempeh, tofu, and soy sauce. Tempe and tofu consumption^{-1} capita^{-1} year^{-1} in Indonesia is 7.35 and 7.87 kg, respectively, and is higher than beef consumption, which is only 0.42 kg^{-1} capita^{-1} year^{-1} (Ministry of Agriculture, 2017). Therefore, in Indonesia, soybeans can be used to meet the nutritional needs of the community as an alternative source of protein to replace beef because they are cheaper.

In addition to protein, amino acids are other important nutrients in soybeans that are needed for human and livestock health (Raei *et al*., 2008). Soybeans contain eight essential amino acids, namely, isoleucine, leucine, lysine, methionine, phenylalanine, threonin, tryptophane, and valine (Goldflus *et al*., 2006). One of the essential amino acids is methionine. Similar to other essential amino acids, methionine cannot be synthesized in the human body and thus must be obtained from food (Courtney-Martin and Pencharz, 2006). Some foods that contain methionine are peanuts, eggs, fish, garlic, beans, meat, onions, soybeans, seeds, and yogurt. Methionine helps the body's metabolism and fat loss. The body also needs methionine to produce two other amino acids, namely, cysteine and taurine, which help the body eliminate toxins, build healthy and strong tissue, and improve cardiovascular health. Gomes and Kumar (2005) and Dever and Elfara (2010) mentioned that the lack of methionine can cause diseases, such as toxemia, rheumatic fever in children, muscle paralysis, hair loss, depression, schizophrenia, Parkinson's disease, liver damage, and impaired growth. Methionine deficiency also causes several hereditary diseases, i.e., hypermethioninemia, which causes symptoms that include mental retardation, growth failure, thrombocytopenia, clubfoot, skeletal abnormalities, lens dislocations, and hearing loss.

Genetic and environmental factors are the main factors that affect the agronomic performance and nutrient content of soybean. In addition, the interaction between these factors affects the agronomic performance and nutrient content of soybeans (Kumar *et al*., 2010; Jeromela *et al*., 2011; Bilyeu and Wiebold 2016). Cheelo *et al*. (2017) revealed that each genotype has varied responses to different environmental conditions. The testing of soybean genotypes in different environments or agroecology will provide different results in terms of agronomic and nutritional performances. Environmental factors, such as climatic conditions (temperature, humidity, rainfall, and light), soil type, and soil nutrient content, considerably affect plant physiological processes, leading to differences in the agronomic performance and nutrient content of soybeans (Arslanoglu and Aytac, 2010; Hampango *et al*., 2017).

A number of studies on the effect of genotype × environmental interaction on agronomic performance and soybean nutrient content have been performed. Gurmu *et al*. (2009) obtained several genotypes with consistent agronomic performance, protein, and oil contents at six sites. Dhungana *et al*. (2017) also conducted a similar study on the agronomic characteristics, starch, protein, and oil level of 17 genotypes at three locations for 2 years. The objective of this research was to study the agronomic performance and nutrient content (protein) of selected soybean lines grown in two different environments. This information will be useful for the selection of soybean lines with high seed yield and protein content.

MATERIALS AND METHODS

Study sites

The studies were carried out at Ngale and Jambegede Research Stations (RSs). Ngale RS is located in Ngale Village, Ngale District, Ngawi Regency, East Java Province, Indonesia. Jambegede RS is located in Kemiri Village, Kepanjen District, Malang Regency, East Java Province, Indonesia. The coordinates and altitude of Ngale RS are 7°24′32.4″S 111°22′22.8″E and 335 m above sea level, and those of Jambegede RS are and 8°10′30″S 112°33′32.4″E and 50 m above sea level.

Plant material

A total of 49 soybean lines originating from the crossing of some varieties (Kaba, Grobogan, and Burangrang) and germplasm (IAC100) were used as plant materials. The codes and pedigrees of the plant materials are presented in Table 1.

Planting and cultural practice

The experiments in the two locations were arranged in a randomized complete block design with three replications. The error was minimized by placing the block in the plot with uniform fertility. The plantings at Ngale RS and Jambegede RS were carried out on 31 March 2017 and 21 April 2017, respectively. The planting space was 40 cm × 15 cm for both locations. Each soybean line was planted in 3 m length with two rows. Fertilizer was applied at the rates of

Table 1. Plant materials used in the study.

Code	Pedigree	Crossing method
G1	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-6-T-66-1	Modified triple cross
G2	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-8-T-79-4	Modified triple cross
G3	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-18-T-93-11	Modified triple cross
G4	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-21-T-97-24	Modified triple cross
G5	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-25-T-106-33	Modified triple cross
G6	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-28-T-111-42	Modified triple cross
G7	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-53-T-179-54	Modified triple cross
G8	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-66-T-238-64	Modified triple cross
G9	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-68-T-247-65	Modified triple cross
G10	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-86-T-69-81	Modified triple cross
G11	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-91-T-152-90	Modified triple cross
G12	IAC-100/Kaba-G-47 × Gro/IAC/Burr/Kaba-13-335-T-127-229	Modified triple cross
G13	IAC-100/Kaba-G-47 × Gro/IAC/Burr/Kaba-13-335-T-127-244	Modified triple cross
G14	IAC-100/Kaba-G-67 × Burr-358-T-2-258	Triple cross
G15	IAC-100/Kaba-G-67 × Burr-422-T-97-260	Triple cross
G16	IAC-100/Kaba-G-67 × Burr-358-T-2-261	Triple cross
G17	IAC-100/Kaba-G-67 × Burr-424-T-99-266	Triple cross
G18	IAC-100/Kaba-G-67 × Burr-433-T-15-286	Triple cross
G19	IAC-100/Kaba-G-67 × Burr-435-T-117-290	Modified triple cross
G20	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-463-T-39-318	Modified triple cross
G21	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-467-58-338	Modified triple cross
G22	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-476-T-78-349	Modified triple cross
G23	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-513-T-251-371	Modified triple cross
G24	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-542-T-21-392	Modified triple cross
G25	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-656-T-8-504	Modified triple cross
G26	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-662-T-82-517	Modified triple cross
G27	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-666-T-112-525	Modified triple cross
G28	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-679-T-167-542	Modified triple cross
G29	IAC-100/Burr-P-96 × Burr-725-T-16-588-725-T-16-588	Backcross
G30	IAC-100/Burr-P-96 × Burr-729-T-23-594-729-T-23-594	Backcross
G31	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-13-801-T-21-625	Modified triple cross
G32	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-13-811-T-31-635	Modified triple cross
G33	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-848-T-1-649	Modified triple cross
G34	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-854-T-7-657	Modified triple cross
G35	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-854-T-7-660	Modified triple cross
G36	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-860-T-13-672	Modified triple cross
G37	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-873-T-28-685	Modified triple cross
G38	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-880-T-35-702	Modified triple cross
G39	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-13-884-7-39-715	Modified triple cross
G40	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-1-906-T-16-724	Modified triple cross
G41	IAC-100/Burr-P-94 × Gro/IAC/Burr/Kaba-13-930-T-SSD-752	Modified triple cross
G42	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-944-T-SSD-766	Modified triple cross
G43	IAC-100/Kaba-G-47 × Gro/IAC/Burr/Kaba-1-963-T-19-777	Modified triple cross
G44	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-966-T-SSD-787	Modified triple cross
G45	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-976-T-SSD-792	Modified triple cross
G46	IAC-100/Kaba-G-80 × Gro/IAC/Burr/Kaba-1-1030-T-209-814	Modified triple cross
G47	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-1054-T-644-819	Modified triple cross
G48	IAC-100/Kaba-G-67 × Gro/IAC/Burr/Kaba-1-1054-T-644-822	Modified triple cross
G49	IAC-100/Burr-P-96 × Gro/IAC/Burr/Kaba-1-1065-T-SSD-832	Modified triple cross

75 kg ha^{-1} urea, 100 kg ha^{-1} SP36, and 75 kg ha^{-1} KCl. Seeds were treated with 12.5 g carbosulfan per 1 kg seed to prevent seedling fly pests. Weed control was conducted at 3, 6, and 9 weeks after planting.

Soil properties

Ngale RS has vertisol soil type, while Jambegede RS has associated alfisol with inceptisol soil type. Therefore, the physical properties of the sites are different. The soil in Ngale RS is dominated by clay fraction (81%), whereas Jambegede RS is dominated by silt fraction reaching (43%) (Balitkabi, 2017). Soil chemical property analysis revealed that most of the soil nutrient content, including N and P_2O_5 content, in Ngale RS were higher than those in Jambegede RS (Table 2).

Weather properties

Ngale and Jambegede RS are classified as type C3 in accordance with the Oldeman climate classification (Balitkabi, 2017). Higher average rainfall was observed in Ngale, and the highest rainfall occurred in April in both locations. In addition to higher rainfall, Ngale RS also had a higher average temperature than Jambegede RS (Table 3).

Protein analysis

Protein analysis was conducted at the Food Laboratory of Indonesian Legume and Tuber Crops Research Institute, Malang. The micro Kjeldhal method (AOAC, 2016) was applied for the protein analysis of 49 soybean lines. First, the total N of samples was measured through a destructive method by using concentrated H_2SO_4, distillation, and titration by using HCl solution. A conversion factor of 5.75 was used for the calculation of soybean protein content with the following equation:

$$PC = N \times cf,$$

where:

PC = protein content (%)
N = total N content (%)
cf = conversion factor for soybean seed (5.75).

Methionine analysis

Methionine analysis was carried out at Saraswanty Laboratory, Bogor. A total of 49 samples of soybean lines were analyzed for methionine contents by using the AccQ Tag UPLC method in accordance with Rohman and Gandjar (2007) and Waters System Guide (2012). An AccQ Tag Ultra C18 column (1.7 µm, 100 mm L × 2.1 i.d, Waters) was used for the separation of amino acids at 49 °C and the detection of UV absorbance at a wavelength of 260 nm. The mobile phases consisted of A AccQ Tag buffer (Waters), 10% A AccQ Tag buffer, aquabidest, and B concentrate (Waters) and were employed by using gradient elution in reference to the Waters System Guide (2012) at a flow rate of 0.5 mL min^{-1}. The identification and quantification of both amino acids were based on the retention time and peak area of the standards.

Analysis of protein digestibility

Protein digestibility analysis was performed at the Laboratory of Pharmacology and Clinical Pharmacy, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta. The protein digestibility of eight selected samples

Table 2. Soil chemical properties of Ngale and Jambegede Research Station during dry season 2017.

Soil chemical properties	Ngale	Jambegede
PH	6.90	7.40
N (%)	0.16	0.07
C organic (%)	1.42	0.80
P_2O_5 (ppm)	80.00	42.80
SO_4 (ppm)	6.57	3.78
Fe (ppm)	7.43	64.30
Mn (ppm)	47.40	33.00
Cu (ppm)	9.46	28.30
Zn (ppm)	0.67	2.90
K ($Cmol^+$/100g)	0.31	0.61
Na ($Cmol^+$/100g)	0.59	0.81
Ca ($Cmol^+$/100g)	78.10	37.10
Mg ($Cmol^+$/100g)	21.80	9.48
KTK ($Cmol^+$/100g)	42.80	38.20

Table 3. Rainfall and temperature in Ngale and Jambegede RS during dry season 2017.

Months	Ngale		Jambegede	
	Rainfall (mm)	Temperature (°C)	Rainfall (mm)	Temperature (°C)
April	245.6	27.1	244	26.7
May	175.8	26.76	17	26.2
June	79.3	26.12	79	25.0
July	14.7	26.08	19	24.2
Average	128.9	26.5	89.8	25.5

of 49 soybean lines that had the highest average protein contents from both locations were analyzed. This in vitro method was performed in reference to Sudarmanto (1991). Pepsin enzyme and trichloroasectic acid were used for protein hydrolysis because they are assumed to occur normally in human gastric acid. The obtained unhydrolyzed solid samples were then dried, and their protein contents were analyzed. Protein digestibility value (%) was calculated on the basis of the differences between the initial protein content of the sample and the final protein content of the dried unhydrolyzed solid sample:

$$PDV = P0 : P1 \times 100\%,$$

where:

PDV = protein content in soybean seeds (%)
P0 = initial protein content
P1 = final protein content.

RESULTS

The combined analysis of eight observed characteristics showed that location affected days to maturity, number of branches, number of productive nodes, 100-seed weight, and seed yield plot^{-1} (Table 4). Location had no effect on days to

Table 4. Mean square of agronomic traits of soybean lines trialed in two locations.

Traits	Locations (L)	Replications × L	Genotypes (G)	G × L	Error
Days to flowering	867.00ns	371.80ns	353.23ns	343.86ns	342.20
Days to maturity	678.00**	0.19ns	9.15**	2.94**	1.67
Plant height	220.95ns	140.11**	118.72**	27.44**	9.45
Branches plant^{-1}	132.67**	0.44*	1.24**	0.48**	0.19
Productive nodes plant^{-1}	1077.69**	3.81**	3.66**	3.07**	0.90
Filled pods plant^{-1}	525.34ns	96.11*	85.39**	48.60**	15.91
100-seed weight	383.43**	1.32ns	12.32**	4.35**	2.55
Seed yield	15.78**	0.57ns	0.48**	0.43*	0.29

*Significant at 95%, **Significant at 99%, ns = not significant

flowering, plant height, and number of filled pods, indicating that the soybean lines had consistent performance for the three characteristics in Ngale and Jambegede. Genotype had a significant effect on almost all characteristics, except for days to flowering. Genotype × environment interactions also affected all agronomic characteristics except for days to flowering.

Days to flowering was not influenced by genotype, location, or genotype × environmental interactions (Table 4). This result indicated that all soybean lines had the same flowering age (34 days) in both locations. Environmental factors and genotype × environment interactions did not significantly affect the days to flowering of the tested soybean lines. Thus, all the soybean lines showed consistent flowering in the two locations.

Days to maturity in Ngale ranged from 75.7 days to 82.3 days, whereas that in Jambegede ranged from 72.0 days to 80.0 days (Table 4). In general, days to maturity among genotypes, except G-17, G-32, G-42, and G-47, in Ngale was not significantly different. In Jambegede, the days to maturity of the genotypes, except for G-17, was also not significantly different. Days to maturity in two different environments was significantly different. All soybean lines showed early maturity in Jambegede but presented early-to-medium maturity in Ngale.

Plant height in Ngale ranged from 43.5 cm to 68.1 cm, whereas that in Jembegede ranged from 38.6 cm to 67.0 cm (Table 5). The line with the highest plant height in Ngale was G-29 and that in Jambegede RS was G-30, whereas the line with the shortest plant height in Ngale was G-13 and that in Jambegede was G-18. Plant height in the two locations was not significantly different.

The number of branches in Ngale ranged from 2.0 branches plant^{-1} to 4.2 branches plant^{-1}, whereas that in Jambegede ranged from 0.5 branches plant^{-1} to 3.0 branches plant^{-1}. G-10 had the largest number of branches at Ngale and Jambegede and had relatively higher plant height than the other lines. The number of branches in the two locations was significantly different, where the number of branches in Ngale was more than that in

Table 5. Days to maturity, plant height, number of branches, and number of productive nodes plant^{-1} in two locations during dry season 2017.

Genotypes	DTM		PH		BRC		NOD	
	L1	L2	L1	L2	L1	L2	L1	L2
G−1	77 c	74 e-i	51.3 g-w	54.1 d-l	3.7 a-c	2.4 l-w	8.1 y-ḍ	13.6 a-e
G-2	75.7 c-e	73 f-i	50.6 h-y	50.6 h-y	3.1 c-j	2.6 h-t	7.9 y-ḍ	12.7 c-h
G-3	77 c	73.7 e-i	45.7 y-ǵ	47.7 t-ḟ	2.9 f-p	2 t-d	7.5 y-ḍ	12.7 b-h
G-4	77 c	72.7 g-i	50.7 h-x	51.4 f-w	2.8 g-r	1.6 y-ḭ	8.1 z-ḍ	11.7 f-l
G-5	76.3 cd	75 c-f	46.6 w-ǵ	44.6 ç-ǵ	3.5 b-g-	1.8 v-ǵ	8.1 y-ḍ	11 j-p
G-6	77 c	74 e-i	53.5 e-f	49.7 j-ḅ	2.7 h-s	1.6 x-ḥ	8.1 y-ḍ	11.4 h-o
G-7	76.3 cd	75 c-f	52.9 f-r	53.6 e-p	3.1 c-l	2.2 q-z	8 y-ḍ	14.3 ab
G-8	77 c	73 f-i	51.1 g-w	45.4 ḅ-ǵ	3.6 a-e	1.8 v-ḟ	8.2 x-ḍ	11.6 g-m
G-9	77 c	74 e-i	53.2 e-q	50.2 i-ḅ	2.9 e-o	2.7 h-s	7.7 z-ḍ	14.8 a
G−10	75.7 c-e	75 c-f	53.9 e-m	50.5 h-ḁ	4.2 a	3 d-m	8.4 w-ç	13.9 a-d
G−11	77 c	74 e-i	53.9 e-m	49.1 m-ç	3.1 c-k	1.9 u-ḙ	7.7 z-ḍ	11.6 g-m
G−12	76.3 cd	73.7 e-i	48.4 q-ḙ	49.9 j-ḅ	2.9 e-o	1.7 w-ḥ	8.2 x-ḍ	13 b-g
G−13	76.3 cd	72.3 hi	43.5 ḙ-ḥ	42.6 ǵḥ	3.9 ab	2 s-ç	8.5 u-ç	14.1 a-c
G−14	77 c	76.3 cd	47.6 t-ḟ	43.2 ḟ-ḥ	3.2 c-i	1.4 ḅ-ḭ	7.8 y-ḍ	12.6 c-i
G−15	77 c	75 c-f	62.2 b-c	47.4 u-ǵ	3.7 a-d	0.9 ḭ-ḳ	8.7 s-ḅ	11 j-p
G−16	77 c	75 c-f	61.7 c	51.9 f-u	3.6 a-e	1.2 ḙ-ḳ	8.3 x-ḍ	12.1 e-j
G−17	82.3 a	80 b	47.7 t-ḟ	42.5 ǵḥ	2.5 j-v	1.3 ç-ḭ	8.4 v-ç	11.4 h-o
G−18	76.3 cd	76.3 cd	48.1 r-ḟ	38.6 ḥ	3.4 b-h	1.4 ḟ-ḳ	8.5 t-ç	9.4 q-y
G−19	77 c	74.7 d-g	56.1 d-g	51.2 g-w	2.4 k-v	1 ḥ-ḳ	7.9 y-ḍ	11.1 i-p
G-20	77 c	75 c-f	43.6 d-ǵ	43.6 ḍ-ǵ	2.4 k-v	2.1 q-z	7.2 ḅ-ḍ	13.6 a-e
G-21	75.7 c-e	74.3 d-h	52.5 f-t	50.1 i-ḅ	2.8 g-r	1.4 ḅ-ḭ	8.2 x-ḍ	11.3 h-o
G-22	76.3 cd	74 e-i	49.3 k-ç	45.6 z-ǵ	2.7 h-s	0.9 ḭ-ḳ	7.9 y-ḍ	9 r-z
G-23	77 c	73 f-i	51.9 f-u	47.7 t-ḟ	2.4 k-v	1.3 ḍ-ĵ	7.4 z-ḍ	11.3 h-o
G-24	77 c	74.7 d-g	52.5 f-t	52.9 f-r	2.7 h-s	1 ḥ-ḳ	7.8 y-ḍ	10.4 l-r
G-25	77 c	72.7 g-i	52.3 f-u	50.5 h-z	3.6 a-e	1.8 v-ḟ	8.5 t-ç	12.6 c-h
G-26	77 c	74.3 d-h	52.5 f-t	53.7 e-f	3 c-l	1.6 y-ḭ	7.4 ḁ-ḍ	10.1 m-s
G-27	77 c	72.7 g-i	55.8 d-g	59 cd	3.6 a-f	1.4 ḁ-ḭ	8.2 x-ḍ	12.4 d-j
G-28	77 c	73.3 f-i	50.5 h-ḁ	46.6 w-ǵ	3 e-n	1.5 z-ḭ	7.9 y-ḍ	12.4 d-j
G-29	77 c	74 e-i	68 a	56.2 d-f	2.3 m-x	0.5 ḳ	8 y-ḍ	10 o-u
G-30	77 c	74.7 d-g	62.2 bc	67 ab	3.1 c-l	1.4 ḁ-ḭ	7.3 ḁ-ḍ	11.8 f-l
G-31	76.3 cd	74.7 d-g	51.8 f-v	52.8 f-s	2.6 i-u	1.1 ǵ-ḳ	7.5 z-ḍ	10 n-t
G-32	79.7 b	74.7 d-g	55.2 d-h	58 c-e	3 d-m	1.2 ḙ-ḳ	8.1 x-ḍ	11 j-p
G-33	77 c	72.3 hi	46.1 x-ǵ	45.6 ḁ-ǵ	2.2 q-z	0.6 ĵḳ	6.8 ḍ	8.8 s-ḁ
G-34	77 c	74 e-i	54.1 d-k	55 d-i	3 c-l	2.1 r-ḅ	8.4 w-ç	12.6 c-h
G-35	77 c	74.7 d-g	50.4 h-ḁ	53 f-r	3.4 b-h	1.3 ç-ḭ	8.1 x-ḍ	10.9 j-q
G-36	77 c	73.7 e-i	52.9 f-r	50.2 i-ḅ	2.9 f-p	1.2 ḟ-ḳ	7.8 z-ḍ	10.5 k-r
G-37	77 c	73 f-i	52.4 f-t	54.9 d-i	2.5 j-v	1 ḥ-ḳ	8.1 x-ḍ	9.9 o-v
G-38	76.3 cd	72.3 hi	49.1 m-ç	49.6 j-ḅ	2.2 o-y	1.1 ǵ-ḳ	7.7 z-ḍ	10 n-t
G-39	76.3 cd	73.7 e-i	48 s-ḟ	46.9 v-ǵ	2 t-d	1 ḥ-ḳ	7 ç-ḍ	9.6 p-x
G-40	77 c	74 e-i	51.8 f-v	54.2 d-j	2.6 i-u	1.7 w-ḥ	7.6 z-ḍ	12 f-k
G-41	77 c	73.7 e-i	45.9 x-ǵ	50.4 h-ḁ	2.4 j-v	2.5 j-v	7.5 z-ḍ	13.9 a-d
G-42	79.7 b	72.7 g-i	48.7 p-ç	49.7 j-ḅ	3 e-n	1.6 y-ḭ	7.5 z-ḍ	11.4 h-o
G-43	77 c	75 c-f	49 n-ç	46.9 v-ǵ	2.6 i-u	1.6 y-ḭ	8.2 x-ḍ	12.3 e-j
G-44	77 c	72.6 g-i	54.2 d-k	53.7 e-n	2.8 g-r	1.7 w-ḥ	8.3 x-ç	11.6 g-m
G-45	77 c	74.7 d-g	52.5 f-t	49.2 l-ç	3.3 b-i	2.2 o-y	7.8 y-ḍ	13.2 b-f
G-46	77 c	74 e-i	48.7 p-ç	48.7 o-ç	2.2 p-z	1.1 ḟ-ḳ	7.4 z-ḍ	9.9 o-w
G-47	79.7 b	72 I	49.4 j-ç	46.6 w-ǵ	2.9 e-o	2.2 q-z	8 y-ḍ	12.2 e-j
G-48	77 c	73.3 f-i	46.5 w-ǵ	48.5 q-ḍ	2.8 g-q	2 t-ḍ	7.3 ḁ-ḍ	12.2 e-j
G-49	77 c	74.7 d-g	52.2 f-u	53.9 e-n	3 c-l	2.3 n-y	7.4 ḁ-ḍ	12.6 c-i
Average	77.1	74.1	51.6	50.1	2.9	1.6	7.9	11.7
Maximum	82.3	80.0	68.1	67.0	4.2	3.0	8.7	14.8
Minimum	75.7	72.0	43.5	38.6	2.0	0.5	6.8	8.8
LSD 5%	2.08		4.94		0.7		1.54	

L1= Ngale RS, L2= Jambegede RS, DTM = days to maturity, PH = plant height, BRC = number of branches plant^{-1}, NOD = number of nodes plant^{-1}, the numbers followed by the same letters are not different at 95% significance level in two locations

Table 6. Pods plant^{-1}, 100-seed weight, seed yield in two locations during dry season 2017.

Genotypes	POD		W100		SYH	
	L1	L2	L1	L2	L1	L2
G1	34.6 e-j	42.5 a-c	19.24 f-w	17.27 s-ǵ	2.66 b-l	2.99 b-f
G-2	27.2 o-ḙ	30.5 e-w	19.46 e-u	18.77 h-z	2.15 f-s	2.29 e-s
G-3	32.53 e-r	28.2 j-ḙ	19.31 e-v	17.31 s-ǵ	2.53 b-n	1.95 h-s
G-4	23.1 ḅ-ḟ	27 o-ḙ	18.62 h-ḁ	17.28 s-ǵ	1.71 n-s	1.86 i-s
G-5	28.03 k-ḙ	27.1 o-ḙ	19.89 e-r	17.01 u-ǵ	2.22 e-s	1.84 j-s
G-6	27.3 o-ḙ	23.4 z-ḟ	21.83 a-e	18.54 i-ḁ	2.39 d-q	1.75 n-s
G-7	31.2 e-u	32.2 e-s	21.34 a-g	20.32 d-p	2.65 b-m	2.62 b-m
G-8	31.4 e-u	26.9 p-ḙ	20.96 a-j	16.65 y-ǵ	2.63 b-m	1.80 m-s
G-9	29.4 g-ç	31.7 e-t	20.27 d-p	18.33 k-ḅ	2.39 d-q	2.32 d-s
G−10	34.4 e-k	29.2 g-ç	20.89 a-j	17.08 t-ǵ	2.86 b-g	2.02 g-s
G−11	26.07 s-ḙ	25.2 u-ḟ	22.72 a-d	20.64 b-l	2.37 d-q	2.05 g-s
G−12	41.4 b-d	27.9 l-ḙ	17.65 r-ḙ	16.37 z-ǵ	3.01 b-e	1.82 k-s
G−13	34.3 e-l	34.2 e-m	19.10 g-y	14.93 ǵ	2.61 b-m	2.00 h-s
G−14	34.3 e-l	31.5 e-u	19.56 e-t	15.06 ḟǵ	2.69 b-j	1.90 i-s
G−15	35.9 d-f	27.8 m-ḙ	23.42 a	17.40 r-ǵ	3.36 a-b	1.93 i-s
G−16	36.8 c-e	30.1 f-x	22.51 a-d	16.77 w-ǵ	3.29 a-c	2.02 g-s
G−17	31.5 e-u	25.2 v-ḟ	17.86 p-ḍ	15.83 ḅ-ǵ	2.21 e-s	1.62 p-s
G−18	29.3 g-ç	23.0 ç-ḟ	23.23 a	18.57 i-ḁ	2.72 b-i	1.72 n-s
G−19	34.7 e-h	45.0 ab	17.82 p-ḍ	15.01 ǵ	2.47 c-p	2.72 b-i
G-20	29.6 f-ḁ	28.1 k-ḙ	19.66 e-s	18.76 h-z	2.33 d-s	2.11 g-s
G-21	26 s-ḙ	22.5 ḍ-ḟ	21.65 a-f	18.03 n-ḍ	2.25 e-s	1.62 p-s
G-22	28.3 i-ḙ	19.5 ḟ	20.93 a-j	19.17 f-y	2.36 d-r	1.49 s
G-23	34.1 e-n	26.4 r-ḙ	23.02 a-c	19.65 e-s	3.17 a-d	2.07 g-s
G-24	33.3 e-o	24.7 v-ḟ	21.02 a-i	17.57 r-ḟ	2.81 b-h	1.74 n-s
G-25	34.1 e-n	28 k-ḙ	19.72 e-s	16.82 v-ǵ	2.68 b-k	1.89 i-s
G-26	27 o-ḙ	21.9 ḙḟ	18.13 l-ḍ	19.71 e-s	1.98 h-s	1.73 n-s
G-27	30.3 f-x	25.6 t-ḟ	16.37 z-ǵ	16.11 ḁ-ǵ	1.98 h-s	1.65 o-s
G-28	28.3 h-ḙ	29.7 f-z	20.28 d-p	15.18 ḙ-ǵ	2.30 e-s	1.82 l-s
G-29	31.3 e-u	26.2 r-ḙ	18.24 k-ḍ	15.03 ǵ	2.29 e-s	1.58 q-s
G-30	33 e-q	29.9 f-y	17.98 n-ḍ	15.71 ḍ-ǵ	2.4 d-q	1.88 i-s
G-31	32.3 e-s	23.9 y-ḟ	19.91 e-r	18.27 k-ç	2.57 b-n	1.75 n-s
G-32	34.7 e-i	27.1 o-ḙ	17.98 n-ḍ	15.84 ḅ-ǵ	2.50 c-o	1.73 n-s
G-33	27.1 o-ḙ	22.1 ḙḟ	19.69 e-s	19.20 f-x	2.14 f-s	1.71 n-s
G-34	29.8 f-z	28.1 k-ḙ	20.41 d-o	17.46 r-ǵ	2.43 d-q	1.96 h-s
G-35	33.1 e-p	24.6 v-ḟ	18.33 k-ḅ	15.77 ç-ǵ	2.42 d-q	1.58 q-s
G-36	31 e-v	24.1 w-ḟ	18.42 j-ḁ	16.69 x-ǵ	2.27 e-f	1.61 q-s
G-37	29.6 f-ḁ	23.2 ḁ-ḟ	19.35 e-v	16.18 ḁ-ǵ	2.29 e-f	1.50 r-s
G-38	26.6 q-ḙ	22.4 ḍ-ḟ	20.58 c-m	18.25 k-ḍ	2.18 e-f	1.64 p-s
G-39	29.6 f-ḁ	26.3 r-ḙ	20.24 d-q	18.63 h-ḁ	2.39 d-q	1.96 h-s
G-40	23.7 z-ḟ	26.6 q-ḙ	23.14 ab	21.13 a-h	2.19 e-s	2.25 e-s
G-41	24.6 v-ḟ	28 l-ḙ	20.68 b-k	17.94 o-ḍ	2.02 g-s	2.00 g-s
G-42	24.4 w-ḟ	27.7 n-ḙ	16.20 ḁ-ǵ	17.79 p-ḍ	1.58 q-s	1.97 h-s
G-43	35.4 d-g	28 l-ḙ	18.06 m-ḍ	16.85 v-ǵ	2.55 b-n	1.89 i-s
G-44	29.5 g-ḅ	26.7 p-ḙ	18.95 g-y	18.04 m-ḍ	2.28 e-s	1.93 i-s
G-45	26.4 r-ḙ	25.4 t-ḟ	18.13 l-ḍ	17.70 q-ḙ	1.92 i-s	1.80 m-s
G-46	26.9 p-ḙ	22.4 ḍ-ḟ	18.65 h-ḁ	17.65 r-ḙ	2.01 g-s	1.59 q-s
G-47	28.7 h-ḍ	25.8 t-ḟ	20.51 c-n	16.70 w-ǵ	2.36 d-r	1.73 n-s
G-48	27.6 o-ḙ	24.7 v-ḟ	17.84 p-ḍ	16.24 z-ǵ	1.98 h-s	1.60 q-s
G-49	28 k-ḙ	48.5 a	18.05 m-ḍ	20.31 d-p	2.01 g-s	3.88 a
Average	30.4	27.7	19.75	17.50	2.40	1.94
Maximum	41.4	48.5	23.42	21.13	3.36	3.88
Minimum	23.1	19.5	16.20	14.93	1.58	1.49
LSD 5%	6.42		2.55		0.86	

L1= Ngale RS, L2= Jambegede RS, POD = number of pods plant^{-1}, W100 = 100 seeds weight, SYH = seed yield ha−1, the numbers followed by the same letters are not different at 95 or 99% significance level in two locations.

Jambegede. The number of productive nodes in Ngale ranged from 6.8 nodes to 8.7 nodes, whereas that in Jambegede ranged from 8.8 nodes to 14.8 nodes (Table 5). The largest number of productive nodes in Ngale was shown by G-15, whereas that in Jambegede was shown by G-9. The number of productive nodes in the two locations was significantly different. Generally, the number of productive nodes plant^{-1} in Ngale was lower than that in Jembegede. Interactions between different genotypes and environments affected the ability of each genotype to adapt to different growth environments.

The number of filled pods, 100-seed weight, and yield ha^{-1} in Ngale were higher than those in Jambegede (Table 6). The number of filled pods in Ngale ranged from 23.10 pods plant^{-1} to 41.4 pods plant^{-1} with an average of 30.48 pods plant^{-1}, whereas that in Jambegede ranged from 19.50 pods plant^{-1} to 48.5 pods plant^{-1} with an average of 27.76 pods plant^{-1} . All of the lines were large seeded with a range of 16.20–23.42 g per 100 seeds in Ngale and 14.93–21.13 g per 100 seeds in Jambegede. Seed yield ha^{-1} varied between 1.58–3.36 t ha^{-1} with an average of 2.40 t ha^{-1} in Ngale and 1.49–3.88 t ha^{-1} with an average of 1.94 t ha^{-1} in Jambegede. G-15 had the highest number of filled pods, 100-seed weight, and seed yield ha^{-1} in Ngale. In Jambegede, G-49 was the soybean line with the highest seed yield ha^{-1}, which reached 3.88 t ha^{-1}. No line, except for G-49, had a seed yield that was higher than 3 t ha^{-1}. The lowest seed yield in Ngale was exhibited by G-42, whereas that in Jambegede was shown by G-22.

Differences in the agronomic characteristics in Ngale and Jambegede indicated the existence of genotype × environmental interactions, which resulted in the differences in genotype ranks at each location. The average value of agronomic characteristics, except for the number of productive nodes, in Ngale was higher than that in Jambegede. This result may due to the differences in agroecosystems that affected the growth and yield of the tested lines. This was supported by soil properties (Table 2) and weather properties (Table 3) showing that C-organic, N-total, and some other elements in Ngale were higher. Thus, the environmental condition in Ngale was more fertile than that in Jambegede. Therefore, the agronomic traits in Ngale were also better.

In addition to the effect on agronomic performance, location differences, and genotype × environmental interactions affected the protein content of soybeans. The protein content of soybean lines in Ngale ranged from 35.02% to 44.02% of dry weight (DW) with an average of 39.43% DW. G19 showed the highest protein content among the other lines, followed by G-48 and G-5, with values of 44.02%, 41.82%, and 41.67%, respectively. The lowest protein content (35.38%) was shown by G-9. In Jambegede, the average protein content of the lines was lower than those in Ngale, reaching 37.36% DW with a range of 34.72%–40.54% DW. G-24, G-38, and G-33 showed the highest protein content with values of 40.54%, 39.55%, and 39.47%, respectively. G-11 had the lowest protein content (34.72%) (Table 7).

The average protein content of the 49 lines tested in Ngale was higher than the average protein content in Jambegede. Based on

Table 7. Protein content (%) of soybean lines at Ngale and Jambegede Research Stations during dry season 2017.

Genotypes	Ngale	Jambegede
G−1	38.09 ± 0.55	38.27 ± 0.68
G-2	38.86 ± 1.03	38.28 ± 0.82
G-3	41.33 ± 0.09	36.44 ± 0.06
G-4	41.47 ± 0.11	38.79 ± 0.38
G-5	41.67 ± 0.87	38.28 ± 0.13
G-6	38.95 ± 0.07	36.20 ± 0.13
G-7	36.88 ± 0.12	36.60 ± 0.79
G-8	37.61 ± 0.15	36.78 ± 0.25
G-9	35.38 ± 0.51	37.03 ± 0.20
G−10	39.63 ± 0.79	35.97 ± 0.37
G−11	37.24 ± 0.45	34.72 ± 0.80
G−12	37.38 ± 0.43	35.41 ± 0.54
G−13	39.66 ± 0.58	37.77 ± 0.13
G−14	41.57 ± 0.65	37.11 ± 0.26
G−15	39.55 ± 0.22	35.54 ± 0.80
G−16	39.29 ± 0.34	37.35 ± 0.19
G−17	37.00 ± 0.28	36.11 ± 0.42
G−18	39.62 ± 0.91	35.66 ± 0.89
G−19	44.02 ± 0.49	37.93 ± 0.13
G-20	40.21 ± 0.80	37.91 ± 0.03
G-21	40.95 ± 0.43	39.30 ± 0.75
G-22	40.40 ± 0.18	37.97 ± 0.47
G-23	37.64 ± 0.44	36.67 ± 0.37
G-24	40.74 ± 1.10	40.54 ± 0.13
G-25	36.88 ± 0.79	37.35 ± 0.62
G-26	39.75 ± 0.70	37.41 ± 0.24
G-27	37.94 ± 0.70	36.11 ± 0.30
G-28	38.78 ± 0.95	36.23 ± 0.60
G-29	40.14 ± 1.17	38.15 ± 0.90
G-30	39.26 ± 0.76	37.08 ± 0.34
G-31	41.29 ± 0.44	37.82 ± 0.01
G-32	41.55 ± 0.27	37.70 ± 0.55
G-33	39.50 ± 0.22	39.47 ± 0.61
G-34	37.72 ± 0.31	36.96 ± 0.29
G-35	38.09 ± 0.06	35.43 ± 0.05
G-36	40.56 ± 0.03	38.09 ± 0.50
G-37	40.99 ± 0.38	39.07 ± 0.51
G-38	40.63 ± 0.49	39.55 ± 0.34
G-39	39.04 ± 0.34	37.39 ± 0.06
G-40	39.36 ± 0.64	36.25 ± 0.74
G-41	40.54 ± 0.90	38.09 ± 0.83
G-42	40.52 ± 0.38	37.71 ± 0.41
G-43	41.47 ± 0.74	37.88 ± 0.13
G-44	37.49 ± 0.06	38.73 ± 0.21
G-45	40.53 ± 0.08	37.44 ± 0.15
G-46	37.70 ± 0.56	37.02 ± 0.05
G-47	37.26 ± 0.22	37.43 ± 0.17
G-48	41.82 ± 0.63	38.14 ± 0.57
G-49	38.42 ± 0.50	35.81 ± 0.61
Average	39.43 ± 0.08	37.36 ± 0.04
Maximum	44.02 ± 0.49	40.54 ± 0.13
Minimum	35.02 ± 0.51	34.72 ± 0.80

Table 8. Average protein, protein digestibility value, digested protein, and methionine content of eight selected soybean lines.

Genotypes	PA	PDV (%)	PD (%)	Met (ppm)
G-4	40.13 ± 0.49	16.80 ± 0.24	6.74 ±0.05	5677.81 ± 25.10
G-5	39.97 ± 10.00	18.07 ± 0.19	7.22 ± 0.04	6018.26 ± 20.62
G−19	40.97 ± 0.36	18.70 ± 0.40	7.66 ± 0.14	5470.77 ± 79.75
G-21	40.12 ± 1.18	18.19 ± 0.16	7.30 ± 0.05	5753.37 ± 28.33
G-24	40.64 ± 0.97	22.64 ± 0.35	9.20 ± 0.28	5202.29 ± 20.25
G-37	40.03 ± 0.14	16.13 ± 0.25	6.45 ± 0.09	5080.85 ± 31.71
G-38	40.09 ± 0.82	22.44 ± 0.09	9.00 ± 0.07	5244.56 ± 5.75
G-48	39.98 ± 1.20	19.70 ± 0.32	7.88 ± 0.26	5213.74 ± 8.59
Average	40.24 ± 0.08	19.08 ± 0.03	7.68± 0.01	5457.71 ± 3.09

PA = protein average from two locations, PDV = protein digestibility value, PD = digested protein (PA × PDV), Met = methionine content

weather data and soil properties from both locations, the N content in Ngale was higher than that in Jambegede. This consequently caused the average protein content of the lines grown in Ngale to be higher than that of lines grown in Jambegede.

In addition to high productivity, soybean protein content should be a priority because soybeans are a source of protein that, in contrast to animal protein, are easily obtained at affordable prices. Eight out of 49 soybean lines had high protein contents that ranged from 39.97% to 40.97% (Table 8). The protein digestibility value of the eight selected lines ranged from 16.13% to 22.64%. The highest value was shown by G-24, and the line with the lowest digestibility value was G-37. The digested protein from the eight lines ranged from 6.74% to 9.20%. G-4 had the lowest digestible protein content, whereas G-24 has the highest digestible protein content among all lines. The soybean lines that had the highest digestible protein content were G-24 and G-38. Eight soybean lines had higher methionine content than the other lines (Table 8). Among the eight lines, G-5 had the highest methionine content of 6,018.20 ppm. G-37 had the lowest methionine content of 5,080.61 ppm. The average methionine content was 5,457.71 ppm.

Correlation among agronomic characteristics revealed that seed yield had a positive correlation with number of branches, productive nodes, and filled pods and 100-seed weight (Table 9). These correlations were found in Ngale and Jambegede RS. A similar correlation also found between the number of pods and the number of branches and productive nodes and between the number of branches and the number of productive nodes. Negative correlations were found between the days to maturity and 100-seed weight in Ngale and between days to maturity and protein content in Jambegede (Table 9).

DISCUSSION

Most agronomic characteristics, except for days to flowering, were affected by genotype × environment interaction. The existence of genotype × environment interaction resulted from the response of the genotype to the environment. The influence of genotype × environment interactions

Table 9. Correlation among agromomic characters and protein content at Ngale and Jambegede Research Stations during dry season 2017.

	DTM	PH	BRC	NOD	POD	W100	SYH	PROT
DTF	0.018	−0.183	−0.178	−0.167	−0.083	−0.008	−0.085	0.239
	0.122	0.140	0.165	0.276	0.149	0.254	0.263	−0.101
DTM		−0.039	−0.148	0.054	−0.017	−0.311**	−0.200	0.040
		−0.189	−0.072	−0.007	0.080	−0.082	0.056	−0.310*
PH			0.156	0.284	0.245	0.088	0.271	0.004
			−0.007	0.058	0.155	−0.048	0.146	0.081
BRC				0.590**	0.344*	0.078	0.348*	−0.227
				0.847**	0.383**	0.178	0.457**	−0.230
NOD					0.400**	0.165	0.422**	−0.166
					0.519**	−0.072	0.467**	−0.254
POD						−0.053	0.809**	−0.146
						−0.114	0.894**	−0.145
W100							0.538**	−0.150
							0.331*	−0.090
SYH								−0.203
								−0.190

Upper = Ngale RS, Lower = Jambegede RS, DTM = days to maturity, PH = plant height, BRC = number of branches plant^{-1}, NOD = number of nodes plant^{-1}, POD = number of pods plant^{-1}, W100 = 100 seeds weight, SYH = seed yield ha$_{-1}$, *Significant at 95%, **Significant at 99%.

indicated the failure of a genotype to perform consistently at different locations (Karasu *et al*., 2009). It suggested that the genotype grows better at a specific location than at another location as indicated by the performance of the agronomic characters. Given that the responsiveness of a characteristic differs from that of other characteristics, some characteristics did not differ when the plant is grown in different locations.

The soybean lines showed consistent days to flowering in the two locations, indicating that the days to flowering of the tested soybean lines was not influenced by environmental factors and genotype × environment interactions. Cober *et al*. (2014) and Zhang *et al*. (2016) stated that days to flowering is strongly influenced by photoperiod duration. The Indonesian region has the same irradiation, which is approximately 12 h. The experiment was conducted in two locations with the same latitude. Thus, there is no difference in photoperiod. Consequently, the genotypes received the same photoperiod and days to flowering

Genotype × environment interaction had a significant effect on days to maturity. This result indicated that some genotypes adapted better to one location than to other locations. Days to maturity has a relationship with temperature and water availability. Low temperatures prolong days to maturity (Kuswantoro *et al*., 2017). It is related to the temperature received by the plant (Kumagai and Sameshima, 2014). Low water availability shortens days to maturity (Kuswantoro and Zen, 2013). Plants have mechanisms to finish their life cycles before severe drought stress occurs. In the present study, Ngale received more rainfall than Jambegede, accounting for the higher water availability in Ngale than in Jambegede.

Plant height was affected by the interaction between genotype × environment. Environmental factors, such as soil fertility, rainfall intensity, and temperature fluctuations, affect plant characteristics, such as plant height. In this experiment, Ngale had higher rainfall and temperature than Jambegede (Table 3). Rainfall affected growth such that plants grew taller in Ngale (Table 5). This study is similar to that of Ngalamu *et al*. (2013), who found that genotype and environmental interaction influences plant height. Kuswantoro (2019) also reported that plant height has a positive correlation with seed yield. However, plant height and seed yield in each location were not correlated (Table 9). This result means that the location had important roles in dictating plant height and seed yield.

The number of branches in the two locations was significantly different, where the number of branches in Ngale was more than that in Jambegede. The number of branches was not followed by the number of productive nodes, where the number of productive nodes in Ngale was lower than in Jambegede. This difference may be due to the location of productive nodes on the main stem and not on branches. Productive nodes on branches are supported by high branch dry matter (Carpenter and Board, 1997). The branch dry matter in Ngale may be lower than that in Jambegede. In this study, branch dry matter was not observed.

The number of filled pods also showed the absence of location effect. However, the presence of genotype × environment interaction influences was observed. This result indicated that the number of filled pods of the soybean lines was highly influenced by genetic factors. The influence of the genetic factor on the number of filled pods is more dominant than that of the environmental factor (Kuswantoro, 2014). The different soil and weather properties of the locations could not change the number of filled pods. This result suggested that the soil and weather properties in two locations did not differ enough to influence the number of filled pods.

Although the productive nodes in Ngale were lower than in Jambegede, the number of filled pods, 100-seed weight, and yield ha^{-1} in Ngale were higher than those in Jambegede. The higher number of productive nodes in Jambegede did not correspond to a higher number of filled pods. 100-seed weight, a yield component, was also greater in Ngale than in Jambegede. Consequently, the yield ha^{-1} in Ngale was higher than that in Jambegede. This result is similar to the result of a study conducted by Kuswantoro (2014), who also reported better agronomic traits in Ngale than in Jambegede.

Most agronomic characteristics in Ngale were higher than those in Jambegede because the agro-ecosystems in Ngale were more beneficial than those in Jambegede as indicated by their soil properties (Table 2) and weather properties (Table 3). Consequently, the performance of agronomic characteristics in Ngale was better than that in Jambegede. The protein content in Ngale was also higher than that in Jembegede. The protein content of soybeans is significantly influenced by environmental conditions (Ohyama *et al*., 2013). The availability of nitrogen for plants can affect the formation of protein, and nitrogen is also an integral part of chlorophyll. Soybean plants absorb nitrogen in the form of NO_3^-, but they can also absorb N in the forms of NH_4^+ and urea. The N compound is transformed into NO_3^- under well-aerated conditions. Some previous studies have also examined the effect of environmental differences and genotype × environment interactions on protein content in soybeans. Some studies reported that genotype × environment interaction has a significant effect on soybean protein (Clemente and Cahoon, 2009; Arslanoglu, 2011; Njoroge *et al*., 2015). Protein content has a relationship with seed yield (Kuswantoro *et al*., 2019).

The agronomic characteristics and protein content of lines in Ngale were higher than those in Jambegede. However, no significant correlation was found between agronomic characteristics, except for days to maturity, and protein content in each location (Table 9). This result indicated that the good performance of the phenotype lead to high agronomic characteristics and protein content. Kuswantoro *et al*. (2019) reported that the number of filled pods and 100-seed weight are positively correlated with protein content. In this study, the highest protein content was shown by G19 and reached 44.02% ± 0.49%. The soybean varieties with the highest protein content that have been released by the Indonesian Agency for Agricultural Research and Development are Detam 1 and Detam 2, which have protein contents of 45.36% and 45.58%, respectively (Balitkabi 2016). Detam 1 and Detam 2 are black-seeded soybean varieties. Usually, black-seeded soybeans have higher protein contents than yellow-seeded soybeans. However, the use of black seed soybeans is limited. In Indonesia, black-seeded soybeans are only used as an ingredient for soy sauce. All lines in this study had yellow seeds that can be used as food products, such as tempeh, tofu, and sprouts, and for soy sauce and soy milk production.

In addition to protein content, protein digestible value and methionine content are important. The protein digestible value indicates the proportion of protein content that can be digested and used by the human body. Among the eight selected lines, G24 and G38 showed the highest protein digestible value. These two soybean lines did not have the highest methionine content. Methionine content did not have a positive relationship with protein digestible value. However, Kuswantoro *et al*. (2019) reported that methionine content has a positive relationship with protein content. Protein from legumes only provides 1%–2 mol% sulfuric-amino acids (methionine and cysteine) compared with WHO's nutrition requirement of 3.5 mol% (Le *et al*, 2016). Kim *et al*. (2014) stated that the methionine content of soybeans can be increased by increasing sulfur availability in soil.

CONCLUSION

The agronomic characteristics, except for days to flowering, of the 49 tested soybean lines were influenced by location, genotype, and genotype × environment interactions. Location had no effect on plant height and filled pods plant^{-1}. The agronomic characteristic and protein content of 49 soybean lines in Ngale were higher than those of the lines in Jambegede. The agronomic performance of the tested lines was inconsistent in two locations. G-15 had the highest yield in Ngale, whereas the highest seed yield in Jambegede was shown by G-49. The average protein content in Ngale was higher than that in Jambegede. The protein digestibility value and digested protein varied with similar protein contents. Methionine content also varied, and the highest methionine content was achieved by G-5 and the lowest was achieved by G-37.

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