Effect of double rows plant system on plant growth, yield components and grain yield in prolific and non-prolific hybrid maize

S Alimuddin$^{1,2}$, Y Musa$^3$, M Azrai$^3$ and L Asrul$^4$

$^1$Student of Graduated School, Universitas Hasanuddin, Makassar, Indonesia
$^2$Lecturer at Agrotechnology Study Program, Faculty of Agriculture, Universitas Muslim Indonesia, Makassar, Indonesia
$^3$Lecturer at Agrotechnology Study Program, Faculty of Agriculture, Universitas Hasanuddin, Makassar, Indonesia
$^4$Head of the Balai Penelitian Tanaman Serealia, Maros

E-mail: alimuddinsuraedah@yahoo.com

Abstract. Double row plant systems in corn plants theoretically can improve the efficiency of light interception in leaves, but their effect on grain yields is not consistent in each hybrid type. This research was conducted in the experimental garden of the Balai Penelitian Tanaman Serealia (Balitsereal) Maros Regency, South Sulawesi. This study aimed to evaluate the response of yields of prolific and nonprolific hybrid corn types to the double row and single row planting systems. Experimental design using Randomized Group Design in divided plot design that was carried out with three replications. The main plot was variety Nasa-29, Bisi-2 (prolific), Bima-19 (nonprolific), while subplot was a double row and single row. The double row planting system did not have a significant effect on plant height, number of leaves, and leaf area index (ILD), but a significant positive effect was found on the number of grains per row of ears, number of ears per plant, and percentage of the weight of the second ear’s grains to the total yield and grain yield. In this study, the significant effect of double rows on each variety tested was not seen on all parameters tested. The double row planting system significantly increases the grain yield and the grain yield was consistent with the increase in the number of ear rows, the number of ear per plant and the percentage of grain weight of the second ears on yield, but not on plant height. The leaf area index achieved in this study may be one of the determinants of increased grain yield. A double row system can be considered as an alternative planting system, especially in the type of prolific hybrid corn to increase the contribution of two ears to grain yield.

1. Introduction

Corn (Zea mays L.) is an important food crop in Indonesia because it is the second source of carbohydrates after rice. Demand for corn continues to increase as a result of increased food, feed, and industrial needs. By recognizing the function and important role of corn, the government is trying to realize corn self-sufficiency by sustainably increasing corn production.

One effort that can be done to achieve self-sufficiency in maize is by planting prolific hybrid maize. According to [1], prolific type hybrid corn is hybrid corn which regularly produces more than
one ear per plant. Research showed that there was no significant difference in yield between prolific maize compared to the free pollinated varieties on single ears, but the total yield was significantly higher in prolific maize than the free pollinated varieties due to the contribution of yield from the second ear [2]. The same was reported by Durieux et al., (1993) that there was a significant contribution of yield from two ears to the total yield of grains in corn [3].

The development of the second ear on prolific maize is highly dependent on environmental conditions [4], accumulation of dry matter [5], photosynthetic activity, the efficiency of partition ratio of dry matter to ear and R / L ratio (root dry weight per unit leaf area) [6]. The rate of accumulation of plant dry matter is determined by the efficiency of photosynthesis, while the rate of photosynthesis is closely related to the proportion of radiation that can be intercepted by leaves. Sun et al., (2019) stated that leaves are the main organ for photosynthesis (about 95%) [7]. The ability of plants to absorb a certain amount of light is determined by the surface area of the leaf that receives light which can be demonstrated by the large leaf area index. The LAI is an important agronomic parameter that reflects plant growth and yield [8]. Corn leaf area affects grain yield [9].

A double row planting system is a form of technological engineering to optimize crop productivity through the spacing between rows. Double rows is a cropping pattern that alternates between two rows of plants and one empty row. The distance between the two double rows is narrower (compared to the distance between the two rows in the single row system), while the empty row gives an open space of 25-50% [10], so that each plant in the row is considered a border plant that receives relatively more light than a single row planting (conventional). Subekti et al., (2015) also suggested that the effect of peripheral plants was greater light reception so that the process of maximum assimilation can provide more production [11]. The results showed that the rice plants on the edge produced 1.5-2 times higher than the production of rice plants that are on the inside [10].

Research on the double row planting system in maize plants showed varied results. According to [12] maize planted with a double row system increases yields by 12.5% than conventional planting systems, and [13] states that a double row in corn increases the diameter of the stem (from 18.4 to 18.8 mm), ear length (from 18.0 to 18.2 cm), grain weight per ear (149.7 to 154.0 g), and grain yield (from 9986 to 10398 kg ha⁻¹). However, [14] reported that the application of twin rows in corn plants had a small and inconsistent effect on grain yield, yield components, plant morphology, leaf area, interception of solar radiation during vegetative growth, and enlargement of the ear. The results of the study [15] in 2010 showed that there was no significant difference in results between double rows vs single rows.

The application of double rows in prolific and non-prolific hybrid corn plants is expected to increase production through increased photosynthetic efficiency due to reduced competition between plants in terms of light absorption, nutrition, and water, which causes increased grain yield. Hybrid types have varied morphological characters so that they have different tolerances in responding to changes in environmental conditions due to spacing between lines. The purpose of this study was to evaluate how the yield response of prolific and nonprolific hybrid corn varieties to the double row and single row planting systems.

2. Methods

2.1. Location
This research was conducted in 2017 at the Maros Balai Penelitian Tanaman Sereal (Balitsereal) Experimental Garden located in Gowa Regency, South Sulawesi, Indonesia.

2.2. Experimental design
This research was conducted using a randomized block design and arranged in the form of a plot design divided by three replications. The main plot was varieties: Nasa-29 and Bisi-2 (prolific), Bima-19 (nonprolific), while subplot is a double row and single row.
2.3. Plant preparation and maintenance

The main plot is 16m x 3m and the subplot is 5m x 3m. Nasa-29, Bisi-2, and Bima-19 varieties are planted with a distance of 50 cm for a gap between two twin rows and 100 cm between twin rows, 20 cm for spacing in rows, while for single rows planted 75 cm between rows and 20 cm in line. One plot consisted of 100 plants.

Fertilization was done using urea and NPK of 300 kg ha\(^{-1}\) each. The urea application is carried out twice, at the age of 7 and 30 days after planting, while the application of NPK fertilizer was done at the same time with the first fertilization of urea. Land irrigation is done every week by flowing water in the area between plots.

2.4. Observation variable

In each plot, eight sample plants were selected to measure plant height, number of leaves, ILD, number of grains per row of ears, number of rows of ears, the weight of 100 grains, and weight of grains per plant. The leaf area index is calculated using the formula:

\[
ILD = \frac{LD}{\text{area}} \quad [16]
\]

While the total leaf area is calculated using the formula:

\[
LD = p \times l \times k \quad [17]
\]

\[LD = \text{total leaf area of the plant}\]
\[p = \text{leaf length}\]
\[l = \text{widest leaf width}\]
\[k = \text{constant (9.39)}\]

In sample plants, the eighth leaf was measured from the top at the silking stage to determine the width and width of the widest leaf. The number of ears per plant and the percentage of the weight of the second grain ears on the yield obtained from the number of ears harvested in each plot, while the weight of grain crops and grain yields are obtained by drying the grain samples to a moisture content of about 15%.

2.5. Data analysis

Data analysis was performed using ANOVA to evaluate the effect of the treatment and its interactions on the variables tested. The treatments that were stated to be significantly different were tested using the Least Significant Difference test at levels 0.05 and 0.01.

3. Results and discussion

3.1. Plant Growth

The results of this study indicate that the height of the Bisi-2 plant which was 239.83 cm was the highest and was significantly different from the height of Nasa-29 and Bima-19 plant. The double row planting system did not have a significant effect on the three varieties tested both on plant height and on the number of leaves. Variety type had a significant effect on ILD. The Nasa-29 variety had an ILD value of 6.51 (m\(^2\) m\(^{-2}\)), significantly higher than that of 5.93 (m\(^2\) m\(^{-2}\)) in Bisi-2, and 5.83 (m\(^2\) m\(^{-2}\)) in Bima-19 (table 1). ILD value in this study was in the 50% silking phase. ILD values describe the efficiency level of light utilization by leaves for photosynthesis and have a close relationship with grain filling. Different ILD values in the three varieties used indicated the different leaf growth responses due to the differences in plant tolerance to double rows, also can be caused by differences in leaf character in the light interception. Differences in plant morphological patterns in maize cause differences in the distribution of light in the canopy so that it affects photosynthesis [18]. The double row system showed a lower ILD value (6.00) compared to 6.20 in the single row system. Similarly, between varieties, ILD was also lower in double row plant system compared to the ILD in single row.
plant system 6.31 and 6.71, respectively in NASA-29, 5.79 and 6.07, respectively in Bisi-2 (both varieties are prolific types). Only in Bima-19 (nonprolific types) ILD in double row plant system showed a higher ILD 5.91 compared to 5.81 in a single plant system. However the difference was not significant. In Bima-19 the ILD value was in line with the number of leaves. However, in NASA-29 and Bisi-2 showed the reverse. The development of corn canopy which affects the ILD value, not only influenced by the double row planting system, it may also be determined by the different leaf morphological characters.

**Table 1.** Effect of double row and single row to plant height, leaf number, and leaf area index on prolific and nonprolific maize.

| Treatment | Plant height (cm) | Leaf Number (plant⁻¹) | Leaf area index (m² m⁻²) |
|-----------|------------------|-----------------------|-------------------------|
| Variety   |                  |                       |                         |
| Nasa-29 (prolific) | 212.33b | 16.81 | 6.51a |
| Bisi-2 (prolific) | 239.83a | 17.33 | 5.93b |
| Bima-19 (nonprolific) | 206.50b | 16.50 | 5.86b |
| Plant system | F test | * | ns | * |
|              | LSD(0.05) | 18.33 | 0.47 |
| Plant system | Double Row | 218.17 | 17.06 | 6.00 |
|              | Single Row | 220.94 | 16.70 | 6.20 |
| Tipe hibrida | F test | ns | ns | ns |
|              | LSD(0.05) | ns | ns | ns |

*N* significant (p<0.05)

*ns* = not significant

3.2. **Yield component and grain yield**

In this study, prolific and nonprolific hybrids produced significantly different numbers of grain per ear row and row number per ear. The number of grains per ear row in NASA-29 (39.31) was significantly higher than in Bisi-2 (38.06) and Bima-19 (36.53). While the highest number of lines per ear was 14.49 in Bima-19, which significantly higher than in Bisi-2 (12.06) but not significant with those in NASA-29 (14.17). The weight of 100 grains did not show a significant difference in yield among the hybrids tested, Nasa-29 showed the weight of 100 grains, which tended to be the highest. It seems that the weight of 100 grains shows an inconsistent relationship with the number of grains per row of ears (Table 2)

The double row planting system significantly showed a higher grains number per ear row, which was 3.67 grains or 9.34% from the single row system. Although, this study did not show a significant interaction between hybrid types and planting systems on the number of grains per row of ear, the
number of rows per ear, and the weight of 100 grains, it seems that the double rows tend to have a higher number (although not significantly) of grains per row of ear, the number of rows per ear, and the weight of 100 grains on each hybrid type tested and the value is in line with each other among the three parameters.

The effect of the double row planting system on the higher number of grains per row of the ear might be due to a more optimal radiation interception thereby increasing the efficiency of photosynthesis in producing a number of assimilates that have an impact on the higher maximum number of kernels filled. The higher number of leaves in a double row may be one of the causes of the high number of grains because the leaves are the most important organ that contributes to the yield of corn. Corn leaves are the main organ for photosynthesis, which is about 95% of the total [7], because corn leaves provide energy for plant growth and development [14]. The higher number of grains per row of the ear by 9.34% in double rows (39.30 grains) compared to those in a single row system (36.63 grains) may also be related to ILD values in double rows. The leaf area index achieved in this study was from 5.71 in the double row Bisi-2 to 6.79 in the single line Nasa-29. The highest number of grains per row of the ear at 39.30 in the double row was achieved at ILD 6.00 m² m⁻² (silking stage). The optimal maximum leaf area index for corn is 5-6 [7]. ILD values that are too high indicate the formation of a denser canopy and the covering effect of the leaves in a higher position, the upper leaves will cover the leaves underneath. Whereas lower ILD showed inefficient use of light for photosynthesis. The leaf area index with a value of 6.00 m² m⁻² in the double row achieved in this study included the optimum ILD value of the silking stage so that it was thought to lead to more efficient utilization of the light by the leaves for grain formation. Sun et al., (2019) suggested that the level of photosynthesis and grain filling in plants is directly influenced by the leaf area duration and ILD [7]. Robles et al., (2012) results stated that the average ILD at the silking stage produced a value of 4.4 m² m⁻² in double rows and 4.2 m² m⁻² for single rows [15].

The number of ear lines and weight of 100 grains was not significantly affected by the planting system, but the number of ear row and weight of 100 grains slightly higher 0.42 (from 13.36 to 13.78) and 0.72 g (from 30.41 to 31.13 g). The higher number of ear rows and the weight of 100 grains in each hybrid tested were in line with the number of leaves but not with plant height.

Table 2. Effect of double row and single row to grain number, rows number, and grain-100 weight on maize prolific and nonprolific.

| Treatment        | Grain number (ear row⁻¹) | Row number (ear⁻¹) | Grain 100 weight (g) | F test | LSD(0.05) |
|------------------|--------------------------|-------------------|----------------------|--------|-----------|
| Variety          |                          |                   |                      |        |           |
| Nasa-29 (prolific) | 39.31a                   | 14.17a            | 31.33                |        |           |
| Bisi-2 (prolific) | 38.06ab                  | 12.06b            | 29.77                |        |           |
| Bima-19 (nonprolific) | 36.53b                 | 14.49a            | 31.06                |        |           |
|                  | F test                   | *                 | *                    |        | ns        |
|                  | LSD(0.05)                | 1.65              | 1.03                 |        |           |
| Plant system     |                          |                   |                      |        |           |
| Double row       | 39.30a                   | 13.78             | 31.13                |        |           |
| Single Row       | 36.63b                   | 13.36             | 30.41                |        |           |
|                  | F test                   | *                 | ns                   |        | ns        |
|                  | LSD(0.05)                | 2.43              | ns                   |        |           |
IOP Conf. Series: Earth and Environmental Science 473 (2020) 012013 doi:10.1088/1755-1315/473/1/012013

|       | Nasa-29 |        |        |       | Bisi-2 |        |        |       | Bima-19 |        |        |       |
|-------|---------|--------|--------|-------|--------|--------|--------|-------|---------|--------|--------|-------|
|       | Double Row | 41.78  | 14.33  | 31.84 | Double Row | 38.50  | 12.22  | 30.23 | Double Row | 37.61  | 14.78  | 31.33 |
|       | Single Row | 36.83  | 14.00  | 30.81 | Single Row | 37.61  | 11.89  | 29.65 | Single Row | 35.46  | 14.20  | 30.78 |
| F test| ns      | ns     | ns     |       |        |        |        |       |        |        |        |       |
| LSD(0.05) | ns | ns | ns |       |        |        |        |       |        |        |        |       |

*significant (p<0.05)
ns = not significant

The number of ears per plant, grain weight per ear, percentage weight of second ear grains to the total weight of grains per plot and yield of grains in prolific and nonprolific hybrids showed significant differences. The number of ears per plant showed that two hybrids of the prolific type, Nasa-29, and Bisi-2, produced 1.32 and 1.43 ears, respectively, which were significantly higher than in Bima-19 (1.06). The same thing was shown by the percentage weight of the second ear grains to the total weight of grains per plot where Nasa-29 (11.37%) and Bisi-2 (17.32%) also showed a significant difference with Bima-19 (2.5%). This is due to the nature of its proliferation which has an impact on the high weight of grains per plant and yield of grains per hectare. Proliferation in maize is the ability of a plant to produce more than one ear [2]. The high percentage of the weight of the second ear on the total weight of grains per plot in the prolific type is caused by the formation of the second ear on a number of plants in each plot so that it directly increases the weight of the grains of the plot. In prolific maize, the yield of grains from the second ear gives a significant contribution to the total yield [3].

In this study, the highest yield or grain production was 10.17 t ha\(^{-1}\) in NASA-29 which was significantly higher than the production of grains in Bisi-2 (8.68 t ha\(^{-1}\)) and in Bima-19 (8.25 t ha\(^{-1}\)). However, the number of ears per plant and the second contribution of ears to yield was highest in Bisi-2 (table 3). This shows that the high yield obtained is not only determined by the number of ears per plant and the contribution of the second ear but also determined by the number of rows per ear, number of grains per row, weight of 100 grains, and weight of grains per plot and yield of grains (unpublished).

The application of the double row system significantly affected the number of ears per plant, the percentage weight of the second ear grains to yield, and grain production while the weight of the ears per plot did not show a significant difference. The higher value in yield per hectare grain in the application of double rows was supported by the higher number of ears per plant and the percentage weight of the second ear grains to yield. It can be explained that the formation of more than one ear per plant and the higher value in the weight of the second ear grains may be related to the greater number of leaves and optimal ILD achievement in double rows so that an increase in a light interception by a more optimal canopy as well. Double row system causes plants at the beginning of vegetative growth did not compete with each other, especially in terms of light because there was a wider free space. The formation of the second ear of corn was also determined by the initial conditions of the plant that can support the adequate accumulation of assimilates for the formation of the ear. Determination of the development of ear on corn plants has been started since the growth phase of V5-V6, i.e., plants have perfect leaves of 5-6 leaves [19]. Collins et al., (1965) concluded that environmental factors such as soil moisture, nitrogen supply, and the availability of adequate assimilation, led to the development of a second ear able to compete with one ear to form grains [20].
Table 3. Effect of Double row and Single Row to Ear Number, Grain Weight at Second Ear, Grain Weight per Plant, and Grain Yield on Maize Prolific and Nonprolific.

| Treatment | Ear number (plant⁻¹) | Grain weight at double ear (%) | Grain weight (kg plant⁻¹) | Grain yield (t ha⁻¹) |
|-----------|----------------------|--------------------------------|---------------------------|----------------------|
| Variety   |                      |                                |                           |                      |
| Nasa-29 (prolific) | 1.36a                | 11.77b                         | 1.38a                      | 10.17a               |
| Bisi-2 (prolific)   | 1.38a                | 17.32a                         | 1.15b                      | 8.68b                |
| Bima-19 (nonprolific) | 1.06b                | 2.50c                          | 1.13b                      | 8.25b                |
| Plant system       |                      |                                |                           |                      |
| Double row         | 1.33a                | 12.96a                         | 1.32                      | 9.58a                |
| Single Row         | 1.22b                | 8.10b                          | 1.12                      | 8.49b                |
| Variety             |                      |                                |                           |                      |
| Nasa-29             |                      |                                |                           |                      |
| Double row         | 1.44                 | 15.38                          | 1.48                      | 10.97                |
| Single Row         | 1.30                 | 8.15                           | 1.27                      | 9.37                 |
| Bisi-2             |                      |                                |                           |                      |
| Double row         | 1.47                 | 20.28                          | 1.21                      | 8.92                 |
| Single Row         | 1.29                 | 14.35                          | 1.10                      | 8.43                 |
| Bima-19             |                      |                                |                           |                      |
| Double row         | 1.17                 | 3.22                           | 1.25                      | 8.84                 |
| Single Row         | 1.11                 | 1.78                           | 1.00                      | 7.66                 |

F test, LSD(0.05)

| Variety | Plant system | F test  | LSD(0.05) |
|---------|--------------|---------|-----------|
| Nasa-29 |              | *       | 0.10      |
| Bisi-2  |              | *       | ns        |
| Bima-19 |              | *       | ns        |

*significant (p<0.05)
ns = not significant

4. Conclusions

Different types of varieties show significant differences in yield components and yield of grains. The double row planting system did not have a significant effect on plant height, the number of leaves, and ILD, but a significant positive effect was found on the number of grains per row of ears, number of ears per plant, and weight percentage of two ear grains on total yield and yield of grains. In this study, the significant effect of double rows on each variety tested was not apparent on all parameters tested.

The double row planting system significantly increases the yield of grains and the yield of these grains is consistent with the increase in the number of ear rows, the number of ear per plant and the percentage of grain weight of two ears on yield, but not on plant height. The leaf area index achieved in this study may be one of the determinants of increasing grain yield. A double row system can be considered as an alternative planting system, especially in the type of prolific hybrid corn to increase the contribution of two ears to the yield of grains.

Acknowledgment

We thank Balai Penelitian Tanaman Serealia Maros for all the facilities provided during this research. To all experimental garden staff in Balit Sereal Bajeng, thank you for the technical assistance provided.
References

[1] Gardner J C, Schatz B G and Olson H M 1987 Performance of a prolific and a non-prolific corn hybrid in central North Dakota *North Dakota farm Res. Dakota, Agric. Exp. Stn.*

[2] Brathwaite O and Brathwaite R A I 2002 Multiple ear effects on yield of maize varieties under tropical wet and dry season conditions [Zea mays L.] *Maydica (Italy)*

[3] Durieux R P, Kamprath E J and Moll R H 1993 Yield contribution of apical and subapical ears in prolific and nonprolific corn *Agron. J.* **85** 606–10

[4] Russell W A 1968 Testcrosses of One-and Two-Ear Types of Corn Belt Maize Inbreds. I. Performance at Four Plant Stand Densities 1 *Crop Sci.* **8** 244–7

[5] Kimio N and Gotoh K 1978 Phycio-ecological Studie on Prolificacy in Maize. The relationship between expression of second ear and some physio-ecological characteristic *Jour. Crop Sci* **47**

[6] H. S, Nakaseko K and Gotoh K 1977 Phycio-ecological Studie on Prolificacy in Maize. Diffrence in dry matter accumulation between prolific and single-ear type hybrid *Japan. Jour. Crop Sci* **47** 206–11

[7] Sun J, Gao J, Wang Z, Hu S, Zhang F, Bao H and Fan Y 2019 Maize Canopy Photosynthetic Efficiency, Plant Growth, and Yield Responses to Tillage Depth *Agronomy* **9** 3

[8] Yin W, Chai Q, Guo Y, Feng F, Zhao C, Yu A and Hu F 2016 Analysis of leaf area index dynamic and grain yield components of intercropped wheat and maize under straw mulch combined with reduced tillage in arid environments *J. Agric. Sci* **8** 26–42

[9] Lambert R J, Brian D M and Rita H M 2014 Effect of leaf area on maize productivity *Maydica* **59** 58–63

[10] Juanda D 2015 *Teknologi Sistem Tanam Jajar Legowo* (Jawa Barat: Pengelolaan Tanaman Terpadu)

[11] Subekti N, Priatmojo A B and Nugraha D 2015 *Jajar Legowo Pada Jagung: Keunggulan, Kelemahan, dan Potensi Perbaikannya* (Bogor: Pusat Penelitian dan Pengembangan Tanaman Pangan)

[12] Jones B P 2010 Effects of Twin-Row Spacing on Corn Silage Growth Development and Yield in the Shenandoah Valley

[13] Gozubenli H, Kilinc M, Sener O and Konuskan O 2004 Effects of single and twin row planting on yield and yield components in maize *Asian J. Plant Sci* **3** 203–6

[14] Novacek M J 2011 Twin-Row Production and Optimal Plant Population for Modern Maize Hybrids

[15] Robles M, Ciampitti I A and Vyn T J 2012 Responses of maize hybrids to twin-row spatial arrangement at multiple plant densities *Agron. J.* **104** 1747–56

[16] Gardner F P, Pearce R B and Mitchell R L 2017 *Physiology of crop plants.* (Scientific Publishers)

[17] Pearce R B, Mock J J and Bailey T B 1975 Rapid Method for Estimating Leaf Area Per Plant in Maize *Crop Sci.* **15** 691–4

[18] Guo J, Xiao K, Guo X and Zhao C 2005 Review on maize canopy structure, light distributing and canopy photosynthesis *J. Maize Sci.* **13** 55–9

[19] Nielsen R L 2007 Ear size determination in corn *Corny News Netw. Artic. Purdue Univ.*

[20] Collins W K, Russell W A and Eberhart S A 1965 Performance of Two-Ear Type of Corn Belt Maize *1 Crop Sci.* **5** 113–6