Growth and production of South Sulawesi local waxy corn genotypes (*Zea mays ceratina* L.)

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**Abstract.** The study was conducted in the Experimental Farm of the Indonesian Cereals Research Institute (ICERI) located in the Gowa Regency, South Sulawesi Province from September to December 2017. The research aimed to study the quantitative and qualitative characters of some local waxy corn genotypes in South Sulawesi. This experiment was arranged in Randomized Block Design with three replications. The treatment included 9 local waxy corn genotypes from Barru, Bone, Bulukumba, Gowa, Jeneponto, Maros, Soppeng, Takalar, Wajo regencies and URI variety as a control. Local waxy corn genotypes of Bone and Bulukumba has the best phenotype characteristics with the highest grain yield (4.13 t/ha and 4.15 t/ha). Qualitative characters that are easily observed among different local waxy corn genotypes are panicle type, silk color (pistils), and kernel type. All the characteristics have high heritability (>0.50). Silking, weight of dry cob without husk, and cob diameter are the characteristics that give direct effect on the production positively (1.05; 0.001; 0.49, respectively).

1. **Introduction**

As food, the nutritional content of corn is not inferior when compared to rice, besides that corn can be used for animal feed, basic materials for the paper industry, corn flour, corn oil, biodiesel, and others. The basic components of corn kernels consist of 13.5% water, 10% protein, 4% oil/fat, 61% carbohydrate/flour, 1.4% sugar, 6% pentose, 2.3% crude fiber, 1.4% ash, and 0.4% other substances. The carbohydrate content of corn kernels can reach 80% of all dry ingredients of the seeds. Carbohydrates in the form of starch are generally in the form of a mixture of amylose and amylopectin [1].

Based on the results of the mapping on the Master Plan for the Acceleration of Indonesian Economic Development (MP3EI), food development for national food security is located in the Sulawesi Island region with an emphasis on several commodities such as rice, corn and soybeans. Waxy corn is one type of corns that is widely consumed by the people of Indonesia. In South Sulawesi, waxy corn is widely cultivated, and consumed with various forms of processed food for food diversification in support of food security [2]. According to Juhaeti et al. [3], South Sulawesi is the best waxy corn producing region in Indonesia, because of its high amylopectin content (> 90%) so that when compared to waxy corn from other regions, the taste is better, tastier, more fluffier and softer.
Local waxy corn generally has a low yield potential, which is less than 2 tons ha\(^{-1}\), characterized by small cob with a diameter of 10-11 mm and very sensitive to downy mildew disease [4]. According to Yasin et al. [5], one of the efforts to improve the productivity and quality of waxy corn plants is through the assembly of superior varieties. Development of the superior varieties is intended to improve the genetic quality of certain traits to be better and higher grain yields.

Waxy corn is one of the types of free-polluted corn which is widely developed by local farmers. This corn is called waxy or sticky corn because it is sticky and fluffier like sticky rice because of its high amylopectin content (> 90%). Waxy corn was discovered in China in the early 1900s with a waxy endosperm. Waxy character is caused by the presence of a single waxy (wx) gene that is recessive epistasis located on chromosome nine [6]. Waxy corn is an early-age local corn that can be harvested young at the age of 65-70 days after planting (DAP). Genetic nature of the local waxy corn genotypes has special advantages over superior varieties, including resistance to abiotic stress, not easy to fall, has high biomass, tastes better, but its productivity is relatively low [7]. In determining local waxy genotypes as the basis for assembling superior varieties, effective selection of the desired plant characteristics such as high yields, early maturity, tolerance to abiotic stress, biotic stress resistance is carried out. The dominant genetic character will facilitate the selection process because the characters that appear are caused more by plant genetic factors than environmental factors. South Sulawesi local waxy corn can be one source of germplasm in the assembly of superior varieties through plant breeding. However, before determining the genotype of the local waxy as the basic population in assembling superior varieties with the desired character, first a growth test and plant production potential are carried out under optimum environmental conditions so that the appearance of genetic characters becomes more maximal.

2. Methodology
The study was conducted in the Experimental Farm of the Indonesian Cereals Research Institute (ICERI) located in the Gowa Regency, South Sulawesi Province from September to December 2017. Nine local waxy corn genotypes from Barru, Bone, Bulukumba, Gowa, Jeneponto, Maros, Soppeng, Takalar, Wajo regencies, and 1 waxy variety of URI.

This study used a Randomized Completed Block Design (RCBD). The genotype as treatment consisted of nine genotypes of the local waxy corn from South Sulawesi and 1 variety of URI waxy corn as a comparison. Each treatment was repeated three times so that there were 30 experimental plots.

In this study, observations were made on 10 sample plants in the two middle plant rows in the experimental plot with the components observed were plant height, cob height, leaf area, male flowering age, female flowering age, harvest age, production of young harvested cob without corncob and grain production. In addition to quantitative observation, qualitative character observations were carried out visually on the waxy population of each genotype. Observations on this character included panicle type, panicle color, husk color, cob hair color, seed type, and seed color.

Data obtained from observations were analyzed using one-way Analysis of variance (ANOVA). If there is a significant effect of the treatment indicated in the F test then a further test analysis was carried out using the Least Significant Difference (LSD) test (\(\alpha=0.01\)). In addition, heritability analysis was performed to determine the heritability value of each parameter. A correlation analysis also was conducted on the data to determine the characteristics that give direct effect on the production using pearson product moment consideration techniques.

3. Results

3.1. Quantitative characters of the local waxy corn of South Sulawesi
Analysis of variance conducted shows that all growth and production parameters of the local waxy corn of South Sulawesi varied between genotypes (\(p<0.01\)). The growth parameters include plant height, cob height, and leaf area are shown in table 1. Table 1 shows that the genotype of the local
waxy corn of Jeneponto (G2) had the highest average plant height (195.07 cm) and not significantly different from the genotype of the local waxy corn of Bulukumba (G8) but significantly different from the other genotypes. The local genotype of Barru (G5) has the lowest average plant height (131.17 cm). Similarly, Jeneponto (G2) local waxy genotype had the highest average cob location height from the ground (99.37 cm) and not significantly different from Bulukumba local waxy genotype (G8) but significantly different from other genotypes. Takalar (G1) local waxy genotype had the lowest average height of cobs location from the ground (56.33 cm). Similarly, Jeneponto (G2) local waxy genotype has the highest average leaf area (468.03 cm²) which was significantly different from Takalar (G1), Maros (G3), and Barru (G5) local genotypes, but not significantly different from genotype the other. Takalar (G1) local waxy genotype showed the lowest average leaf area (350.30 cm²).

**Table 1.** Average of plant height (cm), cob height (cm), and leaf area (cm²) of several local waxy corn from South Sulawesi.

| Genotype origin       | Plant height (cm) | Cob height (cm) | Leaf area (cm²) |
|-----------------------|-------------------|-----------------|-----------------|
| Takalar (G1)          | 136.07 de         | 56.33 d         | 350.30 d        |
| Jeneponto (G2)        | 195.07 a          | 99.37 a         | 468.03 a        |
| Maros (G3)            | 140.43 de         | 68.20 bcd       | 370.88 bcd      |
| Bone (G4)             | 156.40 cd         | 72.10 bc        | 430.55 abcd     |
| Barru (G5)            | 131.17 e          | 58.13 cd        | 352.68 cd       |
| Wajo (G6)             | 170.60 bc         | 81.73 b         | 449.95 ab       |
| Soppeng (G7)          | 137.00 de         | 58.30 cd        | 405.33 abcd     |
| Bulukumba (G8)        | 185.77 ab         | 98.60 a         | 406.88 abcd     |
| Gowa (G9)             | 134.60 de         | 62.70 cd        | 433.85 abc      |
| URI (Comparator variety) | 145.50 de     | 66.50 bcd       | 439.28 ab       |
| **LSD**               | 21.97             | 15.73           | 59.89           |

Numbers followed by the same letter mean are not significantly different based on LSD (α=0.01). DAP = days after planting.

**Table 2.** Average of silking and tasseling ages (DAP), harvest age (DAP), production of young cob without cornhusk per hectare (ton ha⁻¹), and grain production per hectare (ton ha⁻¹) of several local waxy corn of South Sulawesi.

| Genotype origin       | Silking age (DAP) | Tasseling age (DAP) | Harvest age (DAP) | Production of young cob without cornhusk (ton ha⁻¹) | Grain production (ton ha⁻¹) |
|-----------------------|-------------------|---------------------|-------------------|-----------------------------------------------------|----------------------------|
| Takalar (G1)          | 41.00 d           | 43.33 d             | 82.67 gh          | 5.91 bcd                                            | 2.53 b                     |
| Jeneponto (G2)        | 48.33 a           | 50.67 a             | 90.67 a           | 6.19 bc                                             | 3.25 ab                    |
| Maros (G3)            | 42.00 d           | 44.33 d             | 83.33 g           | 5.73 cd                                             | 2.52 b                     |
| Bone (G4)             | 45.00 c           | 47.67 c             | 86.00 f           | 6.65 bc                                             | 4.13 a                     |
| Barru (G5)            | 40.33 d           | 42.67 d             | 82.00 h           | 4.78 d                                              | 2.46 b                     |
| Wajo (G6)             | 47.00 ab          | 49.00 abc           | 88.33 cd          | 6.75 bc                                             | 3.22 ab                    |
| Soppeng (G7)          | 45.67 bc          | 48.33 bc            | 86.67 ef          | 5.76 cd                                             | 2.82 b                     |
| Bulukumba (G8)        | 47.67 a           | 50.33 ab            | 89.00 bc          | 5.99 bc                                             | 4.15 a                     |
| Gowa (G9)             | 46.67 abc         | 49.33 abc           | 87.67 de          | 6.90 b                                              | 3.39 ab                    |
| URI (Comparator variety) | 48.00 a           | 50.33 ab            | 90.00 ab          | 8.98 a                                              | 4.37 a                     |
The production parameters include flowering time of male (silking) and female flowers (tasseling), harvest age, production of young cob without cornhusk per hectare, and grain production per hectare are shown in Table 2. Table 2 shows that the local genotype of Barru (G5) had the earliest average of male flowering age (40 ± 0.33 DAP) and not significantly different from the genotype of local waxy corn of Takalar (G1) and Maros (G3) but significantly different from other genotypes. The genotype of the local waxy of Jeneponto (G2) had the longest average male flowering age (48 ± 0.33 DAP). The local genotype of Barru (G5) had the earliest average female flowering age (42 ± 0.67 DAP) and not significantly different from the genotype of local waxy Takalar (G1) and Maros (G3) but significantly different from other genotypes. The genotype of the local waxy Jeneponto (G2) had the longest average female flowering age (50 ± 0.67 DAP). Barru local waxy genotype (G5) has the fastest average harvest age (82 DAP) and not significantly different from Takalar (G1) local waxy genotype but significantly different from other genotypes. Jeneponto local genotype (G2) has the longest average harvest age (90 DAP).

For production parameters, Table 2 shows that all local waxy corn genotypes had lower production compared to URI variety, which is the comparator genotype. The highest average production of harvested young cobs without cornhusk and grain production per hectare of this variety were 8.98 and 4.36 tons ha\(^{-1}\), respectively, which was significantly different from the other genotypes for each parameter value. On the other hand, the local genotype that showed either the lowest average production of harvested young cobs without cornhusk or grain production per hectare was Barru (4.78 and 2.46 tons ha\(^{-1}\), respectively).

3.2. Qualitative characters of the local waxy corn of South Sulawesi

Based on visual observations, there are variations observed on the qualitative characters of 10 local waxy corn genotypes (Table 3). The variations observed included on panicle type, hair color (pistil), and kernel type. No diversity found on panicle and seed color characters of the observed qualitative parameters of waxy corn genotypes. Table 3 shows that the panicle types characteristics of the local waxy corn genotypes of Takalar (G1), Jeneponto (G2), and Wajo (G6) were classified as open, compared to the local genotypes of Maros (G3), Bone (G4), Barru (G5), Bulukumba (G8), and URI variety that were classified as semi-compact, while the waxy corn genotypes originated from Soppeng (G7) and Gowa (G9) were classified as compact (Figure 1).

| Genotype origin | Qualitative characters |
|-----------------|-----------------------|
|                 | Panicle type | Panicle color | Silk color (pistils) | Kernel type | Kernel color |
| Takalar (G1)    | Open         | Beige         | Beige                 | Dent        | White        |
| Jeneponto (G2)  | Open         | Beige         | Beige                 | Flint       | White        |
| Maros (G3)      | Semi Compact | Beige         | Red                   | Flint        | White        |
| Bone (G4)       | Semi Compact | Beige         | Beige                 | Flint        | White        |
| Barru (G5)      | Semi Compact | Beige         | Beige                 | Flint        | White        |
| Wajo (G6)       | Open         | Beige         | Beige                 | Flint        | White        |
| Soppeng (G7)    | Compact      | Beige         | Green                 | Flint        | White        |
| Bulukumba (G8)  | Semi Compact | Beige         | Beige                 | Flint        | White        |
Three variations on the character of silk color were found on the local waxy corn of South Sulawesi. Local genotypes originated from Takalar, Jeneponto, Bone, Barru, Wajo, Bulukumba, in addition to URI variety, showed beige color compared to silk color of the genotypes originated from Maros and Gowa (red), and the silk color of the local genotype of Soppeng showing green color (Figure 2).

| Gowa (G9) | Compact | Beige | Red | Dent | White |
| URI (Comparator variety) | Semi Compact | Beige | Beige | Dent | White |

Figure 1. Panicle type of local waxy corn in South Sulawesi. G1: Takalar; G2: Jeneponto; G3: Maros; G4: Bone; G5: Barru; G6: Wajo; G7: Soppeng; G8: Bulukumba; G9: Gowa; K1: URI Comparator variety.
Kernel type character also varied between the waxy corn genotypes with local waxy corn originated from Jeneponto, Maros, Bone, Barru, Wajo, Soppeng, and Bulukumba had the pearl seed types (flint), whereas genotypes of waxy corn originated from Takalar, Gowa and also URI variety had dent type of kernel.

### 3.3. Heritability analysis

Based on the results of the analysis of variance of each plant character, the estimated heritability was obtained. The estimated value of heritability is used as a reference in selecting plants with characters that have genetic influence more dominant than environmental influences. Table 4 shows that all characters observed showed high heritability values.

**Table 4.** Observation on qualitative character of 10 local waxy corn genotypes of South Sulawesi.

| Characters                              | $h^2$ value | Criteria |
|-----------------------------------------|-------------|----------|
| Plant height                            | 0.85        | High     |
| Cob height                              | 0.84        | High     |
| Leaf area                               | 0.51        | High     |
| Silking age                             | 0.93        | High     |
| Tasseling age                           | 0.91        | High     |
| Harvest age                             | 0.96        | High     |
| Production of young cob without cornhusk| 0.60        | High     |
| Grain production                        | 0.83        | High     |

$h^2$ = heritability value, $(h^2 ≤ 0.20$ (low); $0.21 ≤ h^2 ≥ 0.50$ (medium); $h^2≥0.50$ (high)
3.4. Analysis of correlation
The correlation coefficient analysis shows the relationship between the characters of grain production with other characters in 10 genotypes of local waxy corn. The results show a significant positive correlation between the grain production characters with leaf area (0.63*), silking age (0.73*), tasseling age (0.74*), and harvest age (0.71*). High significant positive correlation also found between the grain production with characters of dry cob weights (0.84**), dry cob weights without cornhusk (0.80**), and cob diameter (0.77 * *) (data are not shown).

4. Discussion
The diversity of plant appearance is strongly influenced by genetic factors even though it comes from the same plant species. Differences in genetic makeup are one of the factors causing diversity in plant appearance [8]. Diversity in appearance of plants due to differences in genetic makeup is always possible even if the plants used are from the same type [9]. A good corn plant has a high plant character that is not too high but has a strong stem and the location of the cobs that are in the middle of the stem so that it can reduce crop vulnerability due to wind gusts especially in the planting season with high rainfall. This is consistent with the opinion of Murdolelono et al. [10] which stated that the appearance of a good corn plant is a short and sturdy plant so that it is useful in holding back the weakness caused by strong winds.

Leaf area character greatly influences growth, especially on production. The greater the leaf area of the plant, the wider the area of reception of sunlight, so that photosynthate generated from the photosynthesis process will increase. Absorption of sunlight by plant leaves is an important factor that determines photosynthesis to produce assimilates for the final formation of seeds [11]. The difference in the character of flowering age and harvest age in the same environmental conditions is likely due to differences in genetic composition causing diversity in plant character. The transition from vegetative to generative periods is partly determined by internal factors such as genetic and partly by external factors such as temperature and light intensity [6].

Gowa local waxy genotype had the highest average production of young harvest cobs without cornhusk (6.90 tons ha⁻¹), which was significantly lower than URI waxy variety, while Barru local waxy genotype had the lowest average (4.78 tons ha⁻¹). Gowa local waxy genotype has the potential in the development of harvested young cob without cornhusk for consumption compared to other genotypes. Waxy corn is generally more for fresh consumption. This is because the high content of amylopectin in fresh conditions makes waxy corn tastier, fluffier, and softer for consumption. In addition, the low amylose content of waxy corn is very useful for diabetics who need high carbohydrate intake but low in sugar. The differences that arise in these characters may be caused by genetic factors of the plant itself. Factors that affect growth broadly can be categorized as external (environmental) and internal (genetic) factors [12]. Variations appeared between plant populations in the same environmental conditions are assumed comes from the genetic character of plants.

The highest average seed production was found in the local waxy corn genotype of Bulukumba (4.15 ton ha⁻¹) which was not significantly different from the URI variety, while the Barru local waxy genotype had the lowest average (2.46 ton ha⁻¹). Genotype of local waxy corn Bulukumba have been shown to have best results on the production compared to other genotypes [13,14]. The difference in the character of plant production is strongly influenced by genetic characters. In addition, the gene potential of a plant will be maximized if it is supported by optimal environmental conditions. Internal factors that stimulate plant growth are in genetic control, but climate, soil and biological elements such as pests, diseases and weeds and intra- and inter species competition can influence the growth [15]. The corn ideotype usually varied between region, however, corn ideotype generally earlier maturity for harvest, high production, high number of cobs per plant, good quality of cobs and not too high plants, therefore, it is necessary to select all the observed characters [16].

Qualitative character is one of the important indicators in knowing the unique properties found in genotypes so it is very important in describing a genotype. Based on the results of observations of
qualitative characters indicate differences that are likely due to the genetic nature of each different genotype.

5. Conclusions
Based on the research results obtained, it can be concluded that:

1. The local waxy corn genotypes that provide better growth were the genotypes originated from Bone and Bulukumba with the production of harvested young cobs without cornhusk per hectare were 6.65 and 5.99 tons ha\(^{-1}\), respectively and grain seed production per hectare of 4.13 and 4.15 tons ha\(^{-1}\), respectively.
2. Qualitative characteristics that are easily seen among different local waxy corn genotypes are panicle type, silk color (pistils), and kernel type.
3. All the characteristics have high heritability (h\(^2\)>0.50).
4. Silking, weight of dry cob without husk, and cob diameter are the characteristics that give positively direct effect on the grain production (1.05; 0.001; 0.49).

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