Effect of population density on growth and production of hybrid maize

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Abstract. One of the strategies to increase maize production is by selecting the proper combination among variety and planting density. The plant density population experiment was carried out to identify the candidate of maize variety that has high productivity with limited sunlight levels. Our hypothesis was how the erect leaf maize type can get optimal sunlight and affect the productivity. The study was conducted in IP2TP Bajeng, Gowa, South Sulawesi from March to June 2020. This study was designed under split plot design where spacing or plant density as the main plot with 3 levels of treatment (70 cm x 20 cm (population 71,428 plants/ha), 60 cm x 20 cm (population 83,333 plants/ha) and 50 cm x 20 cm (population 100,000 plants/ha). Furthermore, eight genotypes of hybrid maize (ERC 01, ERC 02, ERC 03, ERC 04, ERC 05, ERC 06, ERC 07, ERC 08), including control varieties (JH 45 and Pioneer 36) were treated as the sub-plots. The results indicated that the maize yield increase in line with the increase in plant population. The plant`s spacing of 70 x 20 cm with 100,000 plants/ha was produced 10.61 t/ha, significantly higher than other treatments.

1. Introduction
Maize plants have the ability to adapt to the environment through adjusting in plant ideotypes. The ability of plants is known as plastistas phenotypic [2] and [4]. The growth of maize with optimal productivity is determined by various factors such as the condition of soils, nutrients, water and sunlight. In the early growth of plant, there is often competition between plants in obtaining nutrients, water and sunlight. However, this competition can be minimized by adjusting the spacing according to the type of plant and its genetic character. The type of leaf plant that tends to be erect is related to the level of light absorption for photosynthesis which is greater than flat leaf, while the genetic trait is related to the adaptability of plants in utilizing a limited environment for optimal production. Efforts to reduce intraspecies competition and maximize the use of environmental resources can be done through plant spacing adjustment [4] and [18].

Plant spacing is mainly selected based on agronomic characters of plant, and adaptability in optimizing production. The pattern of spacing according to plant type and adaptability will maximize the agronomic environment. IAARD has been creating new high-yielding varieties adapts to optimal and sub-optimal agro-ecosystems. Development of maize in sub-optimal land by developing varieties of erect and low-N tolerant. The productivity of the erect genotype ERC-14/ERC-19 with an average yield of 13.7 t/ha in a population of 81,632 plants/ha with a square cropping system. This increase in productivity can still be done through population improvement and proper cropping management.

Population adjustment is likely to decrease the interception light of the sun and the formation of chlorophyll leaves were required in the process fotosisntesis [14]. In addition, there was a decrease in

maize grain yield due to a reduction in the number of cobs and the number of grain per cob [3] and [5]. Plant population density that is too high is less effective for increasing crop productivity and harvest index. At some maize hybrids, high density increase percentage of ear abnormalities, obstruction of the process of flowering due to lack of pollen and delay in silking [16]. Yet, setting a population of plants per unit area is very necessary in order to improve the productivity of maize [12]. The objective of the study was to determine the response to growth and production of new superior varieties (CVUB) at various population levels.

2. Methods

The research was carried out in IP2TP Bajeng Gowa, South Sulawesi. Research was using split plot design where the main plot is plant spacing: 70 cm x 20 cm (population 71,428 plants/ha), 60 cm x 20 cm (population 83,333 plants/ha) and 50 cm x 20 cm (population 100,000 plants/ha) and subplots are eight genotypes of hybrid maize (ERC 01, ERC 02, ERC 04, ERC 05, ERC 06, ERC 07 and ERC 08) as well as two control varieties (JH 45 and Pioneer 36).

The seeds were planted 2 seed/hole, age 7 dap was adjusted into 1 plant/hole. Each treatment plot consisted of 6 rows of plants, with a length of 4 m and repeated 3 times. All treatments were fertilized with N, P, K and organic fertilizers with a dose of 200 kg N, 100 kg SP36 and 150 kg K2O and organic fertilizer 2 t/ha. Fertilizer was applied in a single way beside the row of plants, all P and K doses and half the N dose were given at 7 -10 dap and the remaining N doses were given at 40 dap. Organic fertilizers was applied during seed planting. Plant management (weeding, irrigation, and pest and disease control) is carried out by following IAARD practice.

Data collected include plant height at 35 dap and 90 dap, cob height (90 dap), leaf number (90 dap), leaf area index (90 dap), stem diameter (90 dap), yield components (cob length and diameter, number of rows and grain in rows, weight of 100 seeds), and harvest index.

3. Results and Discussion

The results of the analysis indicated that the candidate new variety (CVUB) had a lower plant height than the control variety except ERC 04 which was slightly higher than the control (JH 45 and Pioneer) in population level of 71,428 plants/ha, 83,333 plants/ha and 100,000 plants/ha. In addition, the number of leaves and leaf area index were almost the same as the comparison varieties at the three population levels. This indicates that the respond significantly to the three levels of the population except CVUB ERC 04. Population levels of various CVUB and varieties not showed competition between plant population increases, so the value is still its almost the same. The same relative growth caused by the absence of competition for sunlight signifikan between plants [15].

Table 1. Plant height, number of leaves and leaf area index at 35 dap from various population levels and candidate varieties. Gowa, 2020.

| Candidates/ Varieties | Plant height 35 dap | Number of leaves 35 dap | Leaf area index 35 dap |
|-----------------------|---------------------|------------------------|-----------------------|
|                       | 71,428 83,333 100,000 | 71,428 83,333 100,000 | 71,428 83,333 100,000 |
| ERC 01                | 40.23 47.57 39.95    | 5.43 6.24 5.57        | 0.04 0.04 0.03        |
| ERC 02                | 41.14 45.19 46.19    | 5.38 5.85 5.71        | 0.03 0.03 0.03        |
| ERC 03                | 48.62 56.33 46.00    | 6.14 6.14 5.67        | 0.03 0.04 0.03        |
| ERC 04                | 59.00 51.33 57.81    | 6.00 5.80 5.90        | 0.03 0.04 0.03        |
| ERC 05                | 43.62 42.38 48.10    | 6.04 5.67 5.71        | 0.04 0.04 0.04        |
| ERC 06                | 43.10 52.38 49.48    | 5.81 6.19 5.90        | 0.03 0.03 0.04        |
| ERC 07                | 36.76 41.42 38.14    | 6.14 5.95 5.67        | 0.04 0.04 0.04        |
| ERC 08                | 41.71 45.43 47.62    | 5.95 6.38 6.09        | 0.04 0.04 0.05        |
| JH 45                 | 49.29 54.66 50.00    | 5.99 6.43 6.24        | 0.04 0.04 0.04        |
Enhancing an population of 71,249 plants/ha, plants/ha 83,333 and 100,000 plants/ha not show the difference of the significant with varieties, except CVUB ERC 05 and ERC 08 high lower crop (Table 2). Position cob layout does not show the difference that the significant between CVUB at a rate of 71,428 plants/ha, 83,333 plants/ha and 100,000 plants/ha. While between CVUB ERC 02, ERC 03, ERC 04 and ERC 07 there was no significant difference between the control, while ERC 01, ERC 05, ERC 07 and ERC 08 were significantly different from the control. This genetic factor greatly affects the height of the cob position.

The number of leaves with a population of 71,428, 83,333 and 100,000 plants/ha, there was no significant difference between CVUB and comparison varieties. This indicates that the population increase to 100,000 plants/ha no significant effect to the number of leaves on CVUB and varieties.

Table 2. Plant height, cob height and number of leaves at 90 dap from various population levels and varieties. Gowa, 2020.

| Candidates/ Varieties | Plant height 90 dap | The height of the cob is 90 dap | Number of leaves 90 dap |
|-----------------------|---------------------|-------------------------------|------------------------|
|                       | 71,428  | 83,333 | 100,000 | 71,428  | 83,333 | 100,000 | 71,428  | 83,333 | 100,000 |
| ERC 01                | 209.39  | 202.89 | 203.78  | 97.27   | 94.67  | 95.78   | 12.72   | 13.00  | 12.22   |
| ERC 02                | 209.39  | 216.50 | 217.83  | 102.50  | 107.11 | 112.83  | 12.83   | 13.06  | 12.83   |
| ERC 03                | 214.22  | 217.56 | 210.50  | 116.89  | 120.72 | 116.33  | 13.06   | 12.89  | 13.28   |
| ERC 04                | 216.72  | 216.83 | 210.89  | 128.00  | 123.00 | 124.55  | 12.33   | 13.00  | 12.83   |
| ERC 05                | 179.84  | 175.16 | 181.78  | 94.00   | 93.44  | 94.50   | 12.28   | 12.17  | 12.61   |
| ERC 06                | 199.44  | 205.28 | 208.72  | 113.22  | 119.66 | 121.61  | 12.67   | 13.44  | 13.28   |
| ERC 07                | 166.83  | 168.05 | 164.55  | 89.33   | 91.56  | 87.50   | 12.27   | 12.39  | 12.05   |
| ERC 08                | 173.83  | 172.61 | 180.95  | 93.05   | 94.55  | 98.67   | 13.00   | 12.22  | 12.44   |
| JC 45                 | 200.11  | 206.17 | 202.05  | 108.44  | 111.06 | 112.33  | 12.83   | 12.38  | 12.33   |
| Pioneer 36            | 222.50  | 213.11 | 218.89  | 100.83  | 100.33 | 109.44  | 13.11   | 12.67  | 12.50   |
| Average               | 199.28  | 199.41 | 199.09  | 104.35  | 105.61 | 107.35  | 13.21   | 12.72  | 12.63   |
| LSD                   | 5.15    | 3.30   | 0.91    |
| KK %                  | 4.99    | 6.04   | 13.68   |

The PAR values of CVUB ERC 03, ERC 04, ERC 06 and ERC 07 were higher than the control varieties. This shows that the CVUB has a leaf type that is more erect (leaf angle) or shorter than the control variety. The smaller the leaf angle and leaf length, the greater the PAR value. With a population of 83,333 plants/ha at 30 dap, it showed that the PAR value of CVUB ERC 04 was higher than the control variety (JH 45), while all tested CVUB were higher than the comparison (Pioneer 36). In a population of 100,000 plants/ha, it showed that CVUB ERC 02, ERC 03, ERC 04 and ERC 07 were higher than the control variety (JH 45), while all CVUB were higher than the Pioneer 36 variety. PAR value is highly dependent on genetic and environmental factors growing so that each CVUB and variety has a different value at PAR value of 30 dap. The effect of varieties on different parameters is caused by genetic factors possessed by varieties and their adaptability to the environment [7].

LAI values from various population levels and types of CVUB and comparison varieties did not show significant differences. This shows that at 30 dap each CVUB and varieties still have the same ability to get sunlight in photosynthesis process for the growth of plants. The same relative growth due to the absence of competition in getting the light of the sun significantly between maize [15]. The increase in plant population did not have a significant effect on the LAI value at 30 dap.
Table 3. PAR and LAI at 30 dap from various population levels and candidate varieties. Gowa, 2020.

| Candidates/ Varieties | PAR 30 dap | LAI 30 dap |
|-----------------------|------------|------------|
|                       | Population (plant/ha) | 71.428 | 83.333 | 100.000 | 71.428 | 83.333 | 100.000 |
| ERC 01                | 12.38      | 14.84      | 11.95 | 3.83 | 3.36 | 3.46 |
| ERC 02                | 16.14      | 12.15      | 12.41 | 3.40 | 3.35 | 3.45 |
| ERC 03                | 20.30      | 12.22      | 12.10 | 3.25 | 3.36 | 3.44 |
| ERC 04                | 19.21      | 18.61      | 13.15 | 3.32 | 3.36 | 3.49 |
| ERC 05                | 14.58      | 10.84      | 9.53  | 3.41 | 3.35 | 3.40 |
| ERC 06                | 18.34      | 11.24      | 8.54  | 3.38 | 3.34 | 3.49 |
| ERC 07                | 22.73      | 11.74      | 13.67 | 3.44 | 3.36 | 3.41 |
| ERC 08                | 13.06      | 13.06      | 5.79  | 3.42 | 3.37 | 3.46 |
| JH 45                 | 17.04      | 16.22      | 11.25 | 3.47 | 3.32 | 3.45 |
| Pioneer 36            | 13.64      | 9.52       | 8.36  | 3.42 | 3.35 | 3.47 |
| Average               | 16.74      | 13.10      | 10.67 | 3.39 | 3.35 | 3.45 |
| LSD                   | 2.05       |            | 0.03  |     |     |     |
| KK %                  | 29.35      |            | 1.99  |     |     |     |

Table 4 shows that the PAR values at 60 dap in the population of 71,428, 83,333, and 100,000 plants/ha of the candidate varieties ERC 02, ERC 03, ERC 04, ERC 06 and ERC 07 were higher than the control varieties. This indicates that the CVUB has more erect leaves, thus higher than the indigo varieties JH 45 and Pioneer 36. The larger Pioneer 36 value indicates a larger amount of sunlight received by the bottom leaf will be larger. CVUB with an increase in population PAR values were higher than the comparison varieties. Spacing of plants/population can affect the intensity of sunlight that can be received by plants [17]. The higher the level of sunlight received by the plant's photosynthesis process, the more optimally it supports the plant's products.

Leaf area index (LAI) of various types of CVUB and population level were not significantly different from the comparison varieties (Table 4). CVUB and comparison varieties had almost the same leaf area, so they did not have a significant effect on population and varieties. LAI is the ability of plants to carry out photosynthesis which affects the growth and development of plants, namely leaves that have a large leaf area, the photosynthetic process is maximized. Leaf area shows the potential of plants to carry out photosynthesis which affects plant growth and development [17].

Harvest index n is the ratio of dry weight yield to total dry weight yield of plants. From various candidate varieties and varieties with various population levels, it is shown that the harvest index is classified as optimal, namely 0.40 - 0.59 (Table 4). Various types of candidate varieties and varieties at various population levels, indicated no significant effect on the harvest index. Optimal harvest index is 0.15 - 0.52 which is influenced by plant growth rate, leaf area index, weight of 100 seeds and total dry shell yield [6] and [17].
Table 4. PAR, LAI and harvest index at 60 dap of various population levels and candidate varieties. Gowa, 2020.

| Candidates/ Varieties | PAR 60 dap | LAI 60 dap | Harvest index |
|------------------------|------------|------------|---------------|
|                        | Population (plant/ha) |            |               |
|                        | 71,428     | 83,333     | 100,000       |
| ERC 01                 | 35.17      | 26.46      | 40.86         |
|                        | 2.41       | 2.63       | 2.59          |
|                        | 0.51       | 0.59       | 0.50          |
| ERC 02                 | 43.93      | 33.28      | 30.22         |
|                        | 2.55       | 2.63       | 2.64          |
|                        | 0.41       | 0.50       | 0.59          |
| ERC 03                 | 51.38      | 27.54      | 38.93         |
|                        | 2.39       | 2.62       | 2.56          |
|                        | 0.58       | 0.40       | 0.56          |
| ERC 04                 | 48.48      | 36.86      | 30.57         |
|                        | 2.46       | 2.61       | 2.64          |
|                        | 0.54       | 0.51       | 0.58          |
| ERC 05                 | 28.53      | 29.40      | 26.28         |
|                        | 2.59       | 2.61       | 2.59          |
|                        | 0.55       | 0.49       | 0.54          |
| ERC 06                 | 46.87      | 21.80      | 26.17         |
|                        | 2.52       | 2.60       | 2.58          |
|                        | 0.45       | 0.48       | 0.49          |
| ERC 07                 | 34.76      | 39.77      | 39.28         |
|                        | 2.51       | 2.63       | 2.54          |
|                        | 0.47       | 0.50       | 0.49          |
| ERC 08                 | 40.52      | 27.75      | 25.83         |
|                        | 2.54       | 2.62       | 2.61          |
|                        | 0.55       | 0.52       | 0.49          |
| JH 45                  | 35.29      | 26.43      | 28.79         |
|                        | 2.46       | 2.59       | 2.60          |
|                        | 0.48       | 0.40       | 0.51          |
| Pioneer 36             | 31.44      | 18.45      | 17.14         |
|                        | 2.56       | 2.62       | 2.62          |
|                        | 0.51       | 0.49       | 0.45          |
| Average                | 39.63      | 28.77      | 30.41         |
|                        | 2.50       | 2.61       | 2.59          |
|                        | 0.51       | 0.49       | 0.52          |
| LSD                    | 4.34       | 0.03       | 0.04          |
| KK %                   | 25.46      | 2.70       | 17.81         |

Table 5 shows the production of a population of 71,428 plants/ha ERC 01 population of 83,333 plants/ha ERC 03 and a population of 100,000 plants/ha ERC 01, ERC 03, ERC 05 and ERC 07 higher production than the control variety (JH 45 and Pioneer 36). This shows that CVUB has a different ability to production which is influenced by population level. At high population (83,333 plants/ha and 100,000 plants/ha) the CVUB was superior in productivity than the control. The CVUB with a high population provides high productivity indicating the optimal ability of individual plants to utilize nutrients, sunlight, that is, there is no competition between plants. Proper planting distance results in no competition in getting the nutrients, sunlight (not shade each other) that plants need [9]. Increasing maize production can be done by improving the level of plant density (planting distance), but this is done by paying attention to the type of plant (leaf angle and leaf area).

The length of the cob varieties Pioneer 36 of various population levels higher than CVUB, being no different cob diameter that the significant in CVUB and varieties (Table 6). In general, the length and diameter of the ear tends to decrease with increasing plant population. Wide plant spacing (low population) can increase the length of the cob compared to narrow plant spacing (high population) because the wide plant spacing is able to take advantage of optimal environmental factors [13].
Table 5. Yield and yield components of various population levels and candidate varieties. Gowa, 2020.

| Candidates/ Varieties | Production (t/ha) | Cob length (cm) | Cob diameter (cm) |
|-----------------------|-------------------|-----------------|-------------------|
|                       | 71.428            | 83.333          | 100.000           |
| ERC 01                | 10.34             | 11.08           | 11.74             |
| ERC 02                | 7.39              | 8.61            | 8.28              |
| ERC 03                | 8.30              | 11.57           | 12.82             |
| ERC 04                | 6.29              | 8.00            | 9.56              |
| ERC 05                | 8.12              | 8.93            | 11.14             |
| ERC 06                | 7.40              | 9.11            | 9.27              |
| ERC 07                | 8.81              | 8.95            | 11.18             |
| ERC 08                | 8.32              | 10.23           | 11.03             |
| JH 45                 | 8.30              | 10.13           | 10.20             |
| Pioneer 36            | 9.95              | 11.49           | 10.83             |
| Average               | 8.34              | 9.78            | 10.61             |
| LSD                   | 1.75              | 1.20            | 0.23              |
| KK %                  | 11.19             | 4.89            | 2.92              |

The number of CVUB lines (ERC 01, ERC 02, and ERC 03) from various population levels showed greater than the control varieties (JH 45 and Pioneer 36) (Table 6). This shows that the difference between CVUB and varieties on the number of rows is influenced by genetic factors. In general, each CVUB and varieties with an increase in plant population did not have a significant effect on the number of rows, namely 13.26 - 17.66 classified as good. Good criteria in the number of rows per cob is the range of 14 - 15 rows [17].

The number of seeds in the CVUB row and the control varieties did not differ significantly at various population levels. This shows that the number of row seeds is not affected by the population level and type of CVUB, so there is no significant difference. The number of seeds in a row is strongly influenced by the synchronous/timely pollination phase, which will form more optimal seeds. Synchronization of pollination and fertilization where the number of seeds formed is determined by the number of hairs pollinated by pollen and successfully reaches the process of fertilization and grain filling [11].

The weight of 100 seeds in a population of 71,248 plants/ha ERC 04 and ERC 07 was higher than that of the JH 45 and Pioneer 36 varieties. Meanwhile, the other CVUB did not significantly differ in the weight of 100 seeds with the same population level. In the population of 83,333 plants/ha and 100,000 plants/ha, the weight of 100 seeds was generally higher than the comparison variety and CVUB. The weight of 100 seeds is strongly influenced by genetics and growing environment, but with an increase in population it does not have a significant effect. The weight component of 100 seeds is influenced by genetic and environmental factors growing/population [1].
Table 6. Yield components among the treatment. Gowa, 2020.

| Candidates/ Varieties | Number of rows | Number of seeds in row | Weight 100 seeds (g) | Population (plant/ha) |
|-----------------------|----------------|------------------------|----------------------|-----------------------|
| ERC 01                | 71.428         | 83.333                 | 100,000              | 71.428                |
| ERC 02                | 15.46          | 15.07                  | 15.40                | 31.43                 |
| ERC 03                | 15.73          | 16.00                  | 16.00                | 33.80                 |
| ERC 04                | 13.26          | 13.33                  | 14.00                | 34.10                 |
| ERC 05                | 13.53          | 13.27                  | 13.53                | 32.13                 |
| ERC 06                | 13.73          | 13.73                  | 13.80                | 33.50                 |
| ERC 07                | 13.73          | 13.40                  | 13.67                | 36.07                 |
| ERC 08                | 14.33          | 14.67                  | 13.67                | 34.43                 |
| JH 45                 | 15.07          | 15.60                  | 15.33                | 33.50                 |
| Pioneer 36            | 14.67          | 14.87                  | 14.73                | 36.97                 |

Average 14.74 14.76 14.70 34.31 34.24 32.47 33.18 33.03 32.67

LSD 0.31 0.85 0.97

KK % 4.10 4.89 5.69

4. Conclusion
The increase in plant population has an effect on the grain yield, where CVUB tends to increase its productivity as the population increases (maximum 100,000 plants/ha), while the optimum production comparison variety is at a population of 83,333 plants/ha (Pioneer 36 (11.49 t/ha). Productivity ERC 01 and ERC 03 were superior to other CVUB and comparison varieties at various population levels, namely 8.30 - 12.82 t/ha.

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