Evaluation of prolific hybrids maize performance on different population densities and nitrogen level

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Abstract. Prolificacy in maize is an adaptability character, with influence on production capacity and production stability. Prolificacy is the maize natural property to develop more ears on the same plant. Prolificacy maize can produce more than one ear per plant so it can increase the production per unit area of land. In addition, prolific maize is able to utilize the growth factors more efficiently and has higher yield stability compared to non-prolific maize. Prolific hybrid maize is also reported to be more tolerant to low humidity during the pollination and kernel filling phases. This study aims to determine the prolific percentage and yield of maize hybrid tested at different levels of population density and nitrogen fertilization. The study was conducted in September-December 2017 in Gowa using two candidates varieties of hybrid maize and NASA 29 and Bisi 2 variety as comparisons. The experiments were arranged in a split-plot design with three replications. The main plot is the spacing, ie. double spacing (50+100 cm) x 25 cm (Population of 53,333 plants/ha) and (50+110 cm) x 20 cm (Population of 62,500 plants/ha) and (50 + 100 cm) x 20 cm (Population of 66,666 plants/ha). The subplots were the level of N fertilizer (150 and 225 kg N/ha), The sub-sub plot was the prolific hybrid genotypes (candidate for the multilocation test) and two check varieties of Bisi 2 and NASA 29. The result indicated that Bisi-2 variety has a high prolific percentage of 51.30%. 2. The Nasa-29 variety has the highest total kernel yield production of 11.5 t/ha. 3. Significant increase in yield per unit area can be achieved by assembling varieties that have a high percentage of prolific and average kernel weight per prolific plant ≥50% compared to the single-eared plants.

1. Introduction
The increase in population and the livestock industry has an impact on increasing corn demand. This is a great opportunity to increase maize productivity to meet domestic maize demands and international markets. The maize demand for livestock feed rations is estimated reached 55% while 30% is for food [1,2]. According to the Food Security Agency of Indonesia (BKP), Indonesia's maize consumption in 2017 is around 1.5 kg/capita/year [3].

To fulfill the national maize demand, several efforts can be done, one of them is by maximizing the genetic potential of corn plants, one of which by assembling maize varieties that can produce more than one ear in one plant. This potential is known as prolific traits. Maize has been studied for its prolific potential because modern maize was domesticated from teosinte (Zea mays subsp. parviglumis) which has many ears per plant [4,5]. Prolific maize can produce more than one ear per plant so it can increase the production per unit area of land [6]. In addition, prolific maize is able to utilize the growth factors more efficiently and has higher yield stability compared to non-prolific maize [7]. Prolific hybrid maize is also reported to be more tolerant to low humidity during the pollination and kernel filling phases [8,9].
The growth and productivity of prolific maize are influenced by the population density and nitrogen content [10,11,12]. Sarquis et al. [10] reported that high population density can reduce light interception by 30% which can suppress the growth of second ears in prolific maize. The management of plant population density can increase the yield and maize biomass by maximizing the leaf area index [13,14,15]. High plant population can increase the weight of dry stover, reduce crop index, and decrease crop productivity [16].

Nitrogen also affects the growth and productivity of prolific maize. Nitrogen is a macronutrient that can increase kernel production and protein content of the maize [16,17]. According to Abera et al., [18] 47% of nitrogen added to the soil will be utilized in kernel formation. Nitrogen plays a role in ears formation by influencing leaf area index that is effective to absorb photosynthetically active radiance [19,20]. The optimum dose of nitrogen fertilization can increase the yield up to 43-68% and biomass up to around 25-42% [21]. This study aims to determine the prolific percentage and yield of maize hybrid tested at different levels of population density and nitrogen fertilization.

2. Materials and Methods

The study was conducted in September-December 2017 in Gowa using two candidates varieties of hybrid maize and NASA 29 and Bisi 2 variety as comparisons. The experiments were arranged in a split-plot design with three replications. The main plot is the spacing, ie. double spacing (50+100 cm) x 25 cm (Population of 53,333 plants/ha) and (50+110 cm) x 20 cm (Population of 62,500 plants/ha) and (50 + 100 cm) x 20 cm (Population of 66,666 plants/ha). The subplots were the level of N fertilizer (150 and 225 kg N/ha), The sub-sub plot was the prolific hybrid genotypes (candidate for the multolocation test) and two check varieties of Bisi 2 and NASA 29.

Soil cultivation was carried out by maximum tillage in plots of 4.5m x 6m each. The first fertilization was done with NPK Phonska (15:15 15:15) at the age of 7-10 days after planting(dap) at a dose of 400 kg/ha equivalent to 60 kg N, P, and K per ha. The second fertilization was done at 30 dap with different level of N fertilizer according to the treatment (40 and 140 kg N/ha). The data of plant height, ear height, leaf area index, stem diameter, prolific percentage, seed yield, yield result and yield components (ear length, ear diameter, ear diameter, number of row, number of kernels/row, and 100 kernels weight were collected, leaf chlorophyll index was measured by using a chlorophyll meter Minolta 501.

3. Results and Discussions

3.1. Prolific Percentage

The percentage of plants that have more than one ear or prolific were significantly influenced by varieties and spacing. Of these two factors, variety (genetic) is more dominantly influencing the percentage of prolific plants than the spacing (population). This can be seen from the mean square value of the variety factor was greater (5,854.80) than the plant spacing factor (495.70) (Table 1). The study by Worrajinda et al. [22] also reported that the genotype had a very significant effect on the number of ears with a mean square value of 23.92%.
The percentage of prolific plants in Bisi 2 variety (51.30%) was significantly higher than the percentage of prolific plants in Nasa 29 (32.80%) (Figure 1). The number of ears per plant and other ear characters were influenced by the genetic makeup of each maize genotypes [23].

Figure 1. Percentage of prolific plants in Nasa 29 and Bisi 2 varieties.

Table 1. Analysis of variance on the effect of nitrogen level, spacing/population and varieties on the percentage of prolific, and yields.

| Variables       | Non Prolific Percentage | Prolific Percentage | Yield of prolific ear | Total yield |
|-----------------|--------------------------|---------------------|-----------------------|-------------|
|                 | Replications             | 21,75               | 21,75                 | 0           |
|                 | Nitrogen (N)             | 1,56                | 1,56                  | 0,01        |
|                 | Standard Error (N)       | 33,70               | 33,70                 | 0,01        |
|                 | Spacing (JT)             | 495,75              | 495,75                | 8,25        |
|                 | N*JT                     | 16,40               | 16,40                 | 0,19        |
|                 | Standard Error (JT)      | 102,56              | 102,56                | 1,23        |
|                 | Varieties (V)            | 5854,8              | 5854,8                | 54,51       |
|                 | N*V                      | 24,83               | 24,83                 | 0,05        |
|                 | JT*V                     | 10,75               | 10,75                 | 0,01        |
|                 | N*JT*V                   | 26,79               | 26,79                 | 1,58        |
|                 | Standard Error           | 65,36               | 65,36                 | 1,51        |
|                 | Total                    | 6654                | 6654                  | 67,8        |

Note: * Significant at α level of 5%, ** Highly significant on α level of 1%, n = not significant on α level of 5%.
The percentage of prolific was not only influenced by the genetic but also significantly influenced by the level of plant population density per unit area. The higher the plant population per unit area, the lower the percentage of prolific plants. The results showed that the percentage of prolific plants in the population of 53,333 plants/ha is quite high at 44.42% but decreases to 31.69% at a higher population density of 66,666 plants/ha (Figure 2). The decrease is due to increased competition for light, CO2, water, and air circulation around the plant canopy at higher population levels [13,24].

![Figure 2. Percentage of prolific and non-prolific plants on a different level of spacing/population.](image)

The level of nitrogen fertilization of 150 and 225 kg/ha did not significantly affect the percentage of prolific plants. Percentage of prolific plants on the level of N fertilizer of 150 kg N/ha and 225 kg N/ha were both 38% (Figure 3).

![Figure 3. Percentage of plants with prolific and non-prolific characters at N fertilizer level of 150 and 225 kg N/ha.](image)
3.2. Yield

Average kernels weight per prolific plant was significantly affected by variety and spacing. The average kernels weight per prolific plant in BISI 2 variety was significantly lower than NASA 29 variety, where the average kernels weight of the prolific maize per plant on BISI 2 variety was 229.10 g while the NASA 29 variety was 258.20 g (Figure 4). However, the contribution of the prolific maize Bisi 2 variety to the yield per unit area was significantly higher (63.20%) compared to Nasa 29 variety of 39.30% (Figure 6). That is because the prolific ears of Bisi 2 variety are bigger than Nasa 29 varieties. The difference in weight of ears among varieties is due to genetic factors. The differences in weight, diameter, and length of the ear are affected by genetic factors of the maize [25,26].

![Figure 4. Average kernel weight per plant in prolific maize varieties of Nasa-29 and Bisi-2.](image)

Plant spacing/population also significantly influenced the weight of the kernels per plant in prolific maize. The highest average of kernel weight per prolific plant population was found in the population of 53,333 plants/ha which was 257.90 g and the lowest was in the population of 66,666 plants/ha which was 234.50 g. High plant population density can cause reduced leaf area index and photosynthetically active radiance (PAR) interception which plays a role in photosynthesis and kernel formation [15,26,27].

![Figure 5. Average kernel weight per plant in prolific maize hybrid on different plant spacing/populations.](image)
Varieties significantly influenced the yield of the prolific hybrid maize that were tested, while spacing and nitrogen fertilization did not significantly influence the yield (Table 1). The yield from prolific plants in Bisi 2 variety were 5.90 t/ha higher than Nasa 29 varieties with yield from prolific plants of 4.60 t/ha (Figure 6). However, the total yield obtained by Nasa 29 was higher (11.5 t/ha) compared to Bisi 2 variety (10.40 t/ha). That is because the contribution of kernels from a single eared plant in Nasa 29 was 6.90 t/ha compared to 4.50 t/ha on Bisi 2.
The productivity of hybrid maize varieties that have a higher percentage of prolific plants such as Bisi 2 was not enough to increase the yield per unit area. This is due to the lower average of kernel weight of prolific plants and single eared plants in Bisi 2 than in Nasa variety 29 which has a lower percentage of prolific plants (Figure 4). In addition, the average kernel weight/plants in prolific plants (Bisi 2 and Nasa 29) is only 28% higher than the average weight of kernels/plants in single eared plants, so to increase significantly amount of yield per unit area the other important aspect aside from high percentage of prolific level, but also the average weight of kernels/plants of prolific plants have to be ≥50% higher than single eared plant.

4. Conclusions
1. The Bisi-2 variety has a high prolific percentage of 51.30%.
2. The Nasa-29 variety has the highest total kernel yield production of 11.5 t/ha.
3. Significant increase in yield per unit area can be achieved by assembling varieties that have a high percentage of prolific and average kernel weight per prolific plant ≥50% compared to the single-eared plants.

5. Authorships
Roy Efendi and Baharuddin are the main authors, Herawati, N N Andayani, S H Kalqutny and M Azrai are co-authors

References
[1] Panikkai S, Nurmalina R, Mulatsih S, and Purwati H. 2017. Analisis Ketersediaan Jagung Nasional Menuju Pencapaian Swasembada Dengan Pendekatan Model Dinamik. Inform. Pertan. 26(1): 41–48.
[2] Kasryno F, Pasandaran E, and Adnyana MO. 2007. Gambaran Umum Ekonomi Jagung Indonesia. Pusat Penelitian dan Pengembangan Tanaman Pangan. Badan Penelitian dan Pengembangan Pertanian.
[3] Badan Ketahanan Pangan. 2017. STATISTIK KETAHANAN PANGAN 2017. Jakarta.
[4] Wills DM, Whipple CJ, Takuno S, Kursel LE, Shannon LM, Ross-Ibarra J, and Doebley JF. 2013. From Many, One: Genetic Control of Prolificacy during Maize Domestication. PLoS Genet. 9(6). doi: 10.1371/journal.pgen.1003604.
[5] da Fonseca RR, Smith BD, Wales N, Cappellini E, Skoglund P, Fumagalli M, Samaniego JA, Caroe C, Ávila-Arcos MC, Hufnagel DE, Korneliusen TS, Vieira FG, Jakobsson M, Arriaza B, Willerslev E, Nielsen R, Hufford MB, Albrechtsen A, Ross-Ibarra J, and Gilbert MTP. 2015. The origin and evolution of maize in the Southwestern United States. Nat. Plants 1: 14003. https://doi.org/10.1038/nplants.2014.3.
[6] Muyassir. 2013. Respon Jagung Tongkol Ganda (Zea mays L) Terhadap Pemupukan Urea dan Kompos. J. Manaj. Sumberd. Lahan 2(3): 250–254.
[7] Varga B, Svečnjak Z, Knežević M, and Grzeša D. 2004. Performance of prolific and nonprolific maize hybrids under reduced-input and high-input cropping systems. F. Crop. Res. 90: 203–212. doi: 10.1016/j.fcr.2004.03.003.
[8] Meskelu E, Mohammed M, and Hordoфа T. 2014. Response of Maize ( Zea mays L.) for Moisture Stress Condition at Different Growth Stages. Int. J. Recent Res. Life Sci. 1(1): 12–21.
[9] Yang H, Grassini P, Cassman KG, Aiken RM, and Coyne PI. 2017. Improvements to the Hybrid-Maize model for simulating maize yields in harsh rainfed environments. F. Crop. Res. 204: 180–190. doi: 10.1016/j.fcr.2017.01.019.
[10] Sarquis JI, Gonzalez H, and Dunlap JR. 1998. Yield response of two cycles of selection from a semiprolific early maize (Zea mays L.) population to plant density, sucrose infusion and pollination control. F. Crop. Res. 55: 109–116. doi: 10.1016/S0378-4290(97)00071-3.
[11] Otegui ME. 1995. Prolificacy and grain yield components in modern argentinian maize hybrids. *Maydica* **40**: 371–376.

[12] Tahir M, Tanveer A, Ali A, Abbas M, and Wasaya A. 2008. Comparative Yield Performance of Different Maize (Zea mays L.) Hybrids under Local Conditions of Faisalabad-Pakistan. *Pakistan J. Life Soc. Sci.* **(6)(2)**: 118–120. [http://www pjiss edu pk/ pdf_files/ 2008_2/ 11_tahir118-120.pdf](http://www.pjiss.edu.pk/pdf_files/2008_2/11_tahir118-120.pdf).

[13] Opoku E. 2017. Effect of row width and plant population density on yield and quality of maize (Zea mays) silage. Lincoln Univ. doi: 10.1007/s11104-010-0533-9.

[14] Testa G, Reyneri A, and Blandino A. 2016. Maize grain yield enhancement through high plant density cultivation with different inter-row and intra-row spacings. *Eur. J. Agron.* **72**: 28–37. doi: 10.1016/j.eja.2015.09.006.

[15] Sher A, Khan A, Cai LJ, Ahmad MI, Ashraf U, and Jamoro SA. 2017. Response of Maize Grown Under High Plant Density; Performance, Issues and Management - A Critical Review. *Adv. Crop Sci. Technol.* **5**(3): 1–8. doi: 10.4172/2329-8863.1000275.

[16] Valadabadi SA, and Farahani HA. 2010. Effects of planting density and pattern on physiological growth indices in maize (Zea mays L.) under nitrogenous fertilizer application. *J. Agric. Ext. Rural Dev.* **2**(3): 40–47.

[17] Perchlik M, and Tegeder M. 2017. Improving Plant Nitrogen Use Efficiency through Alteration of Amino Acid Transport Processes. *Plant Physiol.* **175**: 235–247. doi: 10.1104/pp.17.00608.

[18] Ahere T, Debele T, and Wegary D. 2017. Effects of Varieties and Nitrogen Fertilizer on Yield and Yield Components of Maize on Farmers Field in Mid Altitude Areas of Western Ethiopia. *Int. J. Agron.* **2**: 1–13.

[19] Skonieski FR, Viégas J, Martin TN, Nörnberg JL, Meinerz GR, Tonin TJ, Bernhard P, and Frata MT. 2017. Effect of seed inoculation with Azospirillum brasilense and nitrogen fertilization rates on maize plant yield and silage quality. *Brazilian J. Anim. Sci.* **46**(9): 722–730.

[20] Imran S, Arif M, Khan A, Khan MA, Shah W, and Latif A. 2015. Effect of Nitrogen Levels and Plant Population on Yield and Yield Components of Maize. *Adv. Crop Sci. Technol.* **3**(2): 1–7. doi: 10.4172/2329-8863.1000170.

[21] Ogola JBO, Wheeler TR, and Harris PM. 2018. Effects of nitrogen and irrigation on water use of maize crops. *F. Crop. Res.* **78**: 105–117. doi: 10.1016/S0378-4290(02)00116-8.

[22] Worrajinda J, Lertrat K, and Suriharn M. 2013. COMBINING ABILITY OF SUPER SWEET CORN INBRED LINES WITH DIFFERENT EAR SIZES FOR EAR NUMBER AND WHOLE EAR WEIGHT. SABRAO J. Breed. Genet. **45**(3): 468–477.

[23] Xiao Y, Tong H, Yang X, Xu S, Pan Q, Qiao F, Sharif M, Luo Y, Liu H, Zhang X, Yang N, Wang X, Deng M, Jin M, Zhao L, Luo X, Zhou Y, Li X, Liu J, Zhan W, Liu N, Wang H, Chen G, Cai Y, Xu G, Wang W, Zheng D, and Yan J. 2016. Genome-wide dissection of the maize ear genetic architecture using multiple populations. *New Phytol.* **210**: 1095–1106.

[24] Enujeke. 2013. Effects of Variety and Spacing on Growth Characters of Hybrid Maize Asian Journal of Agriculture and Rural Development. *Asian J. Agric. Rural Dev.* **3**(35): 296–310. [http://aessweb.com/journal](http://aessweb.com/journal).

[25] Syafruddin, Nurhayati, and Wati R. 2012. Pengaruh Jenis Pupuk Terhadap Pertumbuhan Dan Hasil Beberapa Varietas Jagung Manis. *J. Floratek* **7**: 107–114.

[26] Khairiyah, Khadijah S, Iqbal M, Erwan S, and Norliam M. 2017. pertumbuhan dan hasil tiga varietas jagung manis (zea mays saccharata sturt) terhadap berbagai dosis pupuk organik hayati pada lahan rawa lebak. *ziraa‘ah* **42**(3): 230–240.

[27] Gitelson AA, Arkebauer TJ, and Suyker AE. 2015. Productivity absorbed photosynthetically active radiation , and light use efficiency in crops : Implications for remote sensing of crop primary production. *J. Plant Physiol.* **177**: 100–109. doi: 10.1016/j.jplph.2014.12.015.