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# *Variation responses on growth and production of three local corn cultivars toward gibberellic acid application*

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The diversity of local corn (*Zea mays* L.) in Indonesia is considerable, potentially contributing to food security, particularly in arid regions. This has led to the development of three local corn cultivars by the Research Centre for Biology, LIPI (currently BRIN), namely Pangkajene, Senggani, and Entog. To enhance the growth and yield of the cultivars, gibberellic acid (GA3) was applied at three different concentrations 0 ppm, 15 ppm, and 30 ppm. Therefore, this research aimed to investigate the growth response and yield of the three local corn cultivars in the context of applying GA3. The results showed that the application of GA3 at concentrations of 15 ppm and 30 ppm to the Entog and Senggani cultivars had a significant impact on stem height and upper internode length compared to the control group. The application of GA3 to the Pangkajene cultivar was observed to increase stem height and internode length but was not significantly different from plants without treatment. Furthermore, the three local cultivars showed an increase in the number of leaves and roots. The application of GA3 to the Entog and Senggani cultivars was observed to stimulate the length and weight of the corn cob, thereby increasing the production of corn kernels per cob. Meanwhile, the use of GA3 had different effects on Pangkajene cultivars, namely inhibiting cob growth and causing a decrease in corn kernels per cob production.

**Keywords:** Arid Region, Cob, GA3, Plant Growth Regulation, Local corn

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## INTRODUCTION

Corn (*Zea Mays* L.) is a cereal crop consumed as a staple food globally due to its high-calorie content, ease of cultivation, post-harvest handling, and adaptability to arid regions (National Geographic, n.d.). It is primarily cultivated on dry land in Indonesia, ranking as the second most consumed food after rice, particularly in arid regions. Compared to national varieties, local corn cultivars are more prevalent among farmers in arid regions such as South Sulawesi. These cultivars are frequently drought-tolerant, requiring minimal input, and showing an earlier maturation period (70-90 days), enabling the possibility of multiple planting in a year. Additionally, the local corn seed is open-pollinated, empowering farmers to produce seeds independently and cultivate varieties with distinctive flavors (Wawo et al., 2019). Cultivars such as Pangkajene, Entog, and Senggani are distinguished by their small cobs and kernels, with relatively short stature and early maturity.

However, several local corn cultivars produce less than hybrid varieties. For example, local corn from South Sulawesi has a cobs weight of 60 to 128 grams (Wawo et al., 2019), or approximately 2 to 4 tons per hectare (Rahayu et al., 2021). Therefore, there is a need to enhance the productivity of local corn cultivars, which have gained significant acceptance within society. The low productivity of corn is mainly due to factors associated with cultivation methods such as continued reliance on seeds from one generation to the next (Hadijah & Margaretha, 2010). To address this challenge, incorporating fertilizer innovations enriched with plant growth regulators has been shown to stimulate plant growth and production. Plant growth regulators are synthetic substances that replicate the effect of natural hormones (Vedamurthy et al., 2021). The first discovery of these regulators occurred in the 20$^{th}$ century and is currently used for cultivating several crops globally (Didi et al., 2020). The precise number of hormones can stimulate plant growth, while excessive application will lead to inhibition (Mutryarny & Lidar, 2018). Further research is required to determine the impact of plant regulators on the growth and yield of local Indonesian corn varieties.

Gibberellic acid (Gibberellin A3 or GA3) is plant growth regulator widely used in crop production. Specifically, GA3 is a member of the terpenoid family that was initially extracted from a plant infected with the fungus *Gibberella fujikuroi* (Datta et al., 2023). According to Hafidha (2017), the application of GA3 in plants plays a significant role in cell growth and division. It disrupts seed and bud dormancy, stimulates stem growth and elongation, as well as induces flowering and fruit development. The application of GA3 to leaves has been shown to enhance the photosynthetic rate, promote growth and development, as well as increase cell division and cell growth, along with stimulation of plant stem elongation (Wiraatmaja, 2017). Despite the significant potential, the response of plants to GA3 is based on

the concentration, type of plant, variety, and age of the plant during the application.

Based on the description, this research aimed to identify the response of local corn cultivars to GA3 applications at a specific concentration, thereby increasing production. The experiment was carried out by examining how the three local corn cultivars, namely Senggani, Enthog, and Pangkajene, grew and produced after GA3 application at different concentrations.

## METHODS

### Research Location

The research was conducted in an open field setting from January to April 2021. The location was situated at an elevation of 250 meters above sea level (coordinates: -6° 29' 39.1086"S, 106° 50' 43.2528"E), with a mean daily temperature of 21–25°C, humidity of 80–90%, precipitation of 13.04 mm and low soil pH (Table 1). The GA3 was prepared in the Research Center for Biology Indonesian Institute of Science (LIPI, currently BRIN), Cibinong, West Java. Before the experiment, the area was cleaned and plowed to obtain a loose, well-drained soil profile with direct exposure to sunlight. The land area of approximately 350 $m^2$ was subdivided into 27 plots, each measuring 3 m x 3 m. Subsequently, each plot was applied with 4 kg (4.5 tons $ha^{-1}$) of manure as a basal fertilizer and 220 g of pesticide. The planting site was left for one week to ensure thorough decomposition of the manure and the removal of pests, including worms. Table 1 shows that the soil properties of the experimental site are suitable for corn cultivation to achieve optimal growth and production. Therefore, this location was selected as the planting site for research.

### Plant Materials

The seed materials used were three local corn cultivars, namely Pangkajene from South Sulawesi, as well as Entog and Senggani from Purbalingga, Central Java. The seed colors of Pangkajene and Senggani cultivars were like bone white, while the Entog cultivar showed a light yellow hue. Moreover, a total of 225 seeds were selected for each cultivar.

### Planting Procedure

The seeds were directly sown in a planting hole approximately 1 cm deep, using a wooden dibber, comprising one seed per hole. The planting was performed under a Factorial Randomized Complete Block Design (RCBD), which consisted of two factors. The first factor was the local corn cultivars, comprising Pangkajene (K1), Entog (K2), and Senggani (K3). The second factor was the application of GA3 at three concentrations of 0 ppm (G0), 15 ppm (G15), and 30 ppm (G30), with each treatment replicated three times.

Before planting, the corn seeds were subjected to a predetermined treatment including soaking in GA3 solution. The preparation of GA3 solution was conducted by weighing 15 mg and 30 mg of GA3 powder, dissolving with 1 ml of alcohol, followed by dilution several times with distilled water to produce concentrations of 15 ppm and 30 ppm, respectively. The volume of distilled water for each seed priming treatment was 1 liter for 24 hours. The initial GA3 application volume was 15 liters when the plants reached three weeks after planting (WAP). Subsequently, 30 liters were applied when the plants reached five WAP.

A total of two rounds of plant maintenance were conducted one month and two months after planting, respectively. Weeding was carried out manually by digging up the weeds, followed by the spray application of insecticide and fungicide. Fertilizer was applied based on the recommendation of the Indonesian Cereals Research Institute (ICERI) (160 kg $ha^{-1}$ nitrogen, 30 kg $ha^{-1}$ phosphate, and 36 kg $ha^{-1}$ potassium) (Purba, 2017). There was no irrigation during the research, as the necessary water was obtained from rainwater.

### Observed Variable and Data Analysis

The observation was conducted during the vegetative and reproductive stages of the plant. A total of 135 plants comprising five per plot were randomly selected from a population of 140 plants per plot. During the vegetative stage, several variables were observed, including plant height (cm), stem diameter (mm) and number of internodes, number of leaves, the length and width of the leaf (cm), number of seminal roots, length of seminal roots (cm), mesocotyl internodes, and crown roots. Meanwhile, the variables observed during the reproductive stage were the emergence time and size of the tassel and ear, cob growth, and kernel production per cob. The data obtained were subjected to statistical analysis using the ANOVA (Analysis of Variance) test at the 5% confidence level and the post-hoc test of DMRT (Duncan's Multiple Range Test). Normality and homogeneity tests were conducted at the 5% confidence level using the SPSS 2.0 software.

**Table 1.** Soil properties in the study area

| | | |
|---|---|---|
| Soil Texture (%) | Sand | 2.00 |
| | Silt | 54.00 |
| | Clay | 44.00 |
| pH | $H_2O$ | 5.30 |
| | KCl | 4.30 |
| Organic matters (%) | C content (Walkley & Black) | 1.92 |
| | N contents (N Kjeldahl) | 0.20 |
| | C/N | 11.00 |
| $P_2O_5$ (mg/100 g) | HCl | 103.00 |
| | Bray | 23.90 |
| $K_2O$ (ppm) | HCl | 4.00 |
| | Morgan | 30.00 |
| Cation Exchange Capacity (CEC) | $Ca^{2+}$ | 5.91 |
| | $Mg^{2+}$ | 0.94 |
| | $K^+$ | 0.03 |
| | $Na^+$ | 0.18 |
| | Total | 7.06 |
| | Total CEC | 14.08 |
| | BC | 50.00 |
| | $Al^{3+}$ | 0.50 |
| | $H^+$ | 0.37 |

## RESULTS AND DISCUSSION

The life cycle of corn plants comprises three distinct stages, as delineated by the International Maize and Wheat Improvement Center (CIMMYT). These stages are germination, vegetative, and reproductive (Awata et al., 2019). The germination stage in corn is characterized by the appearance of plumules from the growing medium, which will remain enclosed within the coleoptile. The vegetative stage starts with the occurrence of the first leaves and concludes with the tassels. Meanwhile, the reproductive stage starts with the occurrence of the tassels and concludes with the maturation of the cob, which coincides with the readiness for harvesting. In this research, observation of growth parameters was conducted exclusively on the vegetative and reproductive growth stages.

### Vegetative Growth Stage

The height of the local corn plants showed variability based on the cultivars and age of the plants. A significant increase in height was observed at the age of 6 to 8 WAP (Figure 1). During this period, the leaves had fully developed, with the plant absorbing water and nutrients from the soil as well as light due to photosynthesis and other physiological processes at an optimal level. At 65 days after planting (DAP), the local corn of the Pangkajene and Senggani cultivars showed a similar height but significantly differed from the Entog cultivar, as presented in Figure 2.

The observed differences in height, stem diameter, length, and number of internodes among the local corn cultivars were influenced by genetic factors and their interaction with the growing environment, including the availability of sufficient nutrients (Hariyadi, 2014). Similarly, Gurung et al. (2018) conducted a germination experiment with multiple corn varieties on different sowing dates. The elongation of the stem and expansion were attributed to the activation of cell divisions and elongation processes initiated by the stem intercalary meristem, at the base of the internode in each corn cultivar (Wang et al., 2022).

Based on the interaction between cultivars and GA3, concentrations of 15 ppm and 30 ppm tended to increase the plant height and upper internode length in all cultivars. The concentration of 15 ppm was observed to have superior efficacy, showing no significant difference from 30 ppm. This suggested that the optimal application of GA3 was within a range of 15 ppm to 30 ppm, as observed in Entog and Senggani cultivars where plant height and internode length were significantly high compared to the untreated plants (Table 2).

Sudirman et al. (2015) reported that an increase in plant height was associated with the application of GA3 to stimulate cell elongation. An increase in plant height was also associated with an expansion in the number and size of cells, leading to stem elongation as well as a higher number of corn plant internodes (Zulfitri, 2015). Generally, the role of GA3 is to stimulate the growth in the stem length of corn through the promotion of cell division and elongation in internodes by the intercalary meristem located at the base of the internode (McKim, 2019). In addition, an increase in stem height is expected due to cell division at the growing stage by the apical meristem. During this stage, the apical meristem tissue passes through cell division, enlargement, and differentiation, causing upward and lateral growth (Mulyani et al., 2020). The increase in cell division of

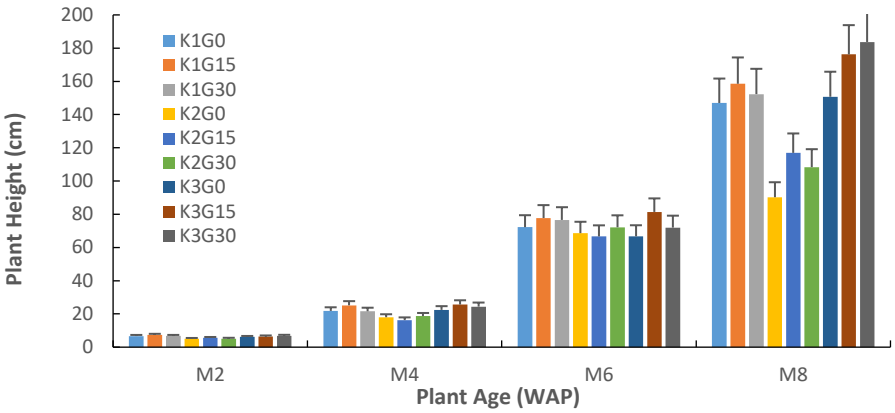


**Figure 1.** The height of local corn plants at the age of 2 (M2), 4 (M4), 6 (M6), and 8 (M8) WAP. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3

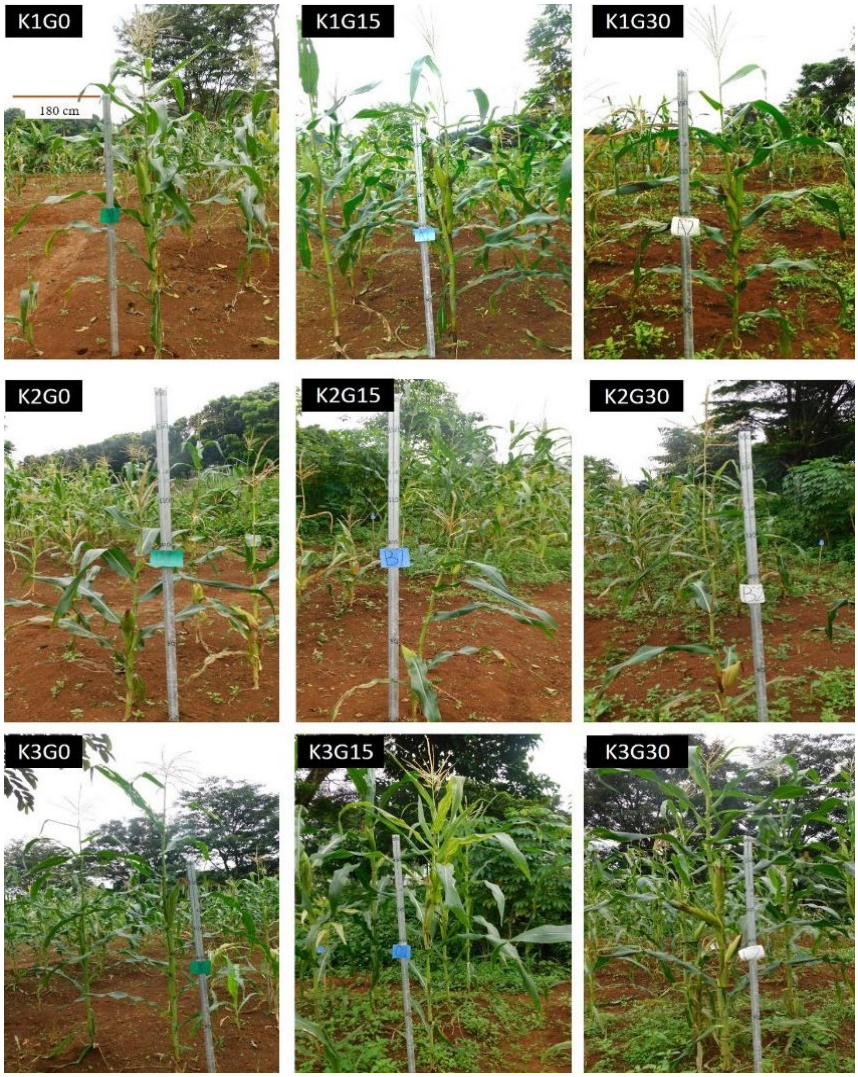


**Figure 2.** The plant height and leaf size of the three local corn cultivars after GA3 application at 8 WAP. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3

the apical and intercalary meristem in the stem should be facilitated by hormones such as GA3 to obtain optimal results (Oktaviani & Usmadi, 2019).

The formation of proteolytic enzymes, which liberate tryptophan in its original form as Auxin, is also supported by GA3. Consequently, the presence of GA3 will cause an increase in the levels of Auxin. In the growing stem, Auxin acidifies the cell wall and activates expansin, while GA3 facilitates the penetration of expansin into the cell wall, thereby increasing cell elongation (Wiraatmaja, 2017). Based on Table 2, the application of GA3 did not influence the number of upper and lower internodes in all three cultivars of local corn. This showed that the number of internodes was a distinctive trait of each cultivar of local corn.

The number of local corn leaves showed a positive correlation with the growth stage, indicating an increase in compatibility. The most observed increase occurred between two and four WAP. At the beginning of the growth cycle, approximately one to two WAP, plants germinated from seeds typically show rudimentary and diminutive plant organs, resulting in less active growth even though nutrients are available in large quantities.

A significant increase in the number of leaves was observed between the second and the sixth WAP, as shown in Figure 3. Subsequently, the growth of the leaves ceased, as indicated by the occurrence of flag leaves. This is followed by the reproductive growth stage, shown by a tassel at the top of the stem, and female flowers from the leaf axils in the middle of the stem after a few days. The growth of height and leaves has stopped because the energy generated from photosynthetic activities is allocated to the reproductive stage. This includes the growth of tassel, ear, cob, seed formation, and grain filling (Wawo et al., 2020).

The application of GA3 did not significantly affect the number of leaves of the local corn. However, all plants treated with GA3 showed a greater tendency to produce more leaves than control. An increase in the number of leaves was related to plant height due to the expansion of stem nodes. This suggested that the number of nodes increased along with leaves. Therefore, the number of nodes and internodes was similar to leaves. Setiawan (2017) stated that direct application of GA3 to the leaves will stimulate leaf growth. Furthermore, GA3 has been demonstrated to stimulate leaf and stem growth and increase leaf area, particularly under environmental stress (Ritonga et al., 2023).

The analysis of the interaction between local corn cultivars and GA3 concentrations of 15 ppm and 30 ppm showed an increase in the number of leaves. However, there was no statistical difference between the treated and untreated plants. The application of GA3 at concentrations of 15 ppm and 30 ppm to Senggani cultivar increased flag leaf size and differed from the control. Furthermore, a concentration of 15 ppm was observed to stimulate the growth of the flag in both the Entog and Pangkajene cultivars, as shown in Table 3.

The application of GA3 showed the potential to increase the number of leaves due to the ability to stimulate cell division. Roy and Nasiruddin (2011) stated that GA3 could stimulate leaf growth by prompting cell expansion and stimulating a cell wall enzyme known as Xyloglucan Endo-transglycosylase (XET). The stimulation of XET would break the bonds in the cell wall-forming molecules, namely hemicellulose, thereby allowing the movement of cellulose microfibrils. This can cause dilation and expansion of the cell wall in the leaves. The mechanism of GA3 in increasing the number of leaves is associated with the action of other hormones, such as auxin and cytokinin. The synthesis of auxin in the shoot apical meristem where leaf primordia are present will initiate leaf formation (Setiawan & Wahyudi, 2014).

A correlation was found between the number of roots and root length. Wawo et al. (2020) reported that local corn cultivars with a higher number of roots tended to show greater root lengths. Meanwhile, those with fewer roots were found to show shorter root lengths. The number and size of seminal and crown roots constitute a defining characteristic of local corn cultivars. Based on observation, Entog cultivars with shorter height showed a diminished number of roots and length compared to Senggani and Pangkajene. Due to the significant role of roots, increasing the number and length of roots will lead to taller plants. Wawo et al. (2020) stated that an increase in the number and length of roots would influence nutrient absorption from the soil, thereby affecting the growth of other plant parts, such as stem height and the number of leaves. This was shown by the histogram, which depicted a significant growth in stem height for Pangkajene and Senggani cultivars compared to Entog, as presented in Figures 1 and 2.

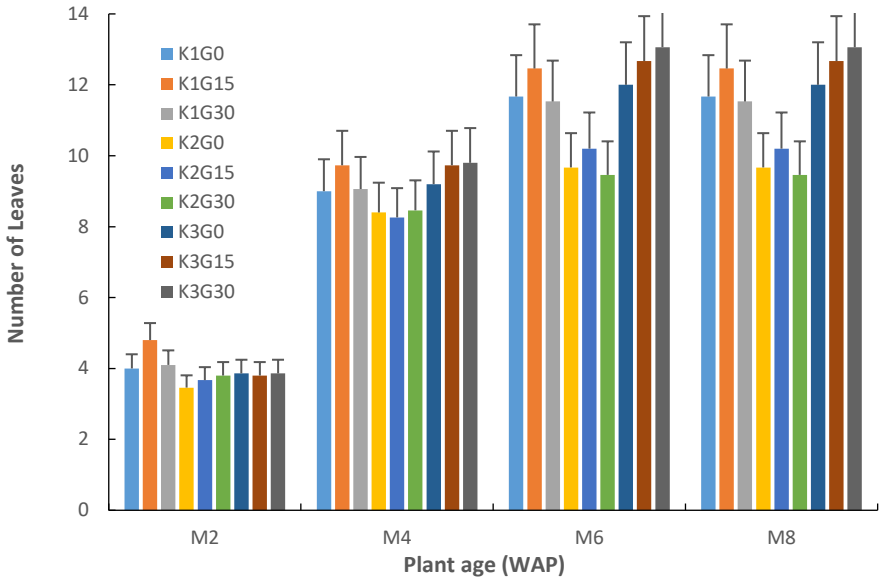


**Figure 3.** Number of leaves of local corn plant at the age of 2, 4, 6, and 8 WAP. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3


**Figure 4.** The length of the root of the three local corn cultivars at harvest after $GA_3$ application. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3

**Table 2.** Interaction between local corn cultivar and $GA_3$ application on the growth in height of stem

| Interaction | Height (cm) | Stem diameter (cm) | Length of upper internode (cm) | Length of lower internode (cm) | Total number of upper internodes | Total number of lower internodes |
|---|---|---|---|---|---|---|
| K1G0 | 146,93$^{c}$ | 7,40$^{ab}$ | 86,14$^{cd}$ | 77,16$^{a}$ | 5,53$^{a}$ | 4,87$^{ab}$ |
| K1G15 | 158,54$^{bc}$ | 7,82$^{ab}$ | 103,13$^{ab}$ | 71,16$^{a}$ | 5,47$^{a}$ | 5,53$^{ab}$ |
| K1G30 | 152,33$^{c}$ | 7,54$^{ab}$ | 95,47$^{bc}$ | 79,48$^{a}$ | 5,47$^{a}$ | 5,33$^{ab}$ |
| K2G0 | 90,25$^{e}$ | 6,88$^{c}$ | 66,58$^{e}$ | 32,28$^{b}$ | 4,87$^{a}$ | 3,13$^{c}$ |
| K2G15 | 116,95$^{c}$ | 6,73 $^{c}$ | 88,38$^{c}$ | 38,86$^{b}$ | 4,80$^{a}$ | 3,07$^{c}$ |
| K2G30 | 108,34$^{d}$ | 6,58$^{c}$ | 81,11$^{d}$ | 38,45$^{b}$ | 4,53$^{a}$ | 3,07$^{c}$ |
| K3G0 | 150,73$^{c}$ | 8,32$^{a}$ | 87,17$^{cd}$ | 64,73$^{ab}$ | 4,53$^{a}$ | 4,07$^{b}$ |
| K3G15 | 176,22$^{ab}$ | 8,61$^{a}$ | 113,16$^{a}$ | 83,55$^{a}$ | 5,33$^{a}$ | 5,67$^{ab}$ |
| K3G30 | 183,71$^{a}$ | 8,43$^{a}$ | 106,07$^{a}$ | 86,29$_{a}$ | 5,07$^{a}$ | 6,27$^{a}$ |

Note: *) Means followed by the same letter in the same column indicated not significantly different by DMRT at the level of 5%. Lower and upper internode of ear position. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3.

**Table 3.** Interaction between local corn cultivar and $GA_3$ application on the growth of leaves

| Interaction | Number of Leaves | Length of Leaves (cm) | Width of Leaves (cm) | Length of Flag Leaves (cm) | Width of Flag Leaves (cm) |
|---|---|---|---|---|---|
| K1G0 | 9,93$^{b}$ | 91,26$^{a}$ | 9,31$^{a}$ | 30,85$^{bc}$ | 4,74$^{cde}$ |
| K1G15 | 10,26$^{b}$ | 90,41$^{a}$ | 9,35$^{a}$ | 33,73$^{abc}$ | 5,60$^{bc}$ |
| K1G30 | 10,20$^{b}$ | 91,10$^{a}$ | 9,55$^{a}$ | 32,82$^{abc}$ | 4,46$^{de}$ |
| K2G0 | 6,87$^{c}$ | 69,77$^{b}$ | 7,16$^{b}$ | 32,08$^{ab}$ | 5,33$^{cd}$ |
| K2G15 | 7,53$^{c}$ | 71,89$^{b}$ | 6,88$^{b}$ | 35,22$^{ab}$ | 5,62$^{bc}$ |
| K2G30 | 7,20$^{c}$ | 70,10$^{b}$ | 7,49$^{b}$ | 30,92$^{c}$ | 3,80$^{e}$ |
| K3G0 | 10,37$^{a}$ | 100,04$^{a}$ | 8,95$^{a}$ | 27,61$^{c}$ | 4,26$^{de}$ |
| K3G15 | 11,40$^{a}$ | 100,91$^{a}$ | 9,02$^{a}$ | 36,52$^{ab}$ | 6,64$^{ab}$ |
| K3G30 | 11,67$^{a}$ | 95,93$^{a}$ | 9,28$^{a}$ | 40,90$^{a}$ | 6,90$^{a}$ |

Note: *) Means followed by the same letter in the same column indicated not significantly different by DMRT at the level of 5%. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3

The analysis of the interaction between cultivars and GA3 concentration showed that the application of 15 ppm and 30 ppm tended to increase the length and number of seminal as well as crown roots despite the insignificant difference with the control (Table 4). This result was due to the collaboration between exogenous GA3 and endogenous auxin, which stimulated root growth (McKim, 2019). Exogenous GA3 was found to have a negligible effect on root growth, except for the inhibition of wild type. This suggested that endogenous auxins played a more significant role in the root growth of local corn (Miceli et al., 2019).

Shita et al. (2020) observed that GA3 played an essential role in the root by facilitating the activity of the auxin hormone, enabling cell division in the root cap. Lestari (2011) and Miceli et al. (2019) showed that the influence of other hormones, such as auxin, increased the number and length of plant roots. It was also observed that seed priming exerted a more significant effect on root development than the application of GA3 solution to the aerial portion of corn plants. According to Adhikari and Subedi (2022), applying GA3 through seed priming could potentially enhance the rate of cell division in roots to promote accelerated growth and development.

As shown in Table 4, the application of GA3 did not impact the size of the mesocotyl internode in all local corn cultivars. This could be attributed to environmental conditions during the experiment and the genetics of the local corn cultivars, which were conducted under damp conditions, as presented in Table 1.

**Reproductive Stage**

The male flower (tassel) of Entog cultivars was observed to be earlier than that of compared to Pangkajene and Senggani. The Entog cultivars have a relatively short plant height with fewer leaves, complete the vegetative growth and enter the reproductive stage earlier than the Senggani and Pangkajene. This showed the occurrence of tassels at the top of the stem. The application of GA3 inhibited tassel growth in Entog cultivars. At 35 DAP, Entog cultivars showed the highest percentage of tassel growth (24.65%) without treatment. Similarly, concentrations of 15 ppm and 30 ppm produced 15.77% and 15.08% tassels of all population, respectively. At 45 DAP, the application of GA3 at a concentration of 15 ppm to Pangkajene cultivars produced the highest percentage of tassel growth (25.27%), 30 ppm (16.37%), and control (8.20%). The application of 0 ppm, 15 ppm, and 30 ppm to Senggani cultivars at the age of 50 DAP produced tassel growth of approximately 18.79%, 25.43%, and 25.67% of all population, respectively (Table 5). In natural conditions, the flowering process is influenced by sunlight and the functioning of endogenous GA3 mechanisms.

**Table 4.** Interaction between local corn cultivar and $GA_3$ application on the growth of root

| Treatment | Length of Seminal Roots (cm) | Number of Seminal Roots (cm) | Length of Crown Roots (cm) | Number of Crown Roots (cm) | Length of Mesocotyl Internode (cm) | Diameter of Mesocotyl Internode (cm) |
|---|---|---|---|---|---|---|
| K1G0 | 30,90$^{ab}$ | 15,67$^{ab}$ | 29,17$^{abc}$ | 10,00$^{ab}$ | 2,23$^{a}$ | 4,47$^{ab}$ |
| K1G15 | 32,73$^{a}$ | 16,33$^{ab}$ | 32,90$^{a}$ | 12,67$^{a}$ | 1,60$^{a}$ | 4,00$^{ab}$ |
| K1G30 | 31,70$^{ab}$ | 14,33$^{bc}$ | 31,87$^{ab}$ | 11,00$^{ab}$ | 1,47$^{a}$ | 4,53$^{ab}$ |
| K2G0 | 23,41$^{c}$ | 10,67$^{c}$ | 22,41$^{d}$ | 7,00$^{b}$ | 2,33$^{a}$ | 1,40$^{b}$ |
| K2G15 | 25,06$^{bc}$ | 15,67$^{ab}$ | 25,07$^{cd}$ | 7,33$^{b}$ | 2,00$^{a}$ | 2,67$^{b}$ |
| K2G30 | 27,67$^{ab}$ | 13,67$^{bc}$ | 22,67$^{d}$ | 8,00$^{b}$ | 1,30$^{a}$ | 2,13$^{b}$ |
| K3G0 | 30,53$^{ab}$ | 15,67$^{ab}$ | 27,27$^{c}$ | 7,67$^{b}$ | 1,73$^{a}$ | 3,63$^{ab}$ |
| K3G15 | 29,47$^{ab}$ | 16,67$^{ab}$ | 26,83$^{c}$ | 8,67$^{b}$ | 1,67$^{a}$ | 4,40$^{ab}$ |
| K3G30 | 33,50$^{a}$ | 18,67$^{a}$ | 28,13$^{bc}$ | 9,33$^{ab}$ | 1,93$^{a}$ | 3,07$^{ab}$ |

Note: *) Means followed by the same letter in the same column indicated not significantly different by DMRT at the level of 5%. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$

**Table 5.** Interaction between local corn cultivar and GA3 application on the growth rate of tassel (%) in plant population

| Treatment | Plant Age (DAP)/ Percentage | | | | | |
|---|---|---|---|---|---|---|
| | 35 (%) | 40 (%) | 45 (%) | 50 (%) | 55 (%) | 60 (%) |
| K1G0 | 0 | 0 | 8,2 | 65,33 | 100 | |
| K1G15 | 0 | 0 | 25,27 | 77,5 | 100 | |
| K1G30 | 0 | 0 | 16,37 | 79,29 | 100 | |
| K2G0 | 24,65 | 61,21 | 100 | | | |
| K2G15 | 15,77 | 51,51 | 100 | | | |
| K2G30 | 15,08 | 49,50 | 100 | | | |
| K3G0 | 0 | 0 | 0 | 18,79 | 70,15 | 100 |
| K3G15 | 0 | 0 | 0 | 25,43 | 71,03 | 100 |
| K3G30 | 0 | 0 | 0 | 25,67 | 79,47 | 100 |

Note: K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$

Local corn cultivars with tall plant height, such as Pangkajene and Senggani, have a greater capacity to absorb sunlight due to a higher number of leaves with a long and wide lamina than Entog. The energy stored in these leaves is used for tassel formation. Additionally, numerous corn leaves protect the flag leaf internode's base, facilitating a more active cell division. The ability of GA3 to promote cell division without light leads to more rapid growth of the tassels. However, the base of flag leaf internode in Entog cultivars is less protected due to the limited number of leaves and small lamina. This allows the light to interrupt cell division at the base, thereby delaying tassel formation (Wawo et al., 2020).

The application of GA3 to Entog cultivars caused a delay in tassel formation. The relatively short plant size and limited number of leaves of the Entog cultivar led to the exposure of all internodes to sunlight, which hinders cell division since GA3 is synthesized in dark conditions (Gupta & Chakrabarty, 2013). The disparity in flowering time among the three local corn cultivars was attributable to genetic factors and environmental conditions. Wahyudin et al. (2017) reported that corn flowering speed could be determined by age, size of the plants, and temperature. It was observed that flowering would not begin until the completion of the vegetative stage. Therefore, Entog cultivars showed an early flowering period due to low and compact stature and shortened vegetative stage (Wawo et al., 2020).

The analysis of the interaction between local corn cultivars and GA3 concentration showed an individual response to treatment. The application of 15 ppm GA3 stimulated tassel length of 34.33 cm in Pangkajene cultivars, which was not significantly different from the control and 30 ppm. Furthermore, Entog and Senggani cultivars showed tassel growth inhibition, as presented in Table 6. Figure 5 shows the discrepancy in size between the tassel and the ear.

Generally, tassel growth occurs due to cell division in meristematic tissues situated at the base of internodes covered by leaves (Ariyanto et al., 2015). As a growth hormone in plants, GA3 plays a role in the process of flowering. The exogenous application of GA3 can stimulate endogenous GA activity during the tassel formation process (Gupta & Chakrabarty, 2013). Ouzounidou et al. (2010) stated that applying GA3 at the beginning of the reproductive growth stage could enhance flowering and reduce the abscission of flowers and fruits. GA3 influenced cell differentiation, as shown by the ability to increase auxin levels in plants (Yennita, 2013). The application


**Figure 5.** The size of tassel and ear of the three local corn cultivars after $GA_3$ application. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$


**Figure 6.** The Length of Cob of the three local corn cultivars after $GA_3$ application. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$

**Table 6.** Interaction between types of local corn cultivar and GA3 concentration on the size of Tassel and Ear of local corn

| Interaction | Length of Tassel (cm) | Length of Ear (cm) | Circumference of Ear (cm) |
|---|---|---|---|
| K1G0 | 31,83$^{abc}$ | 22,10$^{ab}$ | 15,30$^{cd}$ |
| K1G15 | 34,43$^{ab}$ | 21,10$^{ab}$ | 16,20$^{ab}$ |
| K1G30 | 29,90$^{abc}$ | 22,11$^{ab}$ | 15,81$^{ab}$ |
| K2G0 | 23,67$^{de}$ | 15,95$^{c}$ | 14,90$^{cd}$ |
| K2G15 | 18,23$^{f}$ | 17,00$^{c}$ | 15,40$^{c}$ |
| K2G30 | 18,93$^{f}$ | 16,58$^{c}$ | 15,06$^{c}$ |
| K3G0 | 35,13$^{a}$ | 23,88$^{ab}$ | 14,51$^{d}$ |
| K3G15 | 28,53$^{cd}$ | 23,49$^{ab}$ | 15,71$^{ab}$ |
| K3G30 | 29,63$^{bc}$ | 23,38$^{ab}$ | 16,95$^{ab}$ |

Note: *) Means followed by the same letter in the same column indicated not significantly different by DMRT at the level of 5%. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$

of GA3 at a high concentration delayed flowering, while the flower induction would occur when the concentration decreased. However, this is not a universal phenomenon, as various plants require high gibberellin concentrations for flowering (Rolistyo & Sunaryo, 2014).

In corn plants, female flowers (ear) develop several days after tassel growth. As shown in Table 7, the application of GA3 affected the population of plants producing female flowers in each plot. The application of GA3 to Entog cultivars tended to inhibit the growth of female flowers. Regarding Pangkajene and Senggani cultivars, plants treated with GA3 at concentrations of 15 ppm and 30 ppm were observed to stimulate more significant number of female flowers than the control. According to Gupta & Chakrabarty (2013), GA3 could promote the induction and stimulation of the development of female flowers, enabling silks to occur faster. The growth rate of female flowers is significantly influenced by several factors, including the genotype, GA3 application, and environmental conditions, particularly light.

Light is often expected to impede the activity of GA3 stimulation in the Entog cultivars due to the limited number of leaves, which allows stem exposure to sunlight. This phenomenon causes a slight inhibition of the growth of the ear. In the Pangkajene and Senggani cultivars, the ear growing on the node in the middle of the stem was found to be in the shade of corn leaves, facilitating GA3 activity. Consequently, the ear of these two cultivars showed accelerated growth compared to the control. In conditions of low light, GA3 would promote the growth of stem or tip (Gupta & Chakrabarty, 2013). Alabadi (2004) stated that GA3 was produced in dark conditions and stimulated stem elongation, called the etiolation effect. This term showed that the stem elongation in the dark was the plants' response to GA3, although those growing well in the shade were not responsive, as shown by Castro-Camba et al. (2022).

The application of GA3 at 15 ppm and 30 ppm to the three local corn cultivars tended to increase the ear size. However, this was not significantly different from the ear size of the control, as shown in Table 7. The application of GA3 at the start of the reproductive phase would enhance the capacity of storage tissue to harvest (dash nya dihapus) photosynthesis products, such as fruits. Enlarged storage tissue can store more photosynthetic products. As more products are stored, the storage tissue becomes larger, particularly in corn. The role of GA3 in inducing the development of ear includes stimulating the growth of silks to occur faster from the cob to optimize pollination, thereby increasing the size of ear and cob (Gupta & Chakrabarty, 2013).

The priming of corn seeds with GA3 effectively enhanced germination and increased the size of ears and cobs in corn plants (Pipit, 2014). Gupta and Chakrabarty (2013) reported that applying GA3 could increase the activity of amylase and protease enzymes required during germination. Furthermore, soaking kernels in GA3 solution could soften the pericarp, facilitating water penetration into the embryo and enabling germination (Mooy et al., 2021). Pipit (2014) and Mooy et al. (2021) proved that optimal plant growth and production depended on optimal seed germination and seedling development. Additionally, the results showed the importance of a synergy between genetic, climatic, and soil that supported plant growth.

The delayed emergence of silk from the cob, causing a reduction in the seed filling process, then reduced the kernel weight (Maintang & Nurdin, 2013). Rakhmad, (2015) stated that early pollination extended the seed-filling period, allowing more dry matter to accumulate in the seeds. According to Setiawan (2017), there was continued cob stalk and

**Table 7.** Interaction between local corn cultivar and $GA_3$ application on the growth rate of husk (%) in plant population

| $GA_3$ Treatment | Plant Age (DAP)/ Percentage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 35 (%) | 40 (%) | 45 (%) | 50 (%) | 55 (%) | 60 (%) | 65 (%) |
| K1G0 | 0 | 0 | 5,9 | 48,37 | 80,89 | 100 | |
| K1G15 | 0 | 0 | 8,35 | 60,58 | 87,72 | 100 | |
| K1G30 | 0 | 0 | 12,90 | 64,53 | 85,70 | 100 | |
| K2G0 | 18,29 | 42,67 | 90,90 | 100 | | | |
| K2G15 | 12,75 | 40,51 | 94,19 | 100 | | | |
| K2G30 | 12,30 | 42,31 | 97,11 | 100 | | | |
| K3G0 | 0 | 0 | 0 | 15,75 | 43,63 | 80,6 | 100 |
| K3G15 | 0 | 0 | 0 | 19,13 | 65,49 | 88,84 | 100 |
| K3G30 | 0 | 0 | 0 | 20,41 | 40,61 | 89,35 | 100 |

Note: K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm $GA_3$, G15: 15 ppm $GA_3$, G30: 30 ppm $GA_3$

ear growth, with silks experiencing further elongation until fertilization. After the cob and ear have reached final growth, starch and other assimilates are accumulated in the endosperm (seed filling). A delay in pollination will cause a reduction of dry matter distribution during the seed-filling process. Furthermore, as plants enter senescence, there is a corresponding reduction in the number and weight of seeds (Canatoy, 2018).

Fruit enlargement requires an abundant supply of mineral nutrients, which are mobilized from vegetative parts for seed development. In corn, the vegetative part that actively mobilizes the assimilated products to the storage site (cob) is located above the ear. Therefore, increasing the number of leaves above the ear will trigger ear and cob enlargement. Adding exogenous GA3 at the start of fruit formation can also enhance the movement of nutrients, thereby promoting cell division and enlargement (Yamaguci, 2008).

The analysis of the interaction between local corn cultivars and GA3 concentration yielded disparate results. The results showed that at concentrations of 15 ppm and 30 ppm, Entog and Senggani cultivars tended to increase cob size, the number of seeds, and the weight of kernels per cob (Table 8). In comparison, the application of GA3 at 15 ppm and 30 ppm to Pangkajene cultivars reduced cob size, number of seeds, and weight of kernels per cob.

The number of seeds produced per cob depends on the presence of silkon the cob of silk from the cob. The longer silk formation at the base of the spike, the longer pollination period, resulting in optimal fertilization optimal fertilization. The seed-filling after fertilization is associated with the number of leaves above the ear.

Pipit (2014) reported that soaking corn kernels in GA3 could increase the size of corn ears and cobs. During the seed-filling process, GA3 was produced by the embryo, which stimulated cells in the aleurone layer to synthesize and produce the enzyme a-amylase, which facilitated the conversion of starch, in the endosperm to sugar during the growth process of young kernels (Pipit, 2014). According to Gardner et al. (1991), cob served as a determinant of seed or kernel size. Rakhmad (2015) discovered that applying GA3 at a concentration of 50 ppm and 100 ppm to chili plants could increase plant height. However, this increase was inversely proportional to the weight per fruit, length, and number of seeds per cob. A comparable phenomenon could also occur in the local corn of Pangkajene cultivars.

## CONCLUSION

This research showed a significant difference in the response of three local corn cultivars to GA3. The results showed that the application of GA3 at 15 ppm and 30 ppm concentrations to Entog and Senggani cultivars enhanced plant growth. However, there was no significant increase was observed in Pangkajene cultivars. The application of GA3 effectively accelerated the growth period of the tassel and ear in both the Pangkajene and Senggani cultivars, while Entog experienced a delay. Due to the treatment, Entog and Senggani cultivars tended to stimulate cob length and weight, thereby increasing the production of corn kernels per cob. In Pangkajene cultivars, GA3 inhibited cob growth resulting in a decrease in the production of corn kernels per cob. Therefore, the application of GA3 should consider the cultivar and its response to obtain a high yield.

**Table 8.** Interaction between local corn cultivar and $GA_3$ application on the size of cob and kernel

| Interaction | Weight of Cob (gr) | Length of Cob (cm) | Circumference of Cob (cm) | Number of Kernel /Cob | Weight of Kernel /Cob (gr) |
|---|---|---|---|---|---|
| K1G0 | 165,18$^{ab}$ | 17,95$^{a}$ | 13,72$^{ab}$ | 339,68$^{a}$ | 124,25$^{a}$ |
| K1G15 | 154,69$^{ab}$ | 17,25$^{a}$ | 13,58$^{ab}$ | 346,68$^{a}$ | 120,19$^{a}$ |
| K1G30 | 143,42$^{ab}$ | 16,43$^{a}$ | 13,70$^{ab}$ | 300,18$^{a}$ | 120,92$^{a}$ |
| K2G0 | 76,50$^{d}$ | 10,77$^{c}$ | 13,38$^{ab}$ | 194,18$^{bc}$ | 53,73$^{c}$ |
| K2G15 | 79,20$^{d}$ | 10,85$^{c}$ | 13,23$^{ab}$ | 196,83$^{bc}$ | 55,88$^{c}$ |
| K2G30 | 93,47$^{cd}$ | 13,27$^{b}$ | 14,00$^{a}$ | 208,50$^{bc}$ | 62,85$^{c}$ |
| K3G0 | 81,05$^{cd}$ | 15,95$^{a}$ | 11,60$^{d}$ | 123,50$^{c}$ | 53,02$^{c}$ |
| K3G15 | 103,90$^{cd}$ | 16,03$^{a}$ | 12,40$^{cd}$ | 182,00$^{c}$ | 70,28$^{c}$ |
| K3G30 | 120,70$^{bc}$ | 17,17$^{a}$ | 12,72$^{cd}$ | 212,83$^{bc}$ | 86,75$^{bc}$ |

Note: *) Means followed by the same letter in the same column indicated not significantly different by DMRT at the level of 5%. K1: Pangkajene cultivar, K2: Entog cultivar, K3: Senggani cultivar, G0: 0 ppm GA3, G15: 15 ppm GA3, G30: 30 ppm GA3.

## REFERENCES


Afzal, I., Basra, S. M. A., Shahid, M., Farooq, M., & Saleem, M. (2008). Priming enhances germination of spring maize (Zea mays L.) under cool conditions. *Seed Science and Technology*, *36*(2), 497–503. https://doi.org/10.15258/sst.2008.36.2.26

Adhikari. (2022). *RJOAS, 9(129), September 2022*. *9*(September), 113–120. https://doi.org/10.18551/rjoas.2022-09.11

Alabadí, D., G., Joan, B. A., & Miguel, G. Martínez. (2004). Gibberellins repress photomorphogenesis in darkness. *Plant Physiology*, *134(3): 10*.

Awata, L. A. O., Tongoona, P., Danquah, E., Ifie, B. E., Suresh, L. M., Jumbo, M.

Castro-Camba, R., Sánchez, C., Vidal, N., & Vielba, J. M. (2022). Plant Development and Crop Yield: The Role of Gibberellins. *Plants*, *11*(19). https://doi.org/10.3390/plants11192650

Badan Pusat Statistik. (2020). Luas Panen dan Produksi Padi di Indonesia 2019. *Berita Resmi Statistik*, *16*, 2. https://www.bps.go.id/pressrelease/download.html?nrbvfeve=MTc1Mg%3D%3D&sdfs=ldjfdifsdjkfahi&twoadfnoarfeauf=MjAyMC0wMi0yNSAxMzoyNjozMg%3D%3D

Bidadi, H., Yamaguchi, S., Asahina, M., & Satoh, S. (2010). Effect of shoot-applied gibberellin biosynthesis inhibitors on root growth and expression of gibberellin biosynthesis genes in Arabidopsis thaliana. *Journal Plant Root*, *4(1)*, 4–11. https://doi.org/https://doi.org/10.3117/plantroot.4.4

Datta, R., Roy, A., & Paul, S. (2023). Phytohormone signaling in osmotic stress response. In Plant Hormones in Crop Improvement (pp. 89-108). Academic Press.

Canatoy, R. C. (2018). Growth and Yield Response of Sweet Corn ( Zea mays L. var . Saccharata ) as affected by Tillage Operations and Fertilizer Applications Growth and Yield Response of Sweet Corn ( Zea Mays L . Var . Saccharata ) as Affected by Tillage Operations and Fertili. *International Journal of Education and Research*, *6*(4), 265–276.

Chudasama RS and VS Thaker. (2007). Relationship Between Gibberellin Acid and Growth Parameters in Developing Seed and Pod of Pigeon Pea. Baz. *J. Plant Physiol*, *19(1): 43-51*

Didi, D. A., Su, S., Sam, F. E., Tiika, R. J., & Zhang, X. (2022). Effect of plant growth regulators on osmotic regulatory substances and antioxidant enzyme activity of Nitraria tangutorum. Plants, 11(19), 2559.

Gelmesa, D., Abebie, B., & Desalegn, L. (2010). Effects of Gibberellic acid and 2,4- dichlorophenoxyacetic acid spray on fruit yield and quality of tomato (Lycopersicon esculentum Mill.). *Journal of Plant Breeding and Crop Science*, *2*(10), 316–324. http://www.academicjournals.org/jpbcs

Gupta, R. P., & Chakrabarty, S. . (2013). Gibberelic acid in plant ; still a mystery unresolved. *Plant Signaling and Behavior*, *8(9)*, 30–40.

Gurung, D. B., Bhandari, B., Shrestha, J., & Tripathi, M. P. (2018). Productivity of maize (Zea mays L.) as affected by varieties and sowing dates. *International Journal of Applied Biology*, *2*(2), 13–19. https://doi.org/10.20956/ijab.v2i2.4673

Hadijah, A. D., & Margaretha, S. L. (2010). Yield potential and gap analysis of maize production in Sulawesi, Indonesia. *Maize for Asia: Emerging Trends and Technologies.*, 17–20.

Hafidha Asni Akmalia, E. S. (2017). Respon Anatomis Jagung (Zea Mays L.) Sweet Boy-02' Pada Perbedaan Intensitas Cahaya dan Penyiraman. *Jurnal Sains Dasar*, *6*(1), 8. https://doi.org/10.21831/jsd.v6i1.13403

Hariyadi. (2014). Respon tanaman mentimun (Cucumis sativus L.) terhadap pemberian pupuk kandang kotoran ayam dan guano walet pada tanah gambut pedalaman. In *Laporan Penelitian Madya Bidang Keilmuan. Universitas Terbuka Indonesia.*

Kementrian Perindustrian Republik Indonesia. (2016, March 18). *Impor jagung 2,4 juta ton*. https://kemenperin.go.id/artikel/13892/2016

Lestari, E. G. (2011). Peranan Zat Pengatur Tumbuh dalam Perbanyakan Tanaman melalui Kultur Jaringan. *Jurnal AgroBiogen*, *7*(1), 63. https://doi.org/10.21082/jbio.v7n1.2011.p63-68

Maintang, & Nurdin, M. (2013). Pengaruh Waktu Penyerbukan Terhadap Keberhasilan Pembuahan Jagung Pada Populasi. *Agrilan*, *2*(2), 94–108.

McKim, S. M. (2019). How plants grow up. *Journal of Integrative Plant Biology*, *61*(3), 257–277.

https://doi.org/10.1111/JIPB.12786

Miceli, A., Moncada, A., Sabatino, L., & Vetrano, F. (2019). Effect of gibberellic acid on growth, yield, and quality of leaf lettuce and rocket grown in a floating system. *Agronomy*, *9*(7). https://doi.org/10.3390/agronomy9070382

Mooy, H., A, N., & Sumadi. (2021). Respon perkecambahan benih jagung manis terhadap konsentrasi dan lama perendaman giberelin pada suhu lingkungan yangg berbeda. *Jurnal Kultivasi*, *20 (1)*, 53–61. https://doi.org/https://doi.org/10.24198/kultivasi.v20i1.30705

Mulyani, L., Khairani, L., & Susilawati, I. (2020). Pengaruh Penambahan Giberelin terhadap Pertumbuhan dan Persentase Batang dan Akar Tanaman Jagung dengan Sistem Hidroponik. *Jurnal Sumber Daya Hewan*, *1*(1), 6. https://doi.org/10.24198/jsdh.v1i1.30991

Mutryarny, E., & Lidar, S. (2018). Respon Tanaman Pakcoy (Brassica Rapa L) Akibat Pemberian Zat Pengatur Tumbuh Hormonik. *Jurnal Ilmiah Pertanian*, *14*(2), 29–34. https://doi.org/10.31849/jip.v14i2.258

National Geographic. (n.d.). *Food Staple*. Retrieved September 18, 2023, from https://education.nationalgeographic.org/resource/food-staple/

Oktaviani, M. A., & Usmadi, U. (2019). Pengaruh Bio-Slurry dan Fosfor Terhadap Pertumbuhan dan Hasil Bunga Kol (Brassica Oleracea L.) Dataran Rendah. *Jurnal Bioindustri*, *1*(2), 125–137. https://doi.org/10.31326/jbio.v1i2.304

Ouzounidou, G., Ilias, I., Giannakoula, A., & Papadopoulou, P. (2010). Comparative study on the effects of various plant growth regulators on growth, quality, and physiology of Capsicum annuum L. *Pakistan Journal of Botany*, *42*(2), 805–814.

Pipit Dian Pertiwi, A. & Y. N. (2014). Pengaruh Giberelin (Ga3 )Terhadap Pertumbuhan Dan Produksi Tanaman Kedelai (Glycine max (L.) Merrill.). *J. Agrotek. Tropika*, *2*(2), 276–281.

Purba, R. (2017). Pengkajian pemupukan pada usahatani jagung di lahan kering dan lahan basah di kab. Pandeglang, Banten. *Agricore: Jurnal Agribisnis Dan Sosial Ekonomi Pertanian Unpad*, *2*(1), 205–290. https://doi.org/10.24198/AGRICORE.V2I1.15047

Rakhmad, A., & Darmawan, B. (2015). Pengaruh Macam dan Takaran Pupuk Kandang Terhadap Pertumbuhan Adas (Foeniculum vulgare Mill.) (The Effect of Kinds and Rates of Manure on The Growth of Adas ( Foeniculum vulgare Mill.). *Fakultas Pertanian Universitas Lambung Mangkurat*, *40*, 175–183.

Rahayu, H. S. P., Juradi, A., Asnidar, & Gafur, S. (2021). Farmers' preferences for composite corn in dry land area of Central Sulawesi. *IOP Conference Series: Earth and Environmental Science*, *911*(1). https://doi.org/10.1088/1755-1315/911/1/012075

Ritonga, F. N., Zhou, D., Zhang, Y., Song, R., Li, C., Li, J., & Gao, J. (2023). The Roles of Gibberellins in Regulating Leaf Development. *Plants*, *12*(6), 1–19. https://doi.org/10.3390/plants12061243

Rolistyo.A.,Sunaryo., dan T. W. (2014). Pengaruh Pemberian Giberelin Terhadap Produktivitas Dua Varietas Tanaman Tomat (Solanum lycopersicum L.). *J. Agrotek. Trop.*, *4*(95–100).

Roy R and KM Nasiruddin. (2011). Effect of Different Level of GA3 on Growth and Yield Of Cabbage. *J. Environ. Sci. & Natural Resources*, *4(2): 79-8*.

Sari, P. Memen, S. Budiman, C. (2018). *Metadata, citation, and similar papers at core.ac.uk*. *6*(3), 412–421.

Setiawan, I, D. (2017). *Pengaruh Dosis Asam Giberelat Dan Varietas Terhadap Pertumbuhan dan Hasil Jagung Manis (Zea mays saccaharata Sturt)*.

Setiawan, & Wahyudi, A. (2014). Effect of Gibberellin on growth of several pepper varieties in rapid multiplication method. *Bulletin Littro*, *25*(2), 111–118.

Shita, M. ., Hayati, R., & Hayati, E. (2020). Pengaruh komposisi media tanam dan konsentrasi giberelin terhadap pertumbuhan dan hasil bunga mawar (Rosa hybrida L.). *Jurnal Ilmiah Mahasiswa Pertanian*, *5(2)*, 51–60.

Sudirman, Rasyad, A., & Nurhidayah, T. (2015). Pengaruh Pemberian Giberelin terhadap Pertumbuhan dan Produksi Empat Varietas Kedelai ( Glycine max L . Merrill ). *J. Agrotek. Trop.*, *4*(2), 47–54.

Thomas, R. ., R.L, F., & G.J, B. (1993). Separation of VAM fungus and roots effect on soil agregation. *Soil Sci. Am. J*, *57 (2)*, 20–30.

Tiwari, A., R. Offringa, E. H. (2011). Auxin-induced fruit set in Capsicum annuum L. requires downstream gibberellins biosynthesis. *Journal of Plant Growth Regulator*, *31: 570-5*.

Vedamurthy, A. B., Bhattacharya, S., Das, A., & Shruthi, S. D. (2021). Exploring nanomaterials with rhizobacteria in current agricultural scenario. In Advances in nano-fertilizers and nano-pesticides in agriculture (pp. 487–503). Woodhead Publishing.

Wahyudin, A., Ruminta, R., & Nursaripah, S. A. (2017). Pertumbuhan dan hasil tanaman jagung (Zea mays L.) toleran herbisida akibat pemberian berbagai dosis herbisida kalium glifosat. *Kultivasi*, *15*(2), 86–91. https://doi.org/10.24198/kltv.v15i2.11867

Wang, F., Yu, Z., Zhang, M., Wang, M., Lu, X., Liu, X., Li, Y., Zhang, X., Tan, B. Cai, Li, C., & Ding, Z. (2022). ZmTE1 promotes plant height by regulating intercalary meristem formation and internode cell elongation in maize. *Plant Biotechnology Journal*, *20*(3), 526–537. https://doi.org/10.1111/pbi.13734

Wawo, A. H., Lestari, P., & Setyowati, N. (2019). Eksplorasi Jagung Lokal di Sulawesi Selatan dan Studi Pertumbuhannya di Kebun Penelitian Puslit Biologi , LIPI , Cibinong Local Corn Exploration in South Sulawesi and Study on Its Growth in Research Plot of Puslit Biologi , LIPI , Cibinong Pendahuluan. *Biota*, *4*(2), 79–93.

Wawo, A. H., Sumbogo, V. G., & Lestari, P. (2020). Comparison of seed germination and seedling growth between Indonesian local corn cultivars for deciding

the quality of seed. *Biodiversitas*, *21*(7), 3189–3199. https://doi.org/10.13057/biodiv/d210741

Weiss, D., & N. Ori. (2007). *Mechanism of cross talk beetween giberelin and other hormones*. Plant Physiology, 144, 1240–1246.

Wiraatmaja, I. W. (2017). Zat Pengatur Tumbuh Giberelin dan Sitokinin. *Fakultas Pertanian Universitas Udayana*, 1–44.

Yamaguchi, S. (2008). Gibberelin metabolism and its regulation. *Annu. Rev. Plant Biol*, *59 (2)*, 30–51.

Yennita, Toten, I. (2013). Pengaruh gibberellic acid (GA3) terhadap cabai keriting pada fase generative. *Prosiding Seminar Bidang Biologi, SEMIRATA B*, 479–484.

Zulfitri, I. (2015). *Analisis Varietas dan Polibag terhadap Pertumbuhan serta Hasil Cabai (Capsicum annum L.) Sistem Hidroponik*.