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Research Article

Multilocation Test of Prospective Composite Sticky Corn Varieties With High Production in Indonesia

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Sticky corn is required to meet the demand for a national staple food, driven by population growth. In this context, different efforts are carried out to increase productivity by using new superior varieties with easy adaptation to specific and wider environments as well as high resistance to pests and diseases. Therefore, this research aimed to evaluate composite sticky corn variety performance in several locations in Indonesia. The method used was the adaptation testing of 4 prospective and 3 comparative varieties of composite sticky (JPI-1, JPI-2, JPI-3, and JPI-4) and (Sticky Uri, White Srikandi, and local Sticky Takalar) in 6 districts serving as research locations, respectively. Each location was designed using a randomized block design, with 4 replications to obtain 28 experimental units. Meanwhile, observation data were analyzed using analysis of variance (ANOVA). Least significant difference (LSD) test was carried out at the 5% level when there was a difference in the average value and the data analysis was conducted using the DSAASTAT program. The stability of the results was analyzed using the additive main effects and multiplicative interaction (AMMI) model through the PBSTAT program. Additionally, testing for resistance to downy mildew, rust, and leaf blight was carried out in a randomized block design with 4 replications. Proximate analysis testing was performed at the Animal Husbandry Integrated Biotechnology Laboratory, Faculty of Animal Husbandry, Hasanuddin University. The results showed that the prospective composite corn varieties JPI-1, JPI-2, JPI-3, and JPI-4 had the potential for yields significantly superior to the three comparative varieties, with 8.88, 8.54, 8.57, and 8.67 $t \cdot ha^{-1}$, respectively. In the context of the analysis, JPI-1 and JPI-4 reported stable results in all environments. Meanwhile, JPI-3 showed increasingly better results in the optimum environment. Prospective varieties JPI-1, JPI-2 JPI-3, and JPI-4 offered the criteria for resistance to Downy mildew disease *Peronosclerospora maydis*, *Peronosclerospora philippinensis* type, *Bipolaris maydis* type blight, and leaf rust disease type *Puccinia polysora*. Based on the approximate test, JPI-1, JPI-3, and JPI-4 had superior protein content of 11.64, 11.69%–11.86% than the 3 comparative varieties, respectively. The prospective variety JPI-1 had a high amylopectin content of 85.10% equivalent to local sticky parents and higher than the two comparative varieties. Additionally, JPI-2, JPI-3, and JPI-4 had higher amylopectin content than the 2 comparative varieties.

Keywords: adaptation; corn composite; disease resistance; productivity; proximate

1. Introduction

Corn (*Zea mays* L.) is among the most essential carbohydrate-producing food crops besides wheat and rice [1]. This food crop is the second cereal commodity grown in Indonesia after rice. Corn is central as an alternative staple food, snacks, and various other commodities [2]. Moreover, corn is a main component in animal feed and other industries such as raw materials for producing bioethanol. This cereal crop has been developed as a functional food because of the dietary fiber [1].

Sticky corn has the potential as a source of food diversification and industrial materials. In Japan, corn is a source of amylopectin, a raw material for food products, textiles, glue, and paper. Sticky corn is a source of germplasm for developing new cultivars through plant breeding [3]. In addition, sweet corn can be consumed as a fresh or boiled vegetable due to the soft and delicious taste. Sticky corn contains starch from amylopectin, which reaches 100% [4]. The high level of amylopectin is suitable for the diet of diabetics and to increase the weight of livestock. Sticky corn is consumed as porridge and rarely used as a staple food due to poor production and vulnerability to downy mildew. However, the cereal has a low potential yield, producing small cobs with a 10–11 mm diameter, and production of less than 2 tons/ha [5].

In Sulawesi, Indonesia, sticky corn is a typical food ingredient and domestic demand continues to increase with insufficient supply. The national need for corn is growing with the increase in population and the development of the food and feed industry. Data for the 2018–2022 period show that the production has grown with the increase in harvested area, but there has been a particular decline in 2021. The effort to provide sticky corn as an alternative staple food requires the release of appropriate variety. This must express a high-yielding amylopectin content and adapt to environmental changes.

The proposed composite corn genotype is a line assembled and developed from a cross between high protein content and local sticky varieties containing amylopectin. The genotype assembly program is subjected to several breeding stages to obtain a combination of traits from the cross.

Several research types have analyzed and evaluated the sweet corn hybrid performance in targeted environments [6–9]. The corn traits are controlled by multiple genes and are inherited through quantitative genetic variation from combined action. The ability of parents can determine offspring with superior characteristics, such as the balanced proportion of kernel carbohydrates to meet consumer appeal [9].

To obtain the best corn quality, comprehensive testing is needed, including disease resistance. Therefore, this research aims to test the stability of hybrid varieties with many parameters including production, nutrient levels, and disease resistance. Continuous identification, characterization, and evaluation are also required. An important stage in testing the genotype assembly is the multilocation test. Previous research in Indonesia has been conducted concerning the environmental conditions in Java [2, 10]. Tests in different environments are needed to represent the capabilities of different islands in Indonesia. In this context, composite sticky corn variety performance is evaluated in several locations.

2. Materials and Methods

This research evaluated the performance of the adaptation test of 4 prospective and 3 comparative varieties. The 4 prospective corn varieties consisted of JPI-1, JPI-2, JPI-3, and JPI-4, while the 3 comparative varieties are Sticky Uri (JPI-5), White Srikandi (JPI-6), and local Sticky Takalar (JPI-7). JPI-1, JPI-2, JPI-3, and JPI-4 originate from a cross between the White Srikandi and local Sticky Takalar as female and male parents, respectively. The crossover process was conducted from 2017 to 2022 through the 8th generation.

2.1. Testing Time and Location. The adaptation test was carried out during the 2023 planting season (PS) from March to September 2023 in 6 districts. A total of 4 districts were located in South Sulawesi (Gowa, Takalar, Bantaeng, and Maros) and 2 from other provinces (Lombok and Kediri in West Nusa Tenggara and East Java Province) (Table 1). Disease resistance tests were carried out in 2 districts, namely, Gowa (3 locations: location 1, leaf rust test; location 2, leaf blight test; and location 3, downy mildew test specific for the species *Peronosclerospora philippinensis*) and Malang (the specific downy mildew test for the *Peronosclerospora maydis* species) (Table 2).

The plot area used for each experimental unit was 5×3 m with a planting space of 75×20 cm. The samples were collected from the two middle row, randomly taking as 10 plants per plot. The type and dose of fertilizer used was 300 and 400 kg/ha of urea and nitrogen, phosphorus, and potassium. Fertilization was carried out twice when the plants were 7 days old and 30 days after planting (DAP), administering 50% of the dose.

2.2. Adaptation Test Method. The research was carried out using a randomized block design consisting of 7 varieties, repeated 4 times to obtain 28 experimental units at each adaptation test location. Observation data were assessed using analysis of variance (ANOVA), and bi values were used to investigate the stability of results. Least significant difference (LSD) test was carried out at a 5% level when there was a difference in the average value of the varieties in the F test. The results were presented as paired comparatives between prospective and comparative varieties. Meanwhile, the data analysis was carried out using the DSAASTAT program. Analysis of the stability of the results used the additive average effect multiplicative interaction through PBSTAT program.

3. Results and Discussion

3.1. Adaptation Test

3.1.1. Overview Adaptation Test. Data collected from each location were analyzed for combined variance. ANOVA was used to determine the influence of environment, genotype, and interaction of genotype and environment. The results of the integrated variance analysis of yield and agronomic characteristics of 4 prospective composite corn and 3 comparative varieties are presented in Table 3. The combined variance analysis shows that location strongly affects the observed variables except for leaf width, male flowering age, cob appearance, and harvest water content. The effect of location showed that the environmental characteristics of the research sites were quite diverse.

Table 1: Description of adaptation test locations for prospective composite corn varieties in 6 districts.

No.	Location	Soil type	Altitude (a.s.l)	Climate type	Planting date	Harvest date
1.	Bajeng, Gowa, South Sulawesi	Alluvial, land paddy field	89	D	May 06, 2023	August 20, 2023
2.	Sinoa, Bantaeng, South Sulawesi	Latosol, land dry	500	B	May 17, 2023	September 10, 2023
3.	Lembar Lombok Barat, NTB	Alluvial, land dry	14	D3	May 21, 2023	September 05, 2023
4.	Kepung, Kediri, East Java	Alluvial, land dry	67	C2	May 22, 2023	September 07, 2023
5	Galesong, Takalar, South Sulawesi	Alluvial, land paddy field	20	C2	May 24, 2023	September 09, 2023
6.	Lau, Maros, South Sulawesi	Alluvial, land paddy field	25	C2	June 21, 2023	October 06, 2023

The effect of genotype was significant on all observed variables except leaf length. Each prospective variety has a different genetic potential in expressing traits or characters (Supporting table (available here)). Another research reported that the lines tested differ significantly in all characters. Therefore, there are differences in genetic potential between the lines tested [11].

3.2. Average and Potential Results. The results of the average and potential yields in comparative and prospective varieties of JPI-1, JPI-2, JPI-3, and JPI-4 showed that the average yields of 8.16, 7.88, 7.74, and 7.62 t/ha were significantly superior to Sticky Uri-1, White Srikandi, and local Sticky at 6 test locations, respectively. Meanwhile, the respective comparative varieties amount to 6.48, 7.75, and 4.33 t/ha, as reported in Table 4.

The prospective variety JPI-1, especially Sticky Uri and Local, was significantly superior in all locations. In the Maros location, JPI-1 is superior to all comparative varieties. The prospective varieties JPI-2, JPI-3, and JPI-4 were significantly superior for all locations compared to Sticky Uri and Local varieties. Changes in the rank of a genotype at each test location indicate a genotype and environment interaction [12].

4. Results Stability Analysis

The combined ANOVA on seed yielding 4 prospective and 3 comparative varieties at 6 test locations showed a very significant genotype × location interaction (Table 5). This causes the seed yield of each prospective variety to be different in each testing environment. The results state that the interaction of genotype with the environment leads to inconsistent appearance of a trait under different environmental conditions. This causes differences in yield for various planting environments [13]. In addition, the interaction of genotype and environment is a component that influences phenotypic expression [14]. Stability and adaptability tests are needed to determine the level of genotype in each environment.

The variation in crop yield characteristics (t/ha) was caused by location and genotype factors of 7.52 and 43.50, respectively. Based on this proportion, the genotype makes the most significant contribution to the diversity of the characteristics. Stability analysis is used to determine the effect of the interaction of genotype and environment effectively. Therefore, the level of stability and adaptability of the proposed variety can be determined. Previous research reported corn stability tests in West Java, Indonesia. The results showed that 2 varieties, namely, G5 (SR 24 × SR 17) and G11 (SR 31 × SR 17), had good levels of stability and adaptability in terms of earliness and yield [15].

The JPI-1 and JPI-4 genotypes with bi values are not significantly different from 1, and the average yield is higher than the general average. Therefore, the performance of prospective varieties is stable in optimum and suboptimal environments. For the prospective variety, JPI-3 shows that the bi value is significantly different from 1 (Table 6). This is because the genotype is adaptive to the optimum environment. Meanwhile, JPI-2 reports that the bi value is smaller and significantly different from 1 since the genotype produces increased yields.

4.1. Agronomic Components and Yield Components

4.1.1. Plant Growth, Flowering Time, Harvest Time, Plant Height, and Cob Height. Table 7 shows plant growth capacity, male and female flowering age, harvest age, plant height, and cob location. Based on the statistical test, the percentage of prospective corn varieties growth was significantly higher from the comparative variety, except for the JPI-4 variety. The percentage was not significantly different from the comparative variety but increased above 85%. The flowering times for males and females of prospective varieties JPI-1, JPI-2, JPI-3, and JPI-4 were significantly faster than White Srikandi. Additionally, the harvest time was significantly faster than the comparative varieties Sticky Uri and White Srikandi. Genetic factors cause differences between one plant and another [16]. Corn plants have short, medium, and high maturity ranging from 75 to 90 DAP, 90–120 DAP, and more than 120 DAP, respectively [17]. The JPI-2 genotype showed plant height yields that were significantly superior to local Sticky. Meanwhile, JPI-4 reported plant height yields superior to White Srikandi and Local Takalar Sticky. For cob height, JPI-2 was 85.35 cm, while JPI-4 showed a position height superior to White Srikandi and Local Takalar Sticky. The correct position of the cob reduces the intensity of rat pest attacks. The intensity of root and stem lodging was reduced when the height of the cob was located more or less in the middle of the plant.

The characteristics of plant height and cob location were closely related to the suitability of the planting environment. In this context, the environment with high altitudes and strong winds is suitable for shorter plants. Meanwhile, tall plants with suitable cobs are needed in areas susceptible to pest attacks, such as mice. Most plant breeders concentrate

Table 2: Description of disease resistance test locations for prospective composite corn varieties in 2 districts.

No.	Location	Soil type	Altitude (mdpl)	Climate type	Planting date	Harvest date	Information
1	Bajeng, Gowa, South Sulawesi	Alluvial, land dry	89	D	June 11, 2023 June 17, 2023 June 24, 2023	August 26, 2023 Sept 02, 2023 August 10, 2023	Leaf rust Hover down Bubbles (*P. philippinensis*)
2	Gondanglegi, Malang, East Java	Inceptisol, land paddy field	400.1	C2	June 12, 2023	July 31, 2023	Bubbles (*P. maydis*)

Table 3: Middle square of agronomic characters, yield components, and yield of prospective JPI composite corn varieties at several locations.

Variable	Middle quadrate				
	Location	Loc/R	Genotype	Genotype × Lok	Error
Plant growth (%)	222.52**	27.88	76.72**	8.70	13.77
Plant height (cm)	10,549.10**	464.98	2218.36**	381.10*	240.09
Cob height (cm)	2257.33**	456.68	547.79**	148.34*	79.78
Stem fall (%)	0.00**	0.00	0.00**	0.00	0.00
Root reduction (%)	0.00**	0.00	0.00**	0.00**	0.00
Number of leaves	0.15 7**	0.01	0.08**	0.01	0.02
Leaf angle (°)	23.98**	1.50	5.80**	0.67	0.67
Leaf length (cm)	15.12**	0.93	1.41	1.67*	0.94
Leaf width (cm)	10.01	9.34	24.05*	7.29	6.61
Age of male flowering (DAP)	0.31	0.24	0.53*	0.20	0.17
Female flowering age (DAT)	163.09**	2.32	95.97**	3.22	2.55
Harvest age (DAP)	173.52**	1.91	104.23**	3.31**	1.59
Plant appearance aspects (score)	149.72**	1.80	780.59**	6.33**	0.80
Closing husk (score)	2.87**	0.35	0.22**	0.02	0.02
Cob performance (score)	0.19	0.07	2.50**	0.02	0.02
Blight score (score)	0.71**	0.03	0.17**	0.04	0.04
Rust disease score (score)	0.00**	0.00	0.00**	0.00	0.00
Number of harvested plants	0.00*	0.00	0.00**	0.00	0.00
Number of harvested cobs (cobs)	64.71**	1.97	7.57**	0.81	0.66
Harvest cob weight (kg)	42.28**	0.82	7.61**	1.20	0.88
Seed yield (%)	8.09**	0.35	40.93**	0.48**	0.22
Harvest water content (%)	2.94	2.40	44.66**	1.60	2.51
Cob length (cm)	12.26**	2.12	21.98**	1.55	2.31
Cob diameter (cm)	49.94**	1.00	65.23**	0.67*	0.37
Number of seed rows (row)	5.39 7**	0.03	2.49**	0.07**	0.03
Number of seeds per row (seed)	6.76**	0.72	54.88**	1.44**	0.60
Weight of 1000 seed (g)	277.67**	10.76	310.58**	0.93	5.16
Seed yield (f/ha)	7.52	0.28	43.51**	0.40*	0.22

*significant effect at the F test level of 5%.
**significant effect at the F test level of 1%.

Table 4: Average yield (t/ha) of JPI corn seed and comparative varieties at each test site in MT 2023.

Genotype	Yield at 15% moisture content (t/ha)						
	Gowa	Takalar	Bantaeng	Maros	Lombok	Kediri	Average
JPI-1	8.11[ac]	7.70[ac]	7.36[ac]	8.45[ab]c	8.88[ac]	8.48[ac]	8.16[abc]
JPI-2	7.192[ac]	7.87[ac]	7.20[ac]	8.11[ac]	8.54[ac]	7.63c	7.88[ac]
JPI-3	7.95[ac]	7.54[ac]	6.56[ac]	7.69[ac]	8.57[ac]	8.14[ac]	7.74[ac]
JPI-4	7.71[ac]	7.47[c]	6.71[ac]	7.61[ac]	8.67[ac]	7.56[c]	7.62[ac]
Sticky Uri (a)	5.61	6.85	5.53	6.02	7.73	7.12	6.48
White Srikandi (b)	7.82	7.74	6.97	7.88	8.36	7.76	7.75
Local Sticky Takalar (c)	4.38	3.92	3.97	4.41	4.77	4.55	4.33
Average	7.07	7.01	6.33	7.17	7.93	7.32	7.14
SE	0.17	0.21	0.26	0.16	0.27	0.30	0.13
LSD 5%	0.49	0.63	0.78	0.46	0.80	0.89	0.37
CV	4.7	6.1	8.3	4.3	6.7	8.2	6.6

[a]Significantly superior to Sticky Uri-1.
[b]Significantly superior to White Srikandi.
[c]Significantly superior to local Sticky in the LSD 5% test.

selection on shorter plants to withstand lodging caused by strong winds [18]. Selection is also carried out on the characteristics of plant and ear height. Several cases show a decrease and an increase in ear and plant height, respectively [19].

Table 8 shows stem diameter, angle, length, width of leaves, and percentage of leaf rust. The prospective varieties JPI-1, JPI-2, JPI-3, and JPI-4 have stem diameters of 2.38, 2.35, 2.36, and 2.32 cm, respectively. These varieties are superior to the Local Takalar Sticky with a diameter of only 2.22 cm. A large stem makes the plant stronger and reduces the intensity of lodging. The character of leaf angle, length, and width of leaves is used to develop a new variety.

Table 5: Analysis of variance of the combination of environmental × outcome characters in 6 test locations (districts) in MT 2023.

Source of diversity	DF	SQ	MQ	F hit	Prob F	
Location	5	37.58	7.52	27.06	0.00	**
L/R	18	5.00	0.28	1.27	0.22	
Genotype	6	261.04	43.51	108.15	0.00	**
Genotype x location	30	12.07	0.40	1.84	0.01	*
SD	108	23.61	0.22			
Total	167	339.31	2.03			

Abbreviations: DF = degrees of freedom, MQ = middle square, SQ = sum of squares.
*Significantly different based on the 5% F test.
**Very real based on an F test of 1%.

Table 6: Average and stability of composite corn yields (KA 15%) based on the combined analysis of 6 test locations (districts) in MT 2023.

Genotype	Yield (t/ha)			Slope	SE	MQ	MQ	MQ	$R^{**}2$ (%)
	Min	Max	Average			MS-TXL	MS-REG	MS-DEV	
JPI-1	7.36	8.88	8.16	1.01	0.20	0.04	0.00	0.05	0
JPI-2	7.20	8.54	7.88	0.77*	0.20	0.06	0.07	0.05	25
JPI-3	6.56	8.57	7.74	1.26*	0.19	0.06	0.09	0.05	34
JPI-4	6.71	8.67	7.62	1.17	0.14	0.03	0.04	0.03	25
Sticky Uri (a)	5.53	7.73	6.48	1.40	0.50	0.31	0.21	0.34	14
White Srikandi (b)	6.97	8.36	7.75	0.83	0.11	0.02	0.04	0.02	35
Local Sticky Takalar (c)	3.92	4.77	4.33	0.55	0.17	0.08	0.27	0.04	64
Mean						7.36			

Note: bi = regression slope of the average variety in the environmental index, MQ-HXL = contribution of each genotype to the average square of the interaction, MQ-Reg = contribution of each genotype to the regression component in the interaction between genotype × location interaction, MQ-Dev = middle square deviation (deviation of the interaction regression components), R^{**} 2 (%) = squared correlation between the residuals of the main effects of the model and the environmental index.
Abbreviation: SE = standard error.
*Bi value is significantly different from 1.

Table 7: Average plant growth, age, plant height, and position of test composite corn cobs and comparative varieties in 6 test locations (districts) in MT 2023.

Genotype	Growth	Flowering (DAP)		Harvesting (DAP)	Height (cm)	Ear height (cm)
		Female	Male			
JPI-1	91.83^{ab}	56.87^{b}	55.16^{b}	102.21^{ab}	186.42	89.35
JPI-2	91.63^{ab}	57.20^{b}	55.45^{b}	102.79^{ab}	175.59^{c}	85.35^{c}
JPI-3	92.33^{ab}	57.20^{b}	55.50^{b}	103.50^{ab}	187.27	92.23
JPI-4	88.67	57.12^{b}	55.25^{b}	106.39^{ab}	166.70^{bc}	80.20^{bc}
Sticky Uri (a)	88.32	56.87	54.69	110.15	171.42	83.75
White Srikandi (b)	89.15	59.12	57.52	110.49	186.86	91.16
Local Sticky (c)	92.21	52.29	50.87	93.17	192.23	92.65
Average	90.59	56.67	54.92	104.18	180.93	87.81
SE	0.60	0.37	0.36	0.51	3.98	2.46
LSD 5%	1.73	1.07	1.05	1.48	11.50	7.18
CD (%)	4.10	2.20	2.90	0.90	8.60	10.20

Abbreviation: CD = diversity coefficient.
a = significantly superior to Sticky Uri.
b = significantly superior to White Srikandi.
c = significantly superior to local Sticky Takalar in the 5% LSD test.

The leaf angles of the four prospective varieties JPI-1, JPI-2, JPI-3, and JPI-4 did not show significant differences with Sticky Uri, White Srikandi, and local Sticky. The leaf angles of the prospective and comparative varieties were all less than 30°, and the moderate type was between 21.1° and 50° [20]. The angle between small and medium had a straight or bent leaf pattern, which was included in the erect leaf category [21]. Erect-type plants with small to medium leaf angles could increase the number of planted populations.

The average leaf length character of the prospective variety JPI-1 showed superior results and significantly differed from the comparative varieties Sticky Uri, White

Table 8: Average stem diameter, angle, length, and width of leaves, as well as percentage of stem and root fall of maize composite test and comparative varieties in six locations.

Genotype	Stem diameter	Leave angle	Leave length	Leave wide	Stem rot	Root rot
JPI-1	2.38[ac]	26.89	96.42[abc]	9.443[ac]	0.017[abc]	0.02[abc]
JPI-2	2.35[ac]	26.59	95.00[c]	9.29[c]	0.02[abc]	0.01[abc]
JPI-3	2.36[ac]	26.55	94.72	9.40[c]	0.02[abc]	0.02[abc]
JPI-4	2.32[c]	26.82	94.14	9.20	0.02[abc]	0.02[abc]
Sticky Uri (a)	2.30	27.00	94.50	9.16	0.04	0.03
White Srikandi (b)	2.39	26.90	94.12	9.34	0.04	0.03
Local Sticky (c)	2.22	26.32	93.17	9.02	0.06	0.06
Average	2.30	26.72	94.13	9.18	0.04	0.04
SE	0.02	0.26	0.55	0.09	0.00	0.00
LSD 5%	0.05	0.76	1.59	0.27	0.01	0.01
CV	5.70	3.60	2.70	4.50	34.80	24.30

Abbreviation: CV = coefficient of variation.
[a]Significantly superior to Sticky Uri.
[b]Significantly superior to White Srikandi.
[c]Significantly superior to local Sticky in the 5% LSD test.

Srikandi, and local Sticky. The leaf length of JPI-2 is superior and significantly different from local Sticky. The average leaf diameter character of the prospective variety JPI-1 showed superior results and significantly differed from Sticky Uri and local Sticky. In addition, the leaf diameter of JPI-2 is superior and significantly different from local Sticky.

The size of the leaves greatly influences the results of photosynthesis. The percentage of stem and root lodging for all prospective was lower and significantly different from comparative varieties.

4.2. Plant and Ear Appearance, Husk Closure, Leaf Rust, and Leaf Blight. The characteristics of the plant appearance, the closure of the husk, the appearance of the cob, and the attacks of the disease were qualitatively observed by scoring. The average assessment of plant appearance, husk closure, cob appearance, blight, and leaf rust attacks are presented in Table 9. Based on statistical analysis, the prospective varieties JPI-1, JPI-2, JPI-3, and JPI-4 showed good plant performance with average values respective scores of 1.77, 1.85, 1.83, and 1.82, significantly different from the 3 comparative varieties. The appearance of good scores shows that the plants have uniformity and sturdy stems when planted in 6 adaptation testing locations. More uniform plants can facilitate the application of mechanization in the management [22].

The prospective varieties had perfect husk closure with an average score of 2.06, 2.13, 2.13, and 2.11. The closure of the husks was significantly different from the comparative varieties Sticky Uri and White Srikandi. However, the local Sticky had a better husk closure score.

Properly and tightly husk closure can protect the cobs from weather effects, pest attacks, especially the powder beetle (*Sitophilus zeamais*), and cob rots infections. According to [23], tightly closing husks can reduce the intensity of water seeping into the cob to prevent seed germination and growth of pathogenic fungi as well as provide protection from *Sitophilus zeamais* pest.

The appearance of cobs is related to the uniformity of size, seed color, seed filling, and seed damage due to pests and diseases. The cob performances of JPI-1, JPI-2, and JPI-3 showed an average score of 1.30, 1.34, and 1.31, respectively. This is significantly different from the comparative varieties Sticky Uri and White Srikandi. However, the appearance of the cob of JPI-4 is only substantially different from the comparative variety Sticky Uri. The seed is filled to the tip of the cob, with a straight grain arrangement, and an attractive seed color preferred by consumers or farmers.

The scoring of leaf rust disease attacks for prospective varieties JPI-1, JPI-2, JPI-3, and JPI-4 showed a small average of 0.02. This is a significantly different value from the comparative variety, while leaf blight attacks report the smallest average score of 0.03. The value was also significantly different from the 3 comparative varieties. The score for blight and leaf rust infections is less than 1 for prospective varieties, indicating good disease resistance.

4.3. Number of Plants and Harvested Ears, Weight of Harvested Ears, and Length and Diameter of Ears. Table 10 presents the average number, the weight, the length, and the diameter of the ears. The statistical test showed significant differences between the prospective and the comparative varieties on the characteristics, number, weight, length, and diameter of harvested ears. The yield component is caused by the genetic potential of each prospective variety, differences in plant population, as well as number, weight, length, and diameter of the ears. The number of harvest pieces produced by a plant is related to the level of production. Under optimum conditions, more than 2 cob shoots can develop for some genotypes [24].

All prospective varieties showed that the average weight, length, and diameter of the ears were superior to the comparative varieties Sticky Uri and local Sticky. Long cobs produce a higher number of seeds and assimilate, which affects the weight of the crop [25].

Table 9: Average plant and ear appearance, husk closure, leaf rust, and leaf blight at 6 test locations in MT 2022.

Genotype	Plant performance	Husk closure	Ear appearance	Leaf rust	Leaf blight
JPI-1	1.77[abc]	2.06[ab]	1.30[ab]	0.02[aabc]	0.03[abc]
JPI-2	1.85[ac]	2.13[ab]	1.34[ab]	0.02[abc]	0.03[abc]
JPI-3	1.83[ac]	2.13[ab]	1.31[ab]	0.02[abc]	0.03[abc]
JPI-4	1.82[ac]	2.11[ab]	1.37[a]	0.02[abc]	0.03[abc]
Sticky Uri (a)	1.97	2.26	1.53	0.05	0.05
White Srikandi (b)	1.91	2.28	1.48	0.04	0.05
Local Sticky Takalar (c)	2.05	1.33	1.43	0.06	0.07
Average	1.98	1.96	1.48	0.05	0.06
SE	0.03	0.03	0.04	0.00	0.00
LSD 5%	0.09	0.09	0.12	0.01	0.01
CV	7.90	6.80	13.90	7.00	9.80

Note: Score value 1 is the best and 5 is the worst.
Abbreviation: CV = coefficient of variation.
[a]Significantly superior to Sticky Uri.
[b]Significantly superior to White Srikandi.
[c]Significantly superior to local Sticky in the 5% LSD test.

Table 10: Average number of plants and harvested ears, weight of harvested ears, and length and diameter of ears in six test locations (districts) in MT 2023.

Genotype	Number of harvested plants	Number of harvested ears	Weight of harvested ears (kg)	Length of harvested ears (cm)	Diameter of ears (cm)
JPI-1	47.66[ab]	48.62[ab]	8.57[ab]	18.21[ab]	4.41[ab]
JPI-2	47.41[ab]	48.16[b]	8.41[ab]	17.69[ab]	4.33[ab]
JPI-3	47.83[ab]	48.541[ab]	8.29[ab]	17.83[ab]	4.4[ab]
JPI-4	47.25[ab]	48.50[ab]	8.18[ab]	18.31[ab]	4.23[ab]
Sticky Uri (a)	46.54	47.54	7.07	15.33	4.00
White Srikandi (b)	47.54	48.17	8.41	17.97	4.47
Sticky Local Takalar (c)	46.38	47.13	4.97	14.13	3.57
Average	46.82	47.61	6.82	15.81	4.01
SE	0.18	0.22	0.14	0.17	0.05
LSD 5%	0.53	0.65	0.41	0.48	0.15
CV	1.70	1.90	6.10	3.60	4.00

Abbreviation: CV = coefficient of variation.
[a]Significantly superior to Sticky Uri.
[b]Significantly superior to local Sticky in the 5% LSD test.

4.4. Seed Water Content, Number of Rows of Seed, Number of Seeds per Row, Seed Yield, and Weight of 1000 Seed KA 15%. The statistical tests on water content, number of seed rows, number of seeds per row, seed yield, and weight of 1000 KA 15% seed are presented in Table 11. The average water content in JPI-1 is significantly different from the comparative of all varieties. JPI-2, JPI-3, and JPI-4 reported lower water content and were significantly different from the comparative varieties Sticky Uri and local Sticky. The characteristics of the number of rows and seeds in the 4 prospective varieties were superior and significantly different from Sticky Uri and local Sticky. Moreover, the average weight of 1000 seed with a water content of 15% JPI-1 showed superior results. JPI-2 and JPI-3 also reported superiority and were substantially different from local Sticky, while JPI-4 was significantly different from all comparative varieties.

4.5. Testing for Major Diseases. The observations on the intensity of downy mildew attacks (*P. philippinensis*) in Bajeng Gowa at 14, 21, 28, 35, and 42 DAP are presented in Table 12.

The prospective varieties tested did not show a susceptible reaction to downy mildew. However, the check plants of the Anoman variety were susceptible to downy mildew with a percentage of attacks at 42 days after reaching 92.2%, while the local Sticky was tolerant with an intensity of 39.6%. The comparative varieties Sticky Uri and White Srikandi reported a resistant reaction in Bajeng with an average percentage of 9.1% and 5.4% at 42 DAP.

The Anoman and Local Sticky varieties have become quite heavily infected with downy mildew pathogens since 21 DAP. Therefore, the level of resistance of prospective varieties to *P. philippinensis* in Bajeng is relatively good.

Table 11: Average water content, number of rows of seed, number of seeds per row, seed yield, and weight of 1000 KA 15% seed at 6 test locations in MT 2023.

Genotype	Seed water content (%)	Number of seed rows	Number of seeds per row	Seed yield (%)	Weight 1000 seed KA 15% (g)
JPI-1	23.33[abc]	14.86[ac]	32.91[ac]	79.13[abc]	287.14[ac]
JPI-2	23.52[bc]	14.27[ac]	33.16[ac]	78.04[ac]	281.76[c]
JPI-3	23.80[bc]	15.09[ac]	32.77[ac]	78.00[ac]	283.78[c]
JPI-4	22.95[abc]	14.70[ac]	31.08[ac]	77.14[c]	289.72[abc]
Sticky Uri (a)	24.15	13.47	28.04	71.02	279.29
White Srikandi (b)	24.95	14.81	33.08	78.28	282.47
Local Sticky Takalar (c)	25.67	10.80	23.67	74.86	274.95
Average	24.92	13.02	28.26	76.72	278.90
SE	0.25	0.25	0.20	0.26	1.80
LSD 5%	0.73	0.71	0.57	0.75	5.19
CV	6.30	5.50	7.40	2.00	4.20

Abbreviation: CV = coefficient of variation.
[a]significantly superior to Sticky Uri.
[b]significantly superior to White Srikandi.
[c]significantly superior to local Sticky in the 5% LSD test.

Table 12: Average percentage of downy mildew pathogen infections in Bajeng, Gowa 2023.

Genotype	Average percentage of downy mildew infections (%)					Reaction
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	
JPI-1	0.0	3.5	5.3	5.8	5.8	R
JPI-2	0.0	4.6	7.1	8.2	8.2	R
JPI-3	0.6	6.2	11.2	11.7	11.7	R
JPI-4	4.1	12.5	27.7	27.7	27.7	M
Sticky Uri	0.0	4.1	8.5	9.1	9.1	R
White Srikandi	0.0	3.5	5.4	5.4	5.4	R
Local Sticky	0.0	7.2	30.5	37.3	41.6	S
Anoman	7.5	64.2	80.9	98.4	92.2	VS

Abbreviations: M = moderate, R = resistant, V = vulnerable, VS = very susceptible.

The test of prospective varieties against downy mildew (*P. maydis*) carried out in Malang is presented in Table 13. The 4 prospective composite varieties showed a resistant reaction to *P. maydis*, with an average percentage of attacks at 42 DAP, ranging between 9.61% and 10.42%. All comparative varieties, apart from the check plants (susceptible plants) of the Anoman variety, showed a resistant reaction to *P. maydis*. The reaction was susceptible since the average percentage of infection with downy mildew pathogen in check plants was 83.75%. The Anoman variety was infected with the heavy downy mildew pathogen since 21 DAP.

The observations of leaf blight infection in all test genotypes showed that the prospective varieties reacted with an average percentage of attacks at 75 DAP ranging from 18.0% to 20.8%. The resistant comparative varieties showed a reaction to leaf blight. However, the check plants of the Anoman variety reacted with an average attack percentage of 68.5% (Table 14).

Maydis leaf blight is a late-season disease where the most severe development occurs postanthesis [26]. Therefore, the intensity of attacks was carried out during the period. According to [27], leaf blight can occur in corn plants with different intensities and the main factors influencing the disease are climate, planting conditions, and level of resistance.

The observations on the intensity of rust infection in Bajeng are shown in Table 15. The comparative varieties showed a resistant reaction except Anoman variety, which acted very susceptible with a value of 68.2%.

4.6. Nutritional Content. Based on the laboratory analysis results, all prospective varieties show a high carbohydrate content range from 72.56 to 75.74 (Table 16). The result is consistent with the previous study. As a main nutritional content of corn, carbohydrate contents ranged from 72% to 73% and are concentrated in the endosperm [28]. The composition of starch in seed is genetically controlled, and the component influences the functional properties of corn. The physical, chemical, and available properties can guide in selecting appropriate varieties for the desired product. In this context, prospective varieties with high carbohydrate content are suitable for use as food and raw materials for bioethanol production.

Corn contains other macronutrients such as fat and protein, which are genetically controlled [29]. The prospective varieties and comparatives have relatively high fat content. Generally, corn contains 3.5% and 8%–11% fat and protein in the kernel, respectively [27, 30]. The test results

Table 13: Average percentage of downy mildew pathogen infections in Malang in 2023.

Genotype	Average percentage of infections (%)					Response
	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	
JPI-1	0.00	0.00	9.21	9.61	9.61	R
JPI-2	0.00	0.00	10.21	10.42	10.42	R
JPI-3	3.00	6.50	8.37	9.75	9.75	R
JPI-4	4.00	7.67	8.67	18.00	18.00	R
Sticky Uri	0.33	4.13	9.21	10.60	10.60	R
White Srikandi	2.25	6.27	8.37	9.18	9.18	R
Local Sticky	1.00	8.00	10.06	25.42	25.42	M
Anoman	20.62	52.28	71.91	79.57	83.75	VS

Abbreviations: M = moderate, R = resistant, S = susceptible, VS = very susceptible.

Table 14: Average percentage of maydis leaf blight infection in test lines and comparative varieties at 45, 60, and 75 DAP Bajeng, Gowa, 2023.

Genotype	Average percentage of infections (%)			Response
	45 DAP	60 DAP	75 DAP	
JPI-1	1.50	15.60	18.80	R
JPI-2	5.70	18.20	19.60	R
JPI-3	12.70	17.30	18.00	R
JPI-4	12.3	18.40	18.80	R
Sticky Uri	0.00	16.00	20.00	R
White Srikandi	5.30	17.30	19.20	R
Local Sticky	4.70	15.00	20.30	R
Anoman	1.30	39.30	68.50	VS

Abbreviations: M = moderate, R = resistant, S = susceptible, VS = very susceptible.

Table 15: Average percentage of attacks with maydis leaf rust in test lines and comparative varieties at 60 and 75 DAP in Bajeng, Gowa 2023.

Genotype	Average percentage of infections (%)		Response
	60 DAP	75 DAP	
JPI-1	15.5	20.1	R
JPI-2	16.9	19.7	R
JPI-3	18.3	20.0	R
JPI-4	14.3	18.0	R
Sticky Uri	16.8	20.3	R
White Srikandi	14.3	18.0	R
Local Sticky	14.5	20.4	R
Anoman	22.5	68.2	VS

Abbreviations: M = moderate, R = resistant, S = susceptible, VS = very susceptible.

Table 16: Results of analysis of carbohydrate, fat, protein, and amylopectin content in corn seed of prospective varieties and comparative varieties in MT 2023.

Genotype	Protein (%)	Fat (%)	Carbohydrate (%)	Amylopectin (%)
JPI-1	11.64	4.85	75.74	85.10
JPI-2	11.54	5.72	74.51	82.80
JPI-3	11.69	6.63	74.49	82.45
JPI-4	11.86	5.76	73.46	80.90
Sticky Uri (a)	10.97	5.55	72.65	55.95
White Srikandi (b)	11.63	4.76	73.04	38.80
Local Sticky Takalar (c)	10.24	5.08	72.56	85.40

Note: Statistical analysis was not performed.

showed that prospective varieties had a higher protein content than comparative varieties except for White Srikandi.

The amylopectin content in all prospective varieties is relatively high (> 80%) compared to Sticky Uri and White Srikandi. However, the content in the local Sticky is equivalent to all prospective varieties, especially JPI-1. High amylopectin is a determinant of the level of fluffier taste. The increased content in the corn kernels favors the use as an alternative staple food. Therefore, the high amylopectin character of local Sticky Takalar parents has been inherited in the 4 genotypes of prospective varieties through the development of the Dreher method. In this context, corn with special characteristics can be formed through repeated and programmed plant breeding programs [31, 32]. For sticky corn, there is a recessive wx gene in a homozygous state (wxwx) affecting the chemical composition of starch to cause a delicious and savory taste. The backcross breeding method can be applied to introduce donor genes from special corn with high amylopectin content to obtain special characteristics.

5. Conclusion

In conclusion, prospective composite corn varieties JPI-1 as well as JPI-2, JPI-3, and JPI-4 had the potential for higher productivity at 8.88, 8.54, 8.57, and 8.67 t/ha, respectively. JPI-1 and JPI-2 had higher average yields of 8.16 and 7.88 t/ha. Meanwhile, JPI-1, JPI-2, JPI-3, and JPI-4 showed the criteria for resistance to downy mildew, *P. maydis*, *P. philippinensis*, Type H blight *maydis*, and *P. polysora* leaf rust disease. JPI-1 composite corn variety reported a higher protein content of 11.64% and was stable in different environmental conditions with increased average yield in the genotype category. Similarly, JPI-2 had high productivity due to improved environmental conditions. JPI-1 and JPI-2 possessed a relatively high amylopectin content of 85.10% and 82.80% after meeting the eligibility requirements to be released as new superior varieties based on productivity and amylopectin content.

Data Availability Statement

The data used to support the findings of this study are included within the supporting information file(s).

Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. *(Supporting Information)*

See Table S1–S164 in the Supporting Information for a comprehensive data analysis.

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