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# Correlation analysis between agronomic character and yield of Padjadjaran maize hybrids at medium- and high-population densities

**Abstract**. Maize is a prospective food commodity that developed in Indonesia. The use of hybrid corn gives better yield than open-pollinated varieties. Spacing management in hybrid maize production can reduce competition between plants, so that the plant canopy and roots can grow optimally. This research aimed to compare the differences in the phenotypic performance of the agronomic characters of Padjadjaran maize hybrid, determine the dominant agronomic characteristics, and determine the correlation between the growth and yield characteristics at medium- and high-population densities. The experiment was carried out from December 2021 until May 2022 at Sanggar Penelitian, Latihan dan Pengembangan Pertanian (SPLPP) Universitas Padjadjaran, Arjasari, Bandung Regency. This experiment used Randomized Completely Block Design analysis with 20 treatments of Padjadjaran maize hybrids and 4 check varieties, all treatments were replicated 3 times in both population densities. Statistical analysis used multiple regression linear analysis and correlation test. The experimental results showed that the yield of 20 genotypes of Padjadjaran maize hybrids at medium population density was influenced by the ear length, number of seeds per row, and number of seed rows, while in the high population density, it was influenced by number of seed rows. Correlation analysis revealed a positive and significant relationship between the growth and yield components in medium population density. Meanwhile, the correlation at high population density between the components of growth and yield was not consistent.

**Keywords**: Agronomic character · High population density · Maize hybrid · Moderate population density

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## Introduction

Maize (*Zea mays* L.) is a prospective commodity food developed in Indonesia. It has four purposes or functions, called 4F: animal feed (feed), food, fiber, and fuel (Panikkai et al., 2017). Estimatedly, 58% of people need maize for feed, while for food only about 30%, and the rest for industry, seeds and others (Ministry of Agriculture, 2013). Future challenges include how to fulfill the need for maize as a material standard for feed, food, and energy (Zakaria, 2011). In 2020, production of maize reached 21.53 million tons, or growed 5% compared to production of maize feed in 2019 (20.5 million metric tons). Factory feed needed 8.5 million tons and for breeders to 3.48 million tons (Directorate General of PKH, 2020). According to data from the Ministry of Agriculture (2021), maize productivity fluctuated, namely 5.52 ton $ha^{-1}$ in 2019, 5.58 ton $ha^{-1}$ in 2020, and 5.55 ton $ha^{-1}$ in 2021.

Possible efforts to increase production of maize include extensification (area expansion) and intensification (increase productivity) (Bakhri, 2007). Extensification was not effective in limiting agriculture areas. Thus, intensification is conducted to increase production by using superior or hybrid varieties that produce high yield (Winarso, 2014; Yuwariah et al., 2017) and regulating population plants (Yusri, 2013).

Agronomic and yield evaluation is one of the stages carried out by plant breeders to determine the best genotype in terms of agronomics, morphology, and yield (Soeranto, 2018). Yield potency from a plant is determined by growth and yield components (Putra et al., 2015). A total of 20 genotypes of hybrid Padjadjaran maize were selected for the study. This will be seen in appearance character agronomy based on component future growth and results compared to commercial varieties. Each genotype with different parents will be evaluated based on agronomic performance to produce the best genotype.

Genetics can influence the plant appearance (Wardiana, 2015). In addition, Numba et al. (2018) stated that plant height and leaf number on maize are influenced by genotypic factor. Testing of plant agronomic characters has become important issue in order to determine the genotype superiority (Siswati et al., 2015). Correlation test can be performed between agronomic characteristics, in order to provide important key information in plant breeding program. Additionally, Amas et al. (2021) reported that those information can be important step in shortening wheat selection. For example, Pennita et al. (2020) has showed the strong and positive correlation between agronomic character of diameter of the maize ears with another agronomic character of plant height.

Padjadjaran hybrid maizes require an optimal growing environment, one of them is plant population setting. The plant population setting is part of the intensification program to increase plant yield (Wahyudin et al., 2015). According to Gardner et al. (1996), setting plant density aims to minimize intrapopulation competition in order to give optimal environment for plant canopy and roots. However, there are still limited studies regarding plant population density on corn agronomic characteristics. Therefore, present study aimed to determine the correlation between the growth and yield characteristics at medium- and high-population densities.

## Materials and Methods

Present research was carried out in the Sanggar Penelitian, Latihan, dan Pengembangan Pertanian (SPLPP), Faculty of Agriculture, Universitas Padjadjaran in Arjasari District, Bandung Regency, with an altitude of ± 950 meters above sea level. The research was held from December 2021 – May 2022, on agriculture area that has slopes >15%, soil pH 4.5–5.5, and clay soil texture. The average monthly rainfall from December 2021 to May 2022 was 182.9 mm per month. The average temperature at SPLPP Arjasari ranges between 23.3-24.1$^{o}$C.

The materials used in the study were 20 Padjadjaran hybrid genotypes, 4 commercial seed varieties (Table 1), NPK fertilizer (16:16:16), urea fertilizer, Dithane 80 WP, Antracol 70 WP, Sidamethrin 50 EC. The tools used in the study were ruler (measurement of height, width, and length of leaves), analytical scales (for measuring heavy corn maize), a luxmeter (for measuring intensity of light), and cultivation tools.

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**Table 1. Maize genotypes used in present study comprised of Padjadjaran hybrids and commercial varieties**

| Treatment | | | Information |
|---|---|---|---|
| No | Code | Genotipe | |
| 1 | H1 | DR 4 X MDR 7.2.3 | Padjadjaran Hybrids |
| 2 | H2 | DR 4 X MDR 16.6.14 | |
| 3 | H3 | DR 5 X MDR 18.8.1 | |
| 4 | H4 | DR 6 X DR 7 | |
| 5 | H5 | DR 7 X DR 8 | |
| 6 | H6 | DR 8 X MDR 18.8.1 | |
| 7 | H7 | DR 8 X R 9 | |
| 8 | H8 | DR 8 X MDR 1.1.3 | |
| 9 | H9 | DR10 X MDR 9.1.3 | |
| 10 | H10 | DR 11 X DR 16 | |
| 11 | H11 | DR 14 X DR 18 | |
| 12 | H12 | DR 19 X DR 20 | |
| 13 | H13 | MDR 3.1.4 X MDR 18.5.1. | |
| 14 | H14 | MDR 3.1.2 X MDR 153.14.1 | |
| 15 | H15 | MDR 7.4.3 X DR 18 | |
| 16 | H16 | MDR 7.4.3 X 18.8.1 | |
| 17 | H17 | MDR 7.4.3 X MDR 1.1.3 | |
| 18 | H18 | MDR 9.1.3 X MDR 1.1.3 | |
| 19 | H19 | MDR 18.8.1 X MDR 7.1.9 | |
| 20 | H20 | MDR 153.3.2 X MDR 8.5.3 | |
| 21 | C1 | BISI 2 | Commercial Varieties |
| 22 | C2 | BISI 77 | |
| 23 | C4 | PERTIWI 3 | |
| 24 | C5 | NK 212 | |

The experimental design was Randomized Completely Block Design (RCBD), consisted of 20 treatments of Padjadjaran hybrid maize and 4 commercial varieties (BISI 2, BISI 77, Pertiwi 3, NK 212) with three replications and planted in two planting densities, namely medium and high densities. Obtained data was analyzed using multiple linear regression and analysis correlation at 5% significance level. Observation were made on several variables, namely ear diameter, ear length, number of seed rows, number of seeds per row, number of seeds per ear, and weight of seeds per ear (yield).

Medium planting density used a spacing of 70x15 cm, while high density used a spacing of 70x10 cm. Each plot was made 3x3 m. Each planting hole is filled by 1 seed. First fertilizer application was carried out in 30 days after sowing (DAS) using NPK with a dose 150 kg/ha, while second fertilizer was applied in 45 DAS using 150 kg/ha NPK and 300 kg/ha urea. Fertilizer was immersed between planting holes in rows. Harvesting was done at physiological maturity of seeds and husks already yellowish colored, as well as ear hairs colored brown and dry. It was carried out at 117 DAS. Ears drying was carried out for one week under the sun.

## Results and Discussion

Analysis of multiple linear regressions on twenty genotypes of maize under different planting density was modelled by regression equation as depicted in Table 2. At medium population density, there were currently 15 genotypes of Padjadjaran hybrid maize and their yield was influenced by agronomic character with determinations coefficient above 80%.

In general, Padjadjaran maize gave a coefficient of determination of 65% and an estimation yield of 8.2 tons/ha, which was influenced by agronomy characteristics such ear length, number of seeds per row, and number of seed rows (Table 4). From the 15 genotypes of Padjadjaran maize, only 3 best genotypes were obtained. They were really influenced by agronomy characteristics, namely number of seeds per row, ear length, weight of 1000 seeds, and number of seeds per ear with coefficient of determination 97%–100% (Table 3).

Ear length character was related to the number of seeds per ear, so it can give more yield. Aligns with the statement of Noviana & Ishaq (2011), the varieties with long ear showed higher yield. The weight of seeds per ear influenced the production of maize (Noviana & Ishaq, 2011). Enhancement weight seed has a close relationship with high-directed photosynthetic activity to ear (Hartanti et al., 2014). The bigger partitioned photosynthate is allocated to ear, so that the higher seeds weight, vice versa (Hidayati & Armaini, 2015).

On high density, there were 17 genotypes of Padjadjaran hybrid maize that were influenced by agronomic characters with coefficient determinations above 80% (Table 4). In general, Padjadjaran hybrid maize were affected by the number of seeds rows per ear with a coefficient determination of 88% and estimation yield of 4.0 tons/ha (Table 5). From the 17 genotypes of Padjadjaran maize, there were five best genotypes. The yield of those five maize genotypes were strongly influenced by agronomic characteristics, namely ear length, ear diameter, number of seeds per ear, number of seed rows per ear and weight of 1000 seeds with coefficient of determination ranged from 97% to99% (Table 5).

**Table 2. Regression equation model of padjadjaran hybrid and check varieties at medium density**

| Code | Regression Equation | Coefficient of Determination ($R^2$) |
|---|---|---|
| H | Y = -115.503+2.166X1*-3.547X2+0.735X3*+2.491X4*+0.453X5+62.199X6 | 65% |
| H1 | Y = -9.318+0.095X1-10.763X2-0.989X3+3.396X4+0.356X5+78.373X6 | 92% |
| H2 | Y = -13.8889 + 3.5371X1 -11.7747X2+0.0685X3-5.2891X4+0.5721X5+98.7871X6 | 94% |
| H3 | Y = -4.513+1.509X1-1.266X2+1.273X3-5.973X4+0.357X5+66.719X6 | 97% |
| H4 | Y = -203.303+0.122X1+27.106X2+2.538X3+7.224X4-0.351X5+72.865X6 | 85% |
| H5 | Y = 9.1961+6.5685X1-0.5037X2+0.4739X3-0.9699X4+0.0374X5-7.1526X6 | 76% |
| H6 | Y = 42.123+1.458X1+23.672X2+2.988X3-3.072X4+0.215X5-329.272X6 | 96% |
| H7 | Y = 369.335-7.648X1-63.915X2-0.605X3+13.873X4-0.370X5+28.541X6 | 57% |
| H8 | Y = -4.082+4.739X1+30.249X2-2.633X3+7.087X4-0.622X5-10.938X6 | 31% |
| H9 | Y = -119.1281-12.544X1-78.7096X2+4.6357X3+11.3568X4+1.9473X5+130.4652X6 | 94% |
| H10 | Y = 169.948-2.868X1+31.413X2+0.106X3-7.004X4-0.498X5+75.374X6 | 93% |
| H11 | Y = -344.373*+4.228X1+33.183X2+4.694X3*+0.319X4+0.226X5+29.001X6 | 97% |
| H12 | Y = -173.887-15.915X1*+18.824X2+1.0509X3+6.411X4+1.155X5*+100.334X6 | 99% |
| H13 | Y = -591.892-6.498X1+69.022X2+4.402X3+5.515X4+0.692X5+164.874X6* | 97% |
| H14 | Y = -1110.513+9.205X1+163.394X2+7.350X3+25.256X4-1.487X5+172.147X6 | 79% |
| H15 | Y = -9.838+3.152X1-8.393X2-0.536X3-2.694X4+0.619X5*+40.844X6 | 100% |
| H16 | Y = -214.787+0.980X1+7.262X2+3.123X3+2.825X4+0.305X5+77.794X6 | 97% |
| H17 | Y = -263.120+2.128X1-0.276X2+1.353X3+10.423X4+0.468X5+69.280X6 | 52% |
| H18 | Y = -98.705-12.056X1+42.688X2-0.276X3-0.413X4+0.257X5+282.376X6 | 94% |
| H19 | Y = -458.580+0.088X1+86.941X2+0.724X3+1.149X4+0.087X5+159.261X6* | 98% |
| H20 | Y = -356.573+5.257X1+20.993X2-0.330X3+10.276X4+0.278X5+126.120X6 | 96% |
| C1 | Y = 43.7721-2.7644X1-19.2941X2+0.9644X3+0.8307X4+0.4176X5+10.1736X6 | 93% |
| C2 | Y = 359.805+2.108X1-92.205X2-4.071X3-3.563X4+1.074X5+89.481X6 | 97% |
| C4 | Y = -320.157-1.052X1+44.137X2+5.302X3+0.821X4+0.143X5+9.695X6 | 94% |
| C5 | Y = 120.312+3.758X1-57.690X2*+0.265X3+6.654X4+0.524X5*-63.050 | 98% |

Notes: H was Padjadjaran hybrid maize, C was check variety, X1 ear length, X2 was ear diameter, X3 was number of seeds per row, X4 was number of seeds rows per ear, X5 was weight of 1000 seeds , X6 was number of seeds per ear , Y was weight of seeds per ear (yield), * was significant affected yield

**Table 3. Relationship of yield components with yield at medium density**

| No. | Treatment | Yield components that significantly affected yield | Coefficient of Determination ($R^2$) (%) | Yield (tons/ha) |
|---|---|---|---|---|
| A | H (H1 – H20) | Ear length, number of seeds per row, and number of seed rows | 65% | 8.2 |
| 1. | H11 | Number of seeds per row | 97% | 8.2 |
| 2. | H12 | Ear length, weight 1000 seeds | 99% | 8.7 |
| 3. | H13 | Number of seeds per ear | 97% | 8.8 |
| 4. | H15 | Weight of 1000 Seeds | 100% | 7.4 |
| 5. | H19 | Number of seeds per ear | 98% | 6.8 |
| 6. | C1 | | | 5.3 |
| 7. | C2 | | | 11.5 |
| 8. | C4 | | | 8.2 |
| 9. | C5 | | | 8.9 |

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**Table 4. Regression equation model of padjadjaran maize hybrid and check varieties at high density**

| Code | Equality Regression | Coefficient of Determination ($R^2$) |
|---|---|---|
| H | Y= -12.378+1.927X1+1.245X2+0.406X3-4.597X4*+0.283X5+1.068X6 | 88% |
| H1 | Y= -318.085+5.378X1-6.401X2+1.276X3+10.853X4+0.224X5+1.739X6 | 98% |
| H2 | Y= 70.887+0.967X1-8.750X2+0.563X3-0.291X4+0.068X5+0.003X6 | 99% |
| H3 | Y= 35.694-2.046X1+15.888X2-0.088X3-0X4-0.104X5+0.432X6 | 99% |
| H4 | Y= 49.374-9.020X1+26.172X2-2.229X3-1.614X4+0.771X5-0.334X6 | 70% |
| H5 | Y= -52.047+5.659X1-34.118X2*-0.691X3+4.116X4+0.209X5*+1.348X6* | 99% |
| H6 | Y=-77.536 +10.801X1-15.494X2-5.324X3+5.896X4+0.397X5+1.075X6 | 97% |
| H7 | Y= -1.487-0.436X1-7.119X2+0.322X3+2.419X4-0.113X5+1.612X6 | 91% |
| H8 | Y= 3.051-4.278X1-5.035X2+1.001X3-3.302X4+0.349X5*+0.682X6* | 99% |
| H9 | Y= -107.703+11.250X1*+8.580X2*-1.931X3*-1.622X4-0.097X5+1.992X6* | 99% |
| H10 | Y= -299.637+11.566X1+15.673X2-3.0695X3+12.439X4-0.038X5+1.413X6 | 98% |
| H11 | Y= -329.055+27.112X1*-21.153X2*-4.479X3*+10.171X4*+0.217X5*+0.566X6* | 99% |
| H12 | Y= -20.193+4.116X1-11.638X2+0.300X3-1.887X4+0.210X5+0.577X6 | 96% |
| H13 | Y= -37.766+2.302X1+1.834X2+0.285X3+2.516X4+0.005X5+0.470X6 | 78% |
| H14 | Y= -144.015+3.255X1-46.054X2+0.687X3+21.629X4+0.112X5+0.150X6 | 94% |
| H15 | Y= 50.199-0.573X1+5.798X2+0.980X3-1.152X4+0.002X5-0.096X6 | 91% |
| H16 | Y= -66.919+2.394X1-10.693X2+0.125X3+1.7132X4+0.259X5*+1.189X6* | 97% |
| H17 | Y= -45.420+2.501X1-10.474X2+2.042X3+1.876X4+0.200X5-0.139X6 | 45% |
| H18 | Y= -11.929-2.0281X1+70.702X2-2.289X3-4.221X4-0.052X5+1.110X6 | 95% |
| H19 | Y= 1.126-14.978X1-21.695X2+1.807X3-16.831X4-0.213X5+2.224X6 | 94% |
| H20 | Y= -56.108+1.403X1+1.194X2+1.316X3-0.732X4+0.066X5+0.952X6 | 90% |
| C1 | Y= -103.831+2.682X1+32.689X2-0.178X3-3.303X4+0.684X5-1.119X6 | 94% |
| C2 | Y= -278.258-8.163X1+12.516X2+7.672X3+7.181X4+0.068X5+2.119X6 | 77% |
| C4 | Y= -36.614+4.414X1+33.696X2-2.217X3-1.860X4-0.142X5+1.092X6 | 38% |
| C5 | Y= 158.770-5.711X1-22.385X2+0.817X3-6.345X4+0.306X5+1.647X6 | 97% |

Notes: H was Padjadjaran hybrid, C was maize check variety, X1 ear length, X2 was ear diameter, X3 was number of seeds per row, X4 was number of seeds rows per ear, X5 was weight of 1000 seeds , X6 was number of seeds per ear , Y was weight of seeds per ear (yield), * was significant affected yield

**Table 5. Relationship of yield components with yield at high population density**

| No. | Treatment | Yield components that significantly affected yield | Coefficient of Determination ($R^2$) (%) | Yield (tons/ha) |
|---|---|---|---|---|
| B | H (H1 – H20) | Number of Seed Rows | 88% | 4.0 |
| 1. | H5 | Ear Diameter, Weight of 1000 Seeds, Yield Seed | 99% | 3.4 |
| 2. | H8 | Weight of 1000 Seeds, Yield Seed | 99% | 5.5 |
| 3. | H9 | Ear Length, Ear Diameter, Quantity Seeds per Ear, Yield Seed | 99% | 6.5 |
| 4. | H11 | Ear Length, Ear Diameter, Quantity Seeds per Ear, Number of Rows of Seeds per Cob, Weight of 1000 Seeds, Number of Seeds per Ear | 99% | 4.8 |
| 5. | H16 | Weight of 1000 Seeds, Weight of Seeds per Ear | 97% | 3.5 |
| 6. | C1 | | | 3.9 |
| 7. | C2 | | | 4.4 |
| 8. | C4 | | | 5 |
| 9. | C5 | | | 5.9 |

 

The yield was dominant influenced by number of seed rows. The average number of seed rows per ear in the study between 12.00 and 14.89. Overall, average Padjadjaran hybrid has the potential to have the same yield as other plant maize hybrids, namely 12–14 rows per ear (Balitsereal, 2012). The yield of H11 hybrid genotype was most influenced by agronomic characters on high density. It was affected by ear length, ear diameter, number of seeds per row, number of seed rows, weight of 1000 seeds, and number of seeds per ear with coefficient of determination 99% and estimation yield of 4.8 tons/ha. This was in agreement with the results of previous studies. Bahoush & Abbasdokht (2008), Selvaraj et al. (2011), El-Badawy & Mehasen (2011), and Zarei et al. (2012) stated that maize yield was directly affected by ear length, ear diameter, number of seeds per row, number of seed rows and weight of 1000 seeds.

Thus, both on medium and high density, the yield of Padjadjaran hybrid genotypes were effectively identified by observation on agronomic characters, such as ear length, ear diameter, number seeds per row, number of seed rows per ear, weight of 1000 seeds, and number of seeds per ear.

Based on the analysis correlation from 20 genotypes of Padjadjaran hybrid, there was a closeness and positive correlation between gagronomic characters and yield. The correlation between maize agronomic characters and yield component from 20 Padjadjaran hybrids on density medium and high density were displayed in Table 6 and Table 7. According to Ramadhan (2014), if two characters have a positive correlation, the increasing value of one character will followed by another correlated character, vice versa.

On medium density, plant height had a significant correlation with yield components. Tall plants can intercept more solar radiation that increase photosynthesis rate then maximize yield (Rahni, 2012; Surtinah, 2018). The LAI had significant correlation with yield components, except the number of seed rows and number of seeds per ear. Leaf Area Index (LAI) is a parameter that directly influences the growth and development of plants (Wahyudin et al., 2017). According to Surtinah (2018), the photosynthesis process in active leaves gave optimum yield due to the accumulation of dry material.

On high density, plant height correlated positively with ear diameter (r = 0.23*), while with number of seeds per ear had negative correlation. This is caused by competition between plants. High populations of plant can increase etiolation, and the tall plant had more competition with solar radiation, which caused the decreasing photosynthesis rate and supply of photosynthate to be reduced (Aisah & Herlina, 2018).

**Table 6. Correlation between growth components and yield components at medium population density**

| Growth components | Yield Components | | | | | | |
|---|---|---|---|---|---|---|---|
| | EL | ED | NSR | NR | W1000 | NSE | WSE |
| PH | 0.449** | 0.420** | 0.307** | 0.213 | 0.435** | 0.050 | 0.523** |
| LAI | 0.408** | 0.315** | 0.304** | 0.093 | 0.404** | 0.162 | 0.426** |

Notes: PH was plant height, LAI was leaf area index , EL was ear length, ED was ear diameter , NSR was Number of seeds per row, NR was number of seed rows, W1000 was weight of 1000 seeds, NSE was number of seeds per ear, WSE was weight seeds per ear, * was significant correlation, ** was very significant correlation.

**Table 7. Correlation between growth components characters and yield components at high population density**

| Growth components | Yield Components | | | | | | |
|---|---|---|---|---|---|---|---|
| | EL | ED | NSR | NR | W1000 | NSE | WSE |
| PH | 0.21 | 0.23* | 0.16 | 0.19 | 0.01 | -0.24* | -0.04 |
| LAI | 0.26* | 0.37* | 0.23* | 0.29* | 0.24* | -0.17 | 0.10 |

Notes: PH was plant height, LAI was leaf area index , EL was ear length, ED was ear diameter , NSR was Number of seeds per row, NR was number of seed rows, W1000 was weight of 1000 seeds, NSE was number of seeds per ear, WSE was weight seeds per ear, * was significant correlation, ** was very significant correlation.

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## Conclusion

Correlation analysis revealed a positive and significant relationship between the agronomic characters and yield components at medium population density. Meanwhile, the correlation between the components of agronomic characters and yield in the high population density was not consistent.

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