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Growth and development of local waxy corn of Southeast Sulawesi and its implications for cultivation

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Abstract

Waxy corn is an important cereal in Southeast Sulawesi. The Southeast Sulawesi farmers have been long times cultivating waxy corns continuously so there are many local waxy corn in the islands. We try to develop corn through cultivation practices and breeding programs. Consequently, we must know the development of the local waxy corn. This research aims to describe the growth and development phase of the local waxy corn. The growth phase was identified by the leaf collar method and the release of the tassel coupled with leaf growth variables, while the developmental phase was based on silking and seed. Five local waxy corn cultivars and one hybrid variety were used to determine the growth and development phase. The research was carried out at the Experimental Garden of the Faculty of Agriculture, Halu Oleo University, Kendari City, Indonesia, from May to August 2021. Stages of growth after silking can be identified by the development of the kernels on the ear. The result of the research show that (i) the corn staging system divides development into vegetative (V) which take time about 49-55 days and reproductive (R) stages which take times about 31-36 days. Local waxy corn from Southeast Sulawesi typically develops 9-13 leaves, silks about 50-55 days after emergence, and matures about 80-91 days after emergence.

Keywords: Corn Cultivation; Development; Growth; Southeast Sulawesi; Waxy corn

1. Introduction

Waxy corn (*Zea mays* L. var. *ceratina* Kulesh) has many advantages compared to yellow corn. Compared to normal corn, both amylose and dietary fiber, waxy corn was numerically lower but the degree of starch gelatinization was numerically greater [1]. Also digestible and metabolizable energy contents as well as the apparent total tract digestibility of neutral detergent fiber and acid detergent fiber in waxy corn were significantly greater ($p<0.05$) than those in normal corn when fed to growing pigs. Waxy corn is a special type of corn that is rich in anthocyanins and other antioxidant compounds [2]. Waxy corn is a corn in that the endosperm contained high amylopectin [3] with very low levels of amylose [4], in contrast to dent corn and flint corn which contain roughly 75 % amylopectin and 25 % amylose and popcorn which contain roughly 72 % amylopectin and 28 % amylose [5]. The average starch-ethanol conversion efficiency of the waxy corn (93.2%, - 93.0%) was substantially greater than that of the normal corn (88.0%-88.4%) [6]. The amylopectin content makes waxily suitable for several uses for both food, usually consumed in the form of steamed fresh ears, and the preparation of snacks and industrial materials [7].

Waxy corn is an important cereal in Southeast Sulawesi with more than 90% of the total production consumed directly as food. Waxy corn is more delicious than dent corn, therefore more important for human foods, especially farmers in Buton, Muna, and Wawonii islands, Southeast Sulawesi. There are many local waxy corns found in Southeast Sulawesi.

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The local corn origin of Southeast Sulawesi Province is adaptive to local natural conditions. The local corn is selected by farmers to maintain the desired type of corn, while others have and will continue to experience genetic erosion [8]. Local waxy corn has long been cultivated in a certain area by smallholder subsistence farmers so that they have adapted to specific locations. Plant landraces represent heterogeneous, local adaptations of domesticated species, and thereby provide genetic resources that meet current and new challenges for farming in stressful environments. The main contributions of landraces to plant breeding have been traits for more efficient nutrient uptake and utilization, as well as useful genes for adaptation to stressful environments such as water stress, salinity, and high temperatures [9].

The potential grain yields of waxy corn are generally lower than those of dent corn. The potential production rate of waxy local corn is very low, less than 2 tons per hectare [10] and around 2.7 tons per hectare [11]. Plant breeders can increase the potential yield of waxy corn, both developing a corn hybrid and open-pollinated cultivar. We try to develop corn through cultivation practices and breeding programs. Consequently, we must know the development of local waxy corn in Southeast Sulawesi.

Crop managers need to be able to identify the different stages of growth. The most common system used for defining corn growth stages divides the growth cycle into two parts: vegetative growth and reproductive development. Stages of growth before silking can be identified in the field by counting the number of leaves that are fully emerged (with the collar visible) from the whorl. Stages of growth after silking can be identified by the development of the kernels on the ear [12]. At each growth stage of corn, certain aspects of management must be considered as each stage has its problems that may interfere with growth at that stage. These problems include adverse soil conditions, weeds, insects, diseases, and other disorders. Problems that occur early in the season may contribute to the yield loss experienced at the end of the season during harvest. The waxy corn researchers who know how the waxy corn plant develops and functions can do a more precise job of controlling the forces that affect the output. An understanding of the plant relates to his practice decisions on

- selection of most suitable varieties
- timing of fertilizer applications,
- timing of such cultural practices as weed, insect, and disease control,
- timing of harvest operation, and
- production planning for total corn production operations

2. Material and methods

The research was carried out at the Experimental Garden of the Faculty of Agriculture, Halu Oleo University, Kendari City, Indonesia, from Mei to August 2021. Five local waxy corn cultivars (Sultra 1 – Sultra 5) and one hybrid variety (Bisi-2) were used to determine the growth and development phase. The populations were grown in an area of 50 m x 22 m, as row plots, with row lengths of 5 m, row-to-row, and plant-to-plant distances of 0.75 m and 0.25 m, respectively. Two seeds per hill were planted; these were thinned to one plant per hill two weeks after germination. Fertilizers in the forms of Urea, TSP, and KCl were applied at the rate of 100, 200, and 100 kg/ha, respectively seven days after sowing. Urea (200 kg/ha) was applied again 30 days after sowing. Standard cultural practices were followed from sowing until harvesting. Weeds, insects, and diseases were controlled by mechanical and chemical means.

Corn growth stages are based on the leaf collar method, where fully emerged leaves (leaf collar visible) are used to stage vegetative development. Stages of growth after silking can be identified by the development of the kernels on the ear. Key growth stages and brief descriptions are listed in Table 1.

Table 1 Key growth stages in corn

Growth stage	Appearance	Comments
V_E	Emergence	Mesocotyl pushes through the soil surface. Seminal root system active.
V_1-V_2	1-2 collars	1-2 leaves are fully expanded
V_3	3 collars	3 leaves are fully extended with visible collars. Nodal roots are active. The growing point below ground.
V_4-V_5	4-5 collars	4-5 leaves are fully expanded
V_6	6 collars	The growing point above ground. Tassel and ear development start.
V_7-V_{11}	7-11 collars	7-11 collars fully expanded
V_{12}	12 collars	12 leaves have fully expanded, but the bottom two to three leaves may be gone. Ear size, kernel size, and kernel number are being determined. Limits on water and/or nutrients will reduce yields.
V_{13}-V_{14}	13-14 collars	13-14 collars fully expanded
V_{15}	15 collars	The potential kernel number is set. The upper two ears are similar in size, but the uppermost ear will be dominant.
V_T	Tassel	The last tassel branch is fully visible. Complete leaf loss will cause nearly 100% yield loss. Pollination may occur while the tassel is emerging.
R_1	Silking	One or more silks extending from the husk leaves. The most sensitive period for stress. Pollination occurring. N and P uptake are rapid. About 60, 40, and 75% of the total uptake of N, P, and K, respectively.
R_2	Blister	Plant height complete. Ear length complete. Vegetative weight complete. A miniature corn plant is formed in each fertilized kernel.
R_4	Dough	The kernel interior is similar to "dough". The Kernel is about 70% moisture at the start of R4.
R_5	Dent	Kernels at top of the ear have dented. The Starch layer "milk line" has formed and progresses down the kernel. Kernels are about 45% of total dry weight at the start of R5 and nearly 90% of total dry weight at half milk line.
R_6	Physiological Maturity	A black layer has formed at bottom of the kernel. The Kernel is about 30 to 35% moisture.

Source: [13]

3. Results and discussion

The growth and development period of local waxy corn from Southeast Sulawesi is 75-86 days, divided into 47-58 days of the vegetative period and 28 days of the generative period. The result of the research showed that there was a range in the number of days for each phase of growth and development of local waxy corn from Southeast Sulawesi (Table 2). The research was carried out at the experimental Garden of the Faculty of Agriculture, Halu Oleo University, Kendari City, Indonesia, from May to August 2021.

Table 2 Range of the number of days for each phase of growth and development of local waxy corn from Southeast Sulawesi

Phase	**Sultra 1**	**Sultra 2**	**Sultra 3 Days to**	**Sultra 4**	**Sultra 5**	**Bisi 2**
V_E	5-6	5	5	4	4-5	4-5
V_1	7-8	7-8	7-8	7-8	7-8	6-7
V_2	9-11	9-10	9-10	9-11	9-11	7-10
V_3	11-13	11-12	11-13	11-13	11-13	10-15
V_4	14-17	14-15	14-15	14-19	14-19	14-19
V_5	19-22	17-19	15-22	17-24	17-27	18-23
V_6	22-27	19-27	19-29	22-29	22-29	22-26
V_7	25-29	22-31	22-32	27-34	27-31	25-29
V_8	31-45	29-37	31-39	32-40	31-40	28-33
V_9	35-48	35-41	35-41	35-45	34-45	32-36
V_{10}	39-49	39-45	40-45	40-48	41-47	36-40
V_{11}	42-50	42-48	44-48	42-50	44-50	37-42
V_{12}	45-53	44-50	47-50	45-53	47-53	38-43
V_{13}	49-58	47-58	49-55	47-58	50-58	42-49
V_{14}	-	-	-	-	-	46-53
V_{15}	-	-	-	-	-	51-55
V_T	45-52	46-53	46-53	47-52	46-51	53-58
R_1	50-54	49-54	51-55	51-54	51-54	58-64
R_2	53-62	53-61	56-60	55-60	54-60	62-74
R_3	61-69	61-69	59-68	59-68	60-68	70-83
R_4	66-73	67-72	67-73	67-72	67-70	80-94
R_5	69-80	70-80	72-80	70-81	70-80	88-111
R_6	75-86	75-85	78-86	78-86	79-86	114-127

Table 2 shows that the stages of growth and development of local waxy corn from Southeast Sulawesi from stage V_E to stage R_6 were relatively uniform. The number of leaves produced by local waxy corn from Southeast Sulawesi is also uniform. i.e. 13 leaves. This is due to the local corn tested coming from the same source or having adapted to certain environmental conditions of Southeast Sulawesi, which are globally similar.

It is evident from Table 2 that the stages of growth and development and the number of leaves produced by local waxy corn from Southeast Sulawesi are different from the stages of growth and development and the number of leaves produced by commercial hybrid (Bisi 2). This is caused by differences in genetic composition between local corn and hybrid corn. Local corn has not been selected by breeders, while hybrid corn has undergone selection by breeders from each stage of selfing in inbred assembly to testing for heterosis between inbreds. The genetic composition of local corn is a mixture of heterozygotes and homozygotes, while hybrid varieties are only composed of heterozygotes. A hybrid is a cross between strains within a single species. In commercial hybrid corn, these strains are fixed inbred lines. Hybrids are produced and selected because they have desirable characteristics that are greater than those of the individual parents. The cross between two different inbred lines produces an F1 hybrid. This hybrid has two alleles, one contributed by each parent. One is usually dominant and the other recessive. Inbred lines are the result of repeated self-pollination of particular corn populations to produce a plant that essentially has a fixed and uniform genetic composition. Consequently, all the plants of a particular inbred line are identical, but each inbred line will differ in its genetic composition from other inbred lines. When two unrelated inbred lines are crossed to form a hybrid, the resultant seed produces plants with restored vigor and a significantly higher yield than either of the two parents [14].

The details of each period and its implications for cultivation were as follows:

- Stage V_E: Plant emergence from the soil. After planting, the seeds absorb water and the young plant begins to grow. The first internode elongates to raise the plant to the soil surface. The length of time from planting to emergence is in 4 to 6 days. Stage V_E is still long enough that treatment is needed to shorten it, for example by soaking the seeds in water for 24 hours before planting. The linear dimensions of the five varieties of soaked corn increased with an increase in linear dimensions up to about 36th hour of soaking [15]. There were significant differences ($p < 0.05$) between unsoaked and soaked corn varieties. Pre-soaking favored germination speed and percentage in sweet corn seeds, particularly under water-deficit conditions [16].
- Stage V_1: One leaf fully emerged, 2 to 3 days after emergence, with a length of 5.2-5.5 cm, a width of 1.8-2.1 cm, and the position of the collar from the base of the stem is 2.7-3.0 cm, forming 4 main roots with a length of 5-19 cm, has not yet formed root branches, and with sparse root hairs. The main roots that are formed in this phase are long enough so that the basic fertilizers, namely N, P, and K should be given before entering this phase or at the same time as planting the seeds.
- Stage V_2. Two leaves fully emerged, 4 to 5 days after plant emergence. Roots of the first whorl at the coleoptile node have elongated, but have not branched or formed root hairs. The primary roots, especially the radicle, have many branches and root hairs. The first leaf is 5.0-5.5 cm long, 1.7-2.3 cm wide, and 4.2-4.5 cm high from the base of the stem. The second leaf is 12.7-14.2 cm long, 1.7-1.9 cm wide, and 5.6-7.2 cm high from the base of the stem. Roots grow on two coleoptile nodes. The roots in the first node of the coleoptile grow elongated (10-22 cm) and have root hairs half their length, while the roots in the second node (3-13 cm) have not yet formed branches and root hairs.
- Stage V_3. Three leaves fully emerged, 6 to 7 days after plant emergence. The first collar leaf is 5.0-5.2 cm long, 1.7-2.2 cm wide, and 4.2-4.5 cm high from the base of the stem. The second collar leaf is 10.8-15.1 cm long, 1.7-2.1 cm wide, and 6.2-7.5 cm high from the base of the stem. The third collar leaf is 20.8-23.0 cm long, 1.5-1.7 cm wide, and 7.6-9.3 cm high from the base of the stem. The roots in the first coleoptile node grow elongated (20.3-23.4 cm) and along the root, there are many root hairs, while in the second coleoptile node grow 8-10 main roots with varying lengths from 3-15.2 cm and only 4-6 of these roots form the root hairs.
- Stage V_4. Four leaves fully emerged, 10-15 days after plant emergence. The roots of the second whorl have elongated and the first roots of the whorl have root hairs. Cultivation, like weed control, manually, too near the plant after this time were destroy some of the permanent root systems. Therefore, to avoid root damage due to the manual removal of weeds, weed control can be done with the application of herbicides. In corn cultivation, losses from weed competition can range from 18% - 65% [17], and depend mainly on the weed community, the hybrid, and the soil and climate conditions The application of glyphosate (up to 8,640 g ae ha^{-1}) or glufosinate (up to 6,000 ai ha^{-1}) did not reduce yield and 100-grain mass, nor did it influence the nutrient content in the grain of corn bearing cp4epsps and pat genes [18]. This shows the high selectivity of these herbicides. The use of combinations of glufosinate with nicosulfuron, among other post-emergent herbicides, is promising for weed control in corn [19]. The first collar leaf is 4.3-5.8 cm long, 1.5-1.6 cm wide, and 3.5-4.6 cm high from the base of the stem. The second collar leaf is 12.1-15.7 cm long, 1.7-2.2 cm wide, and 7.5-8.3 cm high from the base of the stem. The third collar leaf is 25.2-25.8 cm long, 1.5-1.9 cm wide, and 10.1-12.6 cm high from the base of the stem. The fourth collar leaf is 39.1-39.7 cm long, 1.9-2.1 cm wide, and 11.6-14.3 cm high from the base of the stem. The roots of the third coleoptile node begin to appear (0.3-0.6 cm) above the second node. The roots in the first coleoptile node grow elongated (20.5-25.1 cm) and along the root, there are many branches and root hairs, while in the second coleoptile node grow 8-10 main roots with varying lengths from 10 to 17, 4 cm and all these roots that form root hairs, but 4-5 roots only the base that grows root hairs.
- Stage V_5. Five leaves fully emerged, 12-19 days after plant emergence. The first collar leaf is 4.7-6.0 cm long, 1.5-1.6 cm wide, and 3.9-4.6 cm high from the base of the stem. The second collar leaf is 12.8-15.5 cm long, 1.8-2.3 cm wide, and 8.1-8.6 cm high from the base of the stem. Third-collar leaves 25.7-25.9 cm long, 1.5-1.9 cm wide, and 11.5-12.9 cm high from the base of the stem. The fourth collared leaf is 40.1-55.5 cm long, 2.3-2.5 cm wide, and 16.5-17.6 cm high from the base of the stem. The roots in the fourth node look like buds. The roots at the third node of the coleoptile are elongated (1.4-13.0 cm) and devoid of root hairs. The roots in the second coleoptile node grow elongated (9.5-24.1 cm) and along the root, there are few branches and root hairs, while in the first node of the coleoptile grow 8-10 main roots with varying lengths from 20.1- 32 cm and all these roots that form the root hairs. Primary roots grow slowly after this phase. At this time, male flowers (tassels) begin to develop on the stem tips but are still below ground level. All cob leaves and buds were initiated. In this

phase, tillage too close to the plant can damage the permanent roots. Male flowers (tassels) begin to develop at the tips of the stems, indicating that all leaves and cob shoots have been initiated.

- Stage V_6. Six leaves fully emerged, 15-23 days after plant emergence. The internodes below the fifth and sixth leaves have begun to elongate, the roots of the second whorl have elongated, and the roots of the first whorl have root hairs. The first collar leaf is 5.2-5.4 cm long, 1.9-2.1 cm wide, and 4.3-5.1 cm high from the base of the stem, and the second collar leaf is 10.3-12.3 cm long, 1.7-1.9 cm wide, and 4.9-5.7 cm high from the base of the stem. The third collar leaf is 18.1-20.2 cm long, 1.8-2.0 cm wide, and height from the base of the stem 6.1-7.4 cm. The fourth collar leaf is 25.9-28.1 cm long,1.9-2.0 cm wide, and height from the base of the stem is 8.9-9.6 cm, the fifth collar leaf is 34.3-36.2 cm long, 2.8-3.1 cm wide, and the height from the base of the stem is 11.7-14.1 cm, the sixth collar leaf is 45.5-47 cm long,3.1-3.7 cm wide, and 14.9-16.4 cm high from the base of the stem. The root nodes now form the main part of the root system. Root length reaches 51.1-56.5 cm and along the root is filled with root hairs. The plant now begins to absorb a greater amount of nutrients, so fertilizer applications in amounts adequate to supply those nutrients which are deficient in the soil will be beneficial. Therefore the second fertilization, which is one-third of the N fertilizer, can be given during this phase or the previous phase (V_5 phase). In contrast to long-lived corn (> 120 days), the demand for nitrogen increases dramatically about 40 days after seedling emergence (V_{12} phase). Before this point, the plants have taken up about 18% to 20% of their total nitrogen requirement. However, by the end of silking, they should have 75% of their total requirement [12].
- Stage $V_{7\text{-}8}$. Seventh-eighth leaves fully emerged, 27-35 days after plant emergence. This is the period of rapid leaf formation. The ninth, tenth, and eleventh leaves are full-size but have not fully emerged. The tassel is beginning to develop rapidly. Nutrient deficiencies at this stage seriously restrict leaf growth. The first two leaves have dried. The third collar leaf is 18.7-22.0 cm long, 1.8-2.0 cm wide, and 6.1-7.4 cm high from the base of the stem. The fourth collar leaf is 25.7-30.5 cm long, 2.1-2.4 cm wide, and the height from the base of the stem is 9.9-10.5 cm. The fifth collar leaf is 33.1-41.2 cm long. 2.4-2.5 cm wide, and 14.5-15.4 cm high from the base of the stem. The sixth collar leaf is 46.0-48.5 cm long, 3.1-3.5 cm wide, and high from the base of the stem is 19.2-19.7 cm, the seventh collar leaf is 54.5-57.3 cm long, the width is 4.2-4.4 cm, and the height from the base of the stem is 21.8-25 cm, and the eighth collar leaf is 57.1-62.2 cm long, 4.5-5.2 cm wide, and 28.0-30.3 cm high from the base of the stem. Stem elongation and development of the root node occur in the first three nodes. The stem has experienced rapid elongation and the growing point has reached 5.5 – 6.4 cm from the ground. The segments under the 6^{th}, 7^{th}, and 8^{th} leaves are elongated. The segments under the 5^{th} and 6^{th} leaves have reached their maximum size, which is about 2.1 and 3.6 cm, respectively. Tassels (male flowers) begin to develop rapidly. The roots in the 4^{th} node are elongated.
- Stage $V_{9\text{-}11}$. Ninth - Eleventh leaves fully emerged, 39-43 days after plant emergence. The internodes below the tenth, eleventh, and twelfth leaves are elongating. The internode below the ninth leaf is fully elongated. The 10^{th} and 11^{th} leaves are already of maximum size but only a few have emerged from the whorl. The segment under the 7^{th} leaf is elongated. The segment under the 8th leaf is of maximum size. The ninth collar leaf is 72.5-73.6 cm long, 6.2-7.5 cm wide and 40.1-46.6 cm high from the base of the stem, and the tenth collar leaf is 69.1-74 cm long. 3 cm long, 6.2-8.1 cm wide, and 46.0-48.5 cm high from the base of the stem, and eleventh-collar leaves 70.5-74.5 cm long, 7.3-7.9 cm wide cm, and the height from the base of the stem is 55.6-66.7 cm. The rapid growth of the tassel begins in this phase. Cob buds develop on the 9th and 10th leaves. The top cob buds are smaller than those below. The absorption of nutrients nitrogen, phosphorus, and potassium is very fast in this stage.

Stage $V_{12\text{-}13}$. Twelventh – thirteenth leaves fully emerged, 42-48 days after plant emergence. The tip of the tassel has emerged from the whorl. The upper internodes of the stalk are elongated rapidly. The ears are undergoing rapid enlargement and elongation. Silks from the base of the ears are elongating rapidly. The first (lowest) three or five leaves at the base of the plant may be missing. This stage is a short period and overlaps 40-48 days after the plants germinate. Leaf growth is perfect. Leaf length in this phase ranges from 33.4-66.0 cm, leaf width between 4.2-7.4 cm, and height from the base of the stem between 63.5-101.4 cm. Buttress roots appear at the first node above the ground. The uppermost cob begins to develop rapidly. The number of potential ovules is determined in this phase. The increase in dry weight of the top of the plant in this phase is fast and relatively constant and continues until almost maturity.

The rate of corn plant development at the V_{12} stage is influenced by hybrid maturity. Earlier-maturing hybrids progress through these stages in a shorter time, resulting in smaller ears compared to later-maturing hybrids. If water and nutrient availability can support a higher population, yield differences between early and late hybrids can be equalized by increasing plant density or population. Stress at the V_{12} stage can reduce kernel numbers and ear size. The plant has a peak water demand during this growth stage and it can use one-quarter of an inch per day. The corn plant also needs and utilizes large amounts of nitrogen, phosphorus, and potassium at this stage [20].. During this time, plant stress can greatly affect yield. Moisture stress 2 weeks before or after silking can cause a large grain yield reduction. This is also true for other types of environmental stresses (hail, high temperature, nutrient deficiencies). The 4-week period centered around silking is the most effective time for irrigation if the water supply is short [12].

- Stage V_T. 49 - 55 days after emergence. The entire tassel is visible. This is the final vegetative stage and occurs just before, or at the same time, as silking does. The leaves and tassel have fully emerged. Elongated of the stem internodes has ceased. If an artificial crossing is to be carried out, tassel wrapping is currently carried out.
- R_1. Silking stage, 50 - 55 days after emergence. Silks extending from the husk leaves. The cob and silks are growing rapidly. All silks will continue to elongate until they are fertilized. If an artificial crossing is to be carried out, silk wrapping is currently carried out.
- R_2. Blister stage, 9 – 13 days after silking. The cob, husk, and shank are fully developed. Starch has just begun to accumulate in the endosperm, and the kernels have begun to increase rapidly in dry weight. The plants continue rapid uptake of nitrogen and phosphorus, but the loss of nitrogen and phosphorus from other plant parts to developing grain has begun.
- R_3. Milk stage, 14 – 20 days after silking. The kernel is colored yellow with the inside containing 'milky' white fluid. Kernel moisture content is approximately 80% and starch is beginning to accumulate in the kernel.
- R_4. Dough stage, 21 – 24 days after silking. The kernels are growing rapidly. Starch is accumulating in the endosperm.
- R_5. Dent stage, 24 - 32 days after silking. The embryo is morphologically mature. Dry matter accumulation in the kernels will soon cease.
- R_6. Physiological maturity, 31-36 days after silking. While Bisi 2 hybrid corn has a longer physiological maturity, ie 46-63 days after silking. Late hybrid corn reaches physiological maturity (R_6) about 55 to 65 days after silking [20]. Dry matter accumulation has ceased, but the grain will continue to lose moisture after this time. The husks and some of the leaves are no longer green.

4. Conclusion

The result of the research show that (i) the corn staging system divides development into vegetative (V) which take time about 49-55 days and reproductive (R) stages which take times about 31-36 days. Local waxy corn from Southeast Sulawesi typically develops 9-13 leaves, silks about 50-55 days after emergence, and matures about 80-91 days after emergence.

Suggestions

Based on the research results obtained, the suggestions for cultivating local waxy corn from Southeast Sulawesi are as follows:

- Seeds need to be treated by soaking in water before planting
- Basic fertilizer should be given at the same time as planting
- One-third dose of urea given at the age of 18-20 days after emergence
- Wrapping of tassel and silk for artificial crosses was done at the age of plants 49-55 days after emergence.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that they have no competing interests. The authors have participated on completing this manuscript.

References

[1] Ma D, Li J, Huang C, Yang F, Wu Y, Liu L, Jia Z, Zhang P, Liu X, and Zhang S. 2019. Determination of the energy contents and nutrient digestibility of corn, waxy corn and steam-flaked corn fed to growing pigs. Asian-Australas J Anim Sci. Vol 32, No.10: 1573-1579. DOI: 10.5713/ajas.18.0713

[2] Harakotr B, Suriharn B, Tangwongchai R, Scott MP, Lertrat K. 2014. Anthocyanins and antioxidant activity in coloured waxy corn at different maturation stages. J. Func. Foods. 9: 109-118. DOI: 10.1016/j.jff.2014.04.012

[3] Fergason V. 2001. High amylose and waxy corns. In: Hallauer AR (ed) Specialty Corns: Second edition. CRC Press, Boca Raton, London, New York, Washington DC.

[4] Malucelli LC, Lacerda LG, Filho MASC, Fernandez DER,, Demiate IM, Oliveira CS,Schnitzler E. 2015. Porous waxy maize starch: Thermal, structural and viscographic properties of modified granules obtained by enzyme treatment. J Therm Anal Calorim 120:525–532. DOI 10.1007/s10973-015-4483-6

[5] Lim S and Yi G. 2019. Investigating seed mineral composition in Korean landrace maize (Zea mays L.) and its kernel texture specificity. Journal of Integrative Agriculture 2019, 18(9): 1996–2005. DOI: 10.1016/S2095-3119(18)62055-6

[6] Yangcheng H. 2012. Characterization of normal and waxy corn starch for bioethanol production. [Thesis]. Iowa State University, Iowa.

[7] Chaiyaphum A, Chankaew S, Falab S, Sukto S, Sanitchon J, Lertrat K, and Suriharn K. 2022. Improvement of large-seeded waxy corn (Zea mays L. Var Ceratina Kulesh) populations for food and industrial puprpose. SABRAO Journal of Breeding and Genetics 54 (1) 99-112. DOI: 10.54910/sabrao2022.54.1.10

[8] Hadini, H, Madiki A, Safuan L, Agusrawati. 2017. Exploration and classification of local corn genotypes from Southeast Sulawesi based on Ttheir phenotypic characters. In: Waluyo B, Saptadi D (eds) Proceedings of the 2017 Peripi Komda Jatim, National Seminar: The contribution of breeding science in optimizing the utilization of local genetic resources into high-yielding varieties: Malang, August 24, 2017 (Indonesian).

[9] Dwivedi, S. L., Ceccarelli S, Blair MW, Upadhyaya HD, Are AK, and Ortiz R. 2016. Landrace germplasm for improving yield and abiotic stress adaptation. Trends in Plant Science 21 (1): 31–42.

[10] Edy and B. Ibrahim 2016. The effort to increase waxy corn production as the main ingredient of corn Rrice through the application of phosphate solvent extraction and phosphate fertilizer. Agriculture and Agricultural Science Procedia 9 (2016) 532 – 537

[11] Fowo KY, Suminarti NE, Suryanto A. 2019. Response of three waxy corn (Zea mays L. Var. Ceratina Kulesh) varieties and various planting date of intercropped groundnut (Arachis hypogaea L.) in dry field. International Journal of Plant Biology 10:7459. DOI:10.4081/pb.2019.7459

[12] Keefee K. 2009. Vegetative growth. In: Edward J (ed) Maize Growth and Development. NSW Department of Primary Indusries, Sidney.

[13] Abendroth LJ, Elmore RW, Boyer MJ, Marlay SK. 2011. Corn growth and development. PMR 1009. Iowa State University Extension. Ames, Iowa.

[14] MacRobert JF, Setimela PS, Gethi J, and Worku M. 2014. Maize Hybrid Seed Production Manual. Mexico, D.F.: CIMMYT

[15] Bolaji OT, Awonorin SO, Shittu TA, and Sanni LO. 2017. Changes induced by soaking period on the physical properties of maize in the production of Ogi. Cogent Food & Agriculture 3:1, 1323571. DOI: 10.1080/23311932.2017.1323571

[16] Marinho JL, Sartori AVS, Rodrigues EJ, Bazzo JHB, Ferreira AS, and Zucareli C. 2021. Pre-soaking with gibberellin in sweet corn seed lots with different levels of vigor. Semina: Ciênc. Agrár. Londrina 42: 539-552. DOI: 10.5433/1679-0359.2021v42n2p539

[17] Gharde Y, Singh PK, Dubey RP, Gupta PK. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. Crop Protection 107: 12-18. DOI: 10.1016/j.cropro.2018.01.007

[18] Araújo GV, Albrecht AJP, Albrecht LP, Carvalho HWP, Migliavacca RA, SilvaAFM. 2021. Effect of glyphosate and glufosinate on nutritional content and agronomic performance of maize possessing cp4epsps and pat transgenes. Australian Journal of Crop Scince 15(05):773-779. DOI: 10.21475/ajcs.21.15.05.p3193

[19] Wehrmeiste R, Albrecht AJP, Albrecht LP, Silva AFM, Kashivaqui ESF. 2022. Glufosinate, nicosulfuron and combinations in the performance of maize hybrids with the pat gene. Rev. Ciênc. Agron.,: 53, e20218175. DOI: 10.5935/1806-6690.20220046

[20] Nleya T, Chungu C, and Kleinjan J. 2016. Corn Growth and Development. In: Clay DE, Carlson CG, Clay SA, and Byamukama E (eds) iGrow Corn: Best Management Practices. South Dakota State University, Washington DC