Effect of dose and plant growth regulator application time on agronomic traits and yield components of Lamuru maize

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Abstract. The climate change of dry months for growth and production of corn, demanding the use of growth regulators. Atonic are generally known to increase metabolism and plant growth regulators. However, the optimal application time and dosage according to the location of planting in maize are unknown. This study determines the dosage and optimal time of atonic spray application to increase yield components. The study was conducted in Latosol soil in the dry land of Installation for Research and Assessment of Agricultural Technology (IP2TP) Bacan South Halmahera, North Maluku, from March to July 2019. The study was arranged in a factorial randomized block design with three replications. The first factor consists of the dose of atonic spray consisting of 4 levels, namely: 0.25cc/l, 0.50cc/l, 0.75cc/l and 1.00cc/l. The second factor is the atonic spraying time which consists of 3 levels, namely: 28 days after planting (dap), 49 dap, and 77 dap. The results showed that atonic spraying with a dose of 50cc/l at 28 dap produced the highest weight per 1000 corn seeds significantly different from spraying at 49 and 77 dap at various atonic doses. Spraying carried out at age 77 dap requires a higher atonic dose of 1cc/l to produce a weight per 1000 corn and it was correlated with leaf area at 49 dap (r = 0.682) and with air temperature in July (r =0.35). High humidity (87.4%) in July was negatively correlated with plant height (r = -0.41) and weight of filled corncob (r = -0.37).

1. Introduction
To meet the increasing need for corn food, it is necessary to increase production and productivity. Corn in North Maluku is an important crop for food and animal feed, which is grown in all districts/cities except Ternate with a total area of 4.848ha. Corn production in the form of dry shells reaches 11.728 tons [1]. Increasing the productivity of maize has been carried out with plant properties that are tolerant of biotic and abiotic stresses [2][3]. However, the challenge of cultivation is getting wider and more complex, namely cultivation that can predict and mitigate climate change.

The development of cultivation technology (agronomy) continues to be carried out primarily to increase growth and yield. Besides, assembling varieties and cultivation systems to avoid/suppress yield losses due to drought or climate change. The application of plant growth regulators (PGR) is known to accelerate the adaptation response to drought stress through the spicing of the mRNA protein doubling mechanism [4]. PGR has been found commercially. PGR serves to protect as an abiotic agent of stress or climate change that was not optimal for plant growth. Broadly speaking, PGR is classified into two groups, namely biostimulants and growth inhibitors, both of which fall into five types, namely (1) auxins, (2) cytokinins, (3) gibberellins, (4) abscisic acid, (5) ethylene) [5]. One of the PGR contains
sodium nitrophenol which has physiological functions, including accelerating root growth, germination, accelerating the development of pollen, accelerating flowering, and fertilization and improving crop quality [6].

Planting time which is preceded by climate observation is a new skill and challenge in facing climate change. This is because planting time and data collection on climatic elements such as maximum and minimum temperature, relative humidity, rainfall, wind speed, and irradiation are the main keys in proper corn cultivation (Crop Management practices) [3]. The planting time will determine the growth and production inputs that will be applied.

To avoid plants from sub-optimal climatic conditions such as temperature, location, and sunlight, cultivation technology is needed that can spur and optimize the growth and yield of maize. Zhang et al. [7] reported that the use of PGR could increase maize yields by increasing plant density and reducing the percentage of plant lodging (weak roots). From the report of Spitzer et al., [8], the application of PGR can also be used to obtain optimal maize plant height, which decreases 40-90cm in plant height. From these reports, it is not known the optimal application time of PGR for agronomic properties as well as yields. This is important to respond to the time of the growth phase to climate change as well as practical cultivation management. Thus the aim of this study was to determine the optimal dosage and application time of PGR (active ingredient sodium para nitrophenol-nitroguaiacol) on the properties of agronomic growth and yield. The results of this study are expected to produce a more applicable PGR application innovation (time of administration and dose) based on climate change conditions and plant age (growth phase).

2. Methods

The research was conducted from March to July 2019 in the dry land of IP2TP Bacan South Halmahera, Assessment Institute for Agriculture Technology (AIAT) of North Maluku. The soil type is classified as Latosol. Materials in this study were Lamuru varieties of Maize, PGR namely Atonik with active ingredients are Natrium para nitrophenol-nitrogualakol, fertilizers used were NPK “Phonska” with 15% of nitrogen, phosphate and potassium contents for N, P and K. The experimental design was a factorial Randomized Block Design (RBD) arranged in a 4x3 factorial with 3 replications. The first factor consists of the dose of atonik spray consisting of 4 levels, namely: 0.25cc/l, 0.50cc/l, 0.75cc/l and 1.00cc/l. The second factor was the atonic spraying time which consists of 3 levels, namely: 28 dap, 49 dap, and 77 dap. Observation variables were plant height, number of leaves, leaf area, corn cobs length, the weight of filled corn cobs, 100-Kernel weight. Data analysis was used variance analysis if the real effect continued with Duncan's Multiple Range Test at p ≤ 0.05. Climatic data were also observed such as average temperature, average humidity, rainfall, and length of exposure. Observations were made during the growth of plant data taken at a weather station (BMKG) in Labuha Bacan. The correlation between the observed parameters and the climatic elements is tested for the correlation data on growth and yield as well as the climate elements obtained.

3. Result and discussion

3.1. The climate condition

Humidity during the study showed 76-97%. The lowest average air humidity occurred in the second month after planting (April), reaching 83%. The highest humidity was in the 3rd and 4th months after planting, namely 87%. The daily average temperature is in the range of 24.6-28.3 °C. Temperatures were higher in the first and second months after planting reaching 27 °C. The temperature decreased at month 3 and at the end of planting to 26 °C and 25 °C, respectively (Figure 1). The daily temperature at month had a very significant negative correlation with air humidity (r – 0.523 **) during the planting period (Table 1). These data indicate that the temperature of the planting location is still optimal for maize growth. The desired temperature for corn plants is 23-30 °C and the optimal temperature is 23-27 °C. Humidity was lower (84%) at the beginning of planting (March) and reached the highest (87%) in the last two months of planting.
Rainfall reaches high in the first month to the third month of planting, namely 162.9, 132.1, and 196.4 mm/month (Figure 2). Thus, the initial planting to harvesting phase is included in the wet months. Even so, at the end of planting during the generative phase, it can also be categorized as a humid month because of rainfall of 91.9 mm/month.

Figure 1. Daily mean temperature °C and relative humidity (%) during planting.

Figure 2. Rainfall (mm) and sunshine duration (hours) during planting.
Table 1. Correlation of growth parameters, yield, and climate elements

| weight per 1000 seeds | corn cob length | weight of filled cobs | Plant height (cm) | Number of leaf aged 77 dap | Leaf area aged 28 dap | Leaf area aged 49 dap | Leaf area aged 77 dap | Tav of July | Rh of July | Rainfall of August | Sunlight exposes of July | Sunlight exposes of August |
|-----------------------|----------------|-----------------------|-------------------|--------------------------|---------------------|---------------------|---------------------|-------------|------------|-------------------|--------------------------|--------------------------|
| a 1.00                | 0.039          | -0.014                | -0.009            | -0.403                   | 0.167               | 0.677**             | -0.0364             | 0.351       | -0.212     | -0.1020           | 0.0399                    | 0.1642                   |
| b -                   | 1.000          | 0.620**               | 0.0269            | 0.525**                  | 0.314               | 0.0092              | 0.2237              | -0.013      | -0.312     | -0.2697           | 0.3385                    | 0.1234                   |
| c -                   | -              | 1.00                  | 0.23215           | 0.591**                  | 0.156               | 0.073               | 0.0718              | -0.028      | -0.377*    | -0.085            | 0.1036                    | 0.1793                   |
| d -                   | -              | -                     | 1.00              | 0.149                    | 0.163               | 0.1113              | 0.1594              | 0.184       | -0.414*    | 0.1048            | -0.0353                   | 0.237                    |
| e -                   | -              | -                     | -                 | 1.000                    | 0.211               | 0.088               | 0.2934              | -0.225      | -0.122     | 0.0418            | 0.1023                    | -0.1593                  |
| f -                   | -              | -                     | -                 | -                        | 1.000              | 0.435*              | 0.0179              | 0.172       | -0.305     | -0.264            | -0.2052                   | -0.0201                  |
| g -                   | -              | -                     | -                 | -                        | -                   | 1.000              | 0.10191             | 0.146       | -0.149     | 0.0592            | -0.1570                   | -0.0627                  |
| h -                   | -              | -                     | -                 | -                        | -                   | -                   | 1.000              | 0.125       | 0.001      | 0.2075            | -0.179                    | -0.1113                  |
| i -                   | -              | -                     | -                 | -                        | -                   | -                   | -                   | -          | -0.523**   | -0.0378           | 0.057                     | 0.203                    |
| j -                   | -              | -                     | -                 | -                        | -                   | -                   | -                   | -          | -1.000     | 0.499**          | -0.393*                   | -0.064                   |
| k -                   | -              | -                     | -                 | -                        | -                   | -                   | -                   | -          | -1.000     | 0.135             | -0.675                    | -0.105                   |
| l -                   | -              | -                     | -                 | -                        | -                   | -                   | -                   | -          | -1.000     | 0.065            | -                         | 1.000                    |
| m -                   | -              | -                     | -                 | -                        | -                   | -                   | -                   | -          | -1.000     | 0.105             | 0.065                     | 1.000                    |

Note. *: significant, **: very significant
3.2. Plant parameters

3.2.1. Plant height. The dose of PGR and the time of spraying interacted to determine the height of maize plants aged 49dap. Spraying PGR at a dose of 0.5cc/l at the time of application of 49dap gave the best results, significantly different from the combination of treating a lower PGR dose with an earlier spray time (28dap) or reduced the same with a lower PGR dose. Besides, the combination was also significantly different from the spray time 77dap at a lower dose (0.25cc/l). The best combination was not significantly different in yielding plant height with spray treatment at a higher plant age of 77dap with a high dose (1cc / l) (Table 2).

3.2.2. Number of leaves. The results of the analysis of variance showed that the spraying time treatment interacted with the application dose to determine the number of leaves aged 49dap. Spraying PGR with a dose of 0.75cc/l at the time of application of 49dap gave the highest number of leaves, which was significantly different from several other treatment combinations. However, spraying PGR at an older plant age (77dap) with a PGR dose of 1cc/l also gave a large number of leaves which was not significantly different from the best treatment (Table 2).

Table 2. Effect of treatment interactions on growth and yield components of Lamuru maize.

| Treatment interactions | Plant height 49 dap (cm) | Number of leaves 49 dap | Corn cob length (cm) | Weight of stuffed corn cobs (gr) | 1000 kernel weight (gr) |
|------------------------|--------------------------|-------------------------|----------------------|-------------------------------|------------------------|
| 1                      | 260.0 ac                 | 13.0 d                  | 17.0 bc              | 140.5 c                       | 359.0 a                |
| 2                      | 260.0 ac                 | 13.0 d                  | 15.0 c               | 177.5 bc                      | 345.3 a-c              |
| 3                      | 235.0 cd                 | 13.0 d                  | 15.5 c               | 208.0 ab                      | 332.3 c-e              |
| 4                      | 250.0 a-d                | 14.0 bc                 | 14.6 c               | 182.5 bc                      | 351.0 a-c              |
| 5                      | 205.0 e                  | 15.0 a                  | 17.0 bc              | 211.0 ab                      | 347.3 a-c              |
| 6                      | 275.0 a                  | 14.0 bc                 | 18.1 ab              | 255.0 a                       | 348.3 a-c              |
| 7                      | 265.0 ab                 | 15.0 a                  | 19.8 a               | 262.0 a                       | 338.0 b-d              |
| 8                      | 250.0 a-d                | 15.0 a                  | 17.0 bc              | 260.0 a                       | 334.0 de               |
| 9                      | 230.0 d                  | 13.3 cd                 | 15.1 c               | 185.5 bc                      | 322.0 e                |
| 10                     | 250.0 a-d                | 14.5 ab                 | 16.8 bc              | 175.5 bc                      | 319.3 e                |
| 11                     | 250.0 a-d                | 14.5 ab                 | 17.0 bc              | 262.5 a                       | 348.0 a-c              |
| 12                     | 250.0 a-d                | 15.0 a                  | 18.5 ab              | 257.0 a                       | 356.0 a                |

1 = Spray age 28 days and a PGR dose of 0.25 cc/l; 2 = Spray age 28 dap and a PGR dose of 0.50 cc/l; 3 = Spray age 28 dap and a PGR dose of 0.75 cc/l; 4 = Spray age 28 dap and a PGR dose of 1.00 cc/l; 5 = Spray age 49 dap and a PGR dose of 0.25 cc/l; 6 = Spray age 49 dap and a PGR dose of 0.50 cc/l; 7 = Spray age 49 dap and a PGR dose of 0.75 cc/l; 8 = Spray age 49 dap and a PGR dose of 1.00 cc/l; 9 = Spray age 77 dap and a PGR dose of 0.25 cc/l; 10 = Spray age 77 dap and a PGR dose of 0.50 cc/l; 11 = Spray age 77 dap and a PGR dose of 0.75 cc/l; 12 = spray age 77 dap and a PGR dose of 1.0 cc/l.
Remarks. Different letters in the same column represent significant differences by Duncan’s Multiple Range Test at 5 % significant level.

3.2.3. Leaf area. Leaf area is influenced by the interaction of PGR dose and application time. Spraying PGR at the age of 28dap with a low dose of 0.25cc/l determined the highest leaf area at the age of 88dap was significantly different from several other treatment combinations. However, the high leaf area was not significantly different from the results, also due to the effect of spraying on older plants 77dap with a high dose of 0.50-1cc/l (Table 3).
Table 3. Effect of treatment interactions on leaf area in maize (Zea Mays L.) aged 88 dap

| Treatment interactions | Leaf area (cm²) |
|------------------------|----------------|
| 1                      | 583.4 a        |
| 2                      | 483.4 d-f      |
| 3                      | 453.4 f        |
| 4                      | 513.0 a-d      |
| 5                      | 503.0 b-e      |
| 6                      | 523.4 b-e      |
| 7                      | 523.0 b-e      |
| 8                      | 533.4 a-d      |
| 9                      | 473.0 ef       |
| 10                     | 563.4 ab       |
| 11                     | 564.0 ab       |
| 12                     | 553.4 a-c      |

Remarks. Different letters in the same column represent significant differences by Duncan’s Multiple Range Test at 5% significant level.

3.2.4. Corn cobs length. The results of variance showed that the length of corn cobs was determined by the interaction of the spraying dose and the time of the PGR spray. Spray time of 49dap with a PGR spray dose of 0.75cc/l resulted in the highest ear length which was significantly different from several other treatment combinations. If the spraying is carried out at an older plant, which is 77dap, a higher PGR dose is required, namely 1cc/l, so that the results also give high ear length, which is not significant with the best treatment above (Table 2).

3.2.5. Weight of filled corn cob. The dosage of PGR spraying and the time of spray interacting determine the weight of the filled corn cob. Spray time of 49dap with a PGR spray dosage of 0.75cc/l resulted in the highest weight of filled cob with several other treatment combinations. Spraying at the age of 77dap with a high PGR dose of 1cc/l also produces a high cob weight, not significantly different from the best treatment.

3.2.6. 1000-Kernel weight (g). The time of PGR spraying interacted with the application dose determines the weight per 1000 grain yield. The weight per 1000 grain yield increased when spraying PGR with a dose of 0.25cc/l at the age of 28dap or spraying at the age of 77dap with a spray dose of 1cc/l (Table 2). Weight per 1000 seeds is a yield parameter that is commonly used for the selection of agronomic properties of maize [9]. According to Gardner [10], there is a positive correlation between seed size in dicot plants and cotyledon size.

From the data in Table 2, the 1000 kernel weight was considered high, namely 356 g. These results indicate that the corn was a large seed. According to Saenong et al., [11] weight per 1000 large corn kernels weighs about 298.89 g. The large seeds produce 2 times the cotyledons and have the potential to have a higher photosynthesis rate than the small seeds so that the growth of maize is faster. Thus, the results of the weight parameter 1000 kernel weight indicate that the planting location is suitable for the optimal growth of Lamuru maize. The 1000 kernel weight was affected by PGR spraying and the spraying dose. Spraying PGR at a dose of 1cc/l with 77 dap spraying or 28 dap spraying time at a dose of 0.25cc/l is the best treatment. This is because the 1000 kernel weight was higher compared to other treatment combinations with an increase of 10.5-11.4% compared to several other combinations (Table 2). This result was in line with the report by Wei et al [12] that the weight of corn kernels can be increased by fertilizing up to 7.0% at 360kg N/ha compared to without N fertilization. In addition to the fertilization factor, the weight of corn kernels was influenced by population density per ha [9].
The 1000 kernel weight was related to the agronomic properties of the plant. Plants that produce high seed weights of 1000 are produced from plants with the highest (optimal) leaf area. There was an interesting fact that plants with the highest plant height and number of leaves did not show the highest yield per 1000 seeds (Table 2). These results indicate that the leaf area was a parameter of growth and productivity of maize. To form the optimal leaf area, it is determined by the time of PGR spraying and the spraying dose. Spraying PGR at the age of 28dap with a dose of 0.25cc/l has the effect of increasing the best leaf area at the age of 88dap or just before harvest. The role of the leaf area is for light interception and photosynthesis activities to increase the growth and accumulation of photosynthate (seeds) in maize [13]. According to Lambert et al. [14] to obtain the highest maize productivity was not obtained from plants with the widest leaf area but plants with lower leaf area (optimal).

In general, the effect of PGR treatment shows positive results. The nature of growth and the yield components expected to be optimal for productivity are determined by the PGR treatment. According to Neill et al. [4] giving PGR to maize plants increases the adaptability of plants to environmental stresses and increases cipher proteins for seed production. This is because PGR, especially Gibberellin, increases the chlorophyll content of leaves and some macronutrients.

3.3. Correlation of growth and yield parameters with climatic elements

The 1000 kernel weight was highly correlated with the leaf area at 49dap ($r = 0.677^{**}$). These yield components were not significantly correlated with climatic elements. However, the climatic element, namely the relative humidity in July (at the end) of planting, has a very significant negative correlation with plant height and number of leaves during the generative phase. Thus high humidity (87% average) in the range of 82-95% when the generative phase of the plant is undesirable because it will reduce the number of leaves ($r = -0.377^{**}$) and plant height ($r = -0.414^{**}$).

The yield component in the form of weight per 1000 grain showed a correlation with the leaf area at the age of 49dap ($r = 0.677^{**}$). These results indicate that the leaf area parameters, especially at the age of 49dap, can be used as early agronomic traits for high yielding superior traits in the form of a weight of 1000 seeds. This result is because the leaf area has an effect on photosynthesis and in determining photosynthate in the form of seed weight yield [13][14].

4. Conclusion

Utilizing the wet month at the beginning of planting with the application of PGR and application time determines the productivity of Lamuru maize. The yield component in the form of 1000-kernels weight was determined by the interaction between spraying time and dosage of PGR application. The application of a low dose of PGR (0.50cc/l) in the early wet month of planting (28 dap), the rainfall of 162.9 mm/month determined the leaf area of 49 dap and had a significant positive correlation with 1000-kernels weight. This technology is needed to increase maize productivity in areas that have a short wet month at the beginning of maize growth before entering the dry season.

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