Combining ability analysis of maize lines under optimal and low nitrogen stress

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Abstract. Most of the land for maize development in Indonesia has low N limiting factor, thus it is necessary to develop a proper maize breeding programs tolerant to low N conditions. One of the breeding methods suitable for low N evaluation is the diallel method between inbred parents (homozygous lines) that are tolerant of low N stress. The aim of this study was to assess the genotype tolerance to low N with comparable yields. The research consisted of two stages. The first stage is the development of hybrid maize grains (F1) using the half diallel cross method. This activity was carried out in KP. Maros, Research Center for Cereal Crops. A half-diallel cross refers to the Griffing IV method, by involving 11 low N-tolerant genotypes (AVLN 100-1, AVLN 118-2, AVLN 122-2, AVLN 124-4, AVLN 32-3, AVLN 83-1, AVLN 83-4, AVLN 83-6, AVLN 86-2, MAL 04, and AVLN 124-9). The second stage was carried out in KP. Bajeng to evaluate 52 genotypes of hybrid maize from diallel crosses plus four hybrid varieties Advanta 777, Bisi 18, P 27 and JH 37 for control. The experiment was carried out under conditions of low N stress (100 kg N/ha) and normal N (200 kg N/ha). The experiment used a randomized block design with three replications. Hybrids that are tolerant (T) under conditions of low N stress was best indicated by AVLN 83-4/AVLN 124-4 genotype pair, with significant higher grain yield than Bisi-18 and JH 37 varieties. This hybrid produced average grain yield of 7.87 t/ha under both conditions. Inbred maize genotypes classified as medium tolerant (MT) were AVLN 83-4/AVLN 124-9, AVLN 124-4/AVLN 86-2, AVLN 122-2/AVLN 124-4, AVLN 83-1/AVLN 124-9, has similar yield potential as to the control varieties.

1. Introduction
Maize is one of the important cereal crops in Indonesia and mainly used for feed and food industries. Efforts to meet the increasing demand for maize are through land expansion and introduction of hybrid maize. Nitrogen is one of the macro nutrients needed by the plants including maize. Low soil N nutrient content is one of the limiting factors for increasing maize production. Most of the land for maize development in Indonesia has low N nutrient content [1]. Furthermore, in fertile land, the N content of the soil is depleted due to intensive cultivation and is not balanced with the return of N nutrients from plant biomass into the soil.

Maize plants are very sensitive to N nutrient deficiencies, especially high-yielding varieties of hybrid maize which is very responsive to N fertilization because most the commercial varieties are bred under optimal N environmental conditions. In general, farmers overcome this problem by giving
fertilizers that are high or excessive than plant needs. The application of high N fertilizer in addition to increasing production costs, can also cause environmental pollution due to chemicals.

Based on the results of research by [2], [3], showed that to obtain a hybrid maize yield of 11-14 t/ha, the N nutrients given to hybrid maize plants ranged from 180-250 kg N/ha. One way to suppress the decline in maize yields due to stress of low N fertilizer doses is to plant tolerant or adaptive varieties of low N [4], [5].

Most of the hybrid maize varieties released and marketed in Indonesia today are still for an optimal environment. These varieties will obtain high yields when planted in optimal land conditions, but if planted under abiotic stress conditions such as nutrient division of N, lower grain yield was expected. Hybrid maize varieties grown on marginal land usually require a high input of inorganic N fertilizer so that it will be unaffordable for poor farmers. Therefore, low N tolerant maize varieties are prospectus to overcome the problem of farmers whose land is low in N nutrients. Genotype selection for maize under N stress conditions (low N) will be more efficient than selection under normal N conditions to obtain low N tolerant genotypes [6], [1].

High-yielding varieties of low-N tolerant maize can be obtained through plant breeding programs [7]. The formation of hybrid varieties can be done through crosses using the diallel method between inbred parents (homozygous lines) that are tolerant of low N stress. Diallel crossing is a method to determine general combining ability (DGU) and specific combining ability (DGK) of several inbred lines. DGU is the ability to combine one line with another, while DGK is the specific appearance of the combination of crosses of two inbred lines compared to the whole cross [8].

The purpose of this study was to assess grain yield of hybrid candidates under optimal and low N environments by using diallel analysis.

2. Materials and Methods

The research was conducted from April to August 2020 in Maros and Bajeng experimental farms. Firstly, the development of hybrid maize grains (F1) was conducted in Maros ICERI using the half diallel cross method. A half-diallel cross according to the Griffing IV method involves 11 low N-tolerant genotypes (AVLN 100-1, AVLN 118-2, AVLN 122-2, AVLN 124-4, AVLN 32-3, AVLN 83-1, AVLN 83-4, AVLN 83-6, AVLN 86-2, MAL 04, and AVLN 124-9).

Secondly, evaluation of 55 genotypes of hybrid maize from diallel crosses plus four hybrid varieties Advanta 777, Bisi 18, P 27 and JH 37 was conducted in Bajeng Experimental farm. The experiment was conducted under conditions, low N stress (100 kg N/ha) and normal N (200 kg N/ha). The experiment used a randomized block design with three replications for each fertilizer dose. Combined analysis of N fertilization was carried out to determine the interaction between genotypes with different N doses. Grains were planted at spacing of 70 cm x 20 cm. The plot area of each genotype is 1.4 m x 5 m. Each genotype was fertilized with 60 kg P₂O₅ and 90 kg K₂O/ha. Half of the N dose and all the P and K doses were given at 7 days after planting (DAP). The remaining dose was applied at 35 DAP. The variables analyzed were leaf chlorophyll, grain yield, harvest index, number of grain per cob, and 1000 kernel weight. Leaf chlorophyll was measured using Soil Plant Analysis Development (SPAD) 502, carried out on 10 random samples at the age of 45 DAP. Grain yields were calculated from 20 plants at random, weighed and converted at 15.5% moisture content.

The 1000 kernel weight was obtained by weighing 1000 grain taken from six harvest samples, then converted at a moisture content of 15.5%. To find out the differences between each genotype, the data were analyzed using LSD at the 5% level. Stress tolerance index (STI) was calculated by the following formula [9]:

\[
STI = \frac{Y_0 \times Y_s}{Y_0' \times Y_s'}
\]
STI criteria:

1. **Tolerance (T)** = $ITC \geq 1.0$
2. **Moderate tolerance (MT)** = $0.5 \leq ITC \leq 1.0$
3. **Susceptible (P)** = $ITC \leq 0.5$

Note:
- $Yo$ = Yield of dry shelled maize kernels in an optimal environment (t/ha)
- $Ys$ = Yield of dry shelled maize kernels in a sub optimal environment (t/ha)
- $Yo'$ = Average total maize yield in optimal environment (t/ha)
- $Ys'$ = The average total yield of maize in a sub-optimal environment (t/ha)

3. **Results and Discussion**

3.1 **Genotype evaluations under low N stress**

Among the 52 maize inbred genotypes tested under low nitrogen stress (100 kg N/ha), grain yield produced varies from 2.48-6.29 t/ha. In addition, under normal nitrogen conditions (200 kg N/ha), average yield varies from 3.71-9.46 t/ha (Table 1). Plants that experience low nitrogen fertilization stress generally experience a decrease in yield, where the level of yield reduction for each plant genotype will vary depending on the adaptability of each genotype to stress conditions.

Several genotypes that consistently had grain yields that were equal or not significantly different from the control varieties, both at normal and low N were AVLN 83-4/AVLN 124-4, AVLN 122-2/AVLN 83-4, AVLN 118-2/AVLN 83-4, AVLN 83-6/AVLN 122-2, AVLN 83-6/AVLN 100-1, AVLN 118-2/AVLN 83-6, AVLN 124-4/AVLN 86-2, MAL 04/AVLN 86-2, AVLN 122-2/AVLN 124-4 and AVLN 83-1/AVLN 124-9. With normal N fertilization (200 kg N/ha) grain yields ranged from 8.09-9.46 t/ha and at low N (100 kg N/ha) ranged from 4.23-6.29 t/ha.

The results of statistical analysis of 52 maize inbred genotypes with four control varieties tested showed that the AVLN 83-4/AVLN 124-4 genotypes had significantly higher grain yield differences than the control varieties Bisi-18 and JH 37. AVLN 83-4/ genotypes AVLN 124-4 at low N fertilizer conditions (100 kg N/ha) obtained the highest grain yield of 6.29 t/ha and under normal N fertilization conditions (200 kg N/ha) the highest grain yield was 9.46 t/ha and had an average. The highest average yield under normal and low N conditions was 7.87 t/ha (Table 1). This indicated that the AVLN 83-4/AVLN 124-4 genotype had stable yields in both normal and low N conditions. Variations in the response of grain yields between genotypes to the application of N or different levels of soil fertility in maize have been studied previously [10], [11], [12].

Based on the stress tolerance index in the treatment of normal N fertilization (200 kg N/ha) and low N (100 kg N/ha) at IP2TP locations. Bajeng, all tested inbred genotypes showed a very sensitive to tolerant level of tolerance (Table 1). Grain yields decreased significantly in all genotypes fertilized with normal N (200 kg N/ha) and low N (100 kg N/ha) resulting in differences in the tolerance index for low N. Therefore, the difference in grain yield can be used to separate the genotype tolerance level for low N. Maize genotypes for low N tolerance based on grain yield were categorized as Sensitive/P (ITC 0.5), medium tolerant/MT (0.1 ≤ ITC ≥0.5) and Tolerant/T (ITC 1).

The genotype of inbred maize that was classified as tolerant (T) was AVLN 83-4/AVLN 124-4, had grain yields at N 200 kg/ha at 9.46 t/ha and at N 100 kg/ha at 6.29 t/ha. Inbred maize genotypes classified as medium tolerant (MT) were AVLN 83-4/AVLN 124-9, AVLN 124-4/AVLN 86-2, AVLN 122-2/AVLN 124-4, AVLN 83-1/AVLN 124-9, and the control variety ADV 777. The tolerant inbred genotype – medium tolerant to low N stress, was able to suppress the relative yield reduction compared to the sensitive inbred genotype.
Table 1. Grain yield of several genotypes at the level of nitrogen fertilization stress conditions in IP2TP. Bajeng, 2020.

| No. | Hybrid | N (kg/ha) | Average | STI | Yield loss |
|-----|--------|-----------|---------|-----|------------|
|     |        | Y 200     | Y 100   |     |            |
|     |        | Yield (t/ha) |         |     |            |
| 1   | AVLN 83-4/AVLN 32-3 | 7.06 | 5.59 | 6.33 | 0.68 | MT | 20.77 |
| 2   | AVLN 32-3/AVLN 100-1 | 5.47 | 4.00 | 4.74 | 0.38 | P | 26.86 |
| 3   | AVLN 83-6/AVLN 32-3 | 6.97 | 4.15 | 5.56 | 0.50 | MT | 40.41 |
| 4   | AVLN 32-3/AVLN 86-2 | 5.90 | 3.24 | 4.57 | 0.33 | P | 45.19 |
| 5   | AVLN 124-4/AVLN 32-3 | 7.50 | 4.68 | 6.09 | 0.61 | MT | 37.64 |
| 6   | AVLN 122-2/AVLN 32-3 | 6.90 | 4.28 | 5.59 | 0.51 | MT | 37.99 |
| 7   | AVLN 32-3/AVLN 124-9 | 7.34 | 3.74 | 5.54 | 0.47 | P | 49.10 |
| 8   | AVLN 118-2/AVLN 32-3 | 6.58 | 4.06 | 5.32 | 0.46 | P | 38.28 |
| 9   | MAL 04/AVLN 32-3 | 9.18 | 3.88 | 6.53 | 0.62 | MT | 57.76 |
| 10  | AVLN 83-4/AVLN 100-1 | 7.74 | 3.53 | 5.64 | 0.47 | P | 54.33 |
| 11  | AVLN 86-2/AVLN 83-4 | 7.21 | 4.72 | 5.97 | 0.59 | MT | 34.55 |
| 12  | **AVLN 83-4/AVLN 124-4** | **9.46** | **6.29** | **7.87** | **1.03** | T | 33.56 |
| 13  | AVLN 122-2/AVLN 83-4 | 8.09 | 4.23 | 6.16 | 0.59 | MT | 47.68 |
| 14  | AVLN 83-4/AVLN 124-9 | 7.82 | 5.58 | 6.70 | 0.76 | MT | 28.66 |
| 15  | AVLN 118-2/AVLN 83-4 | 8.56 | 4.46 | 6.51 | 0.66 | MT | 47.96 |
| 16  | AVLN 83-4/AVLN 83-1 | 7.41 | 4.39 | 5.90 | 0.56 | MT | 40.70 |
| 17  | AVLN 83-6/AVLN 100-1 | 8.24 | 3.89 | 6.06 | 0.56 | MT | 52.73 |
| 18  | AVLN 86-2/AVLN 100-1 | 7.91 | 4.01 | 5.96 | 0.55 | MT | 49.31 |
| 19  | AVLN 124-4/AVLN 100-1 | 7.46 | 3.29 | 5.37 | 0.42 | P | 55.93 |
| 20  | AVLN 122-2/AVLN 100-1 | 6.47 | 4.56 | 5.52 | 0.51 | MT | 29.50 |
| 21  | AVLN 100-1/AVLN 124-9 | 7.62 | 4.39 | 6.01 | 0.58 | MT | 42.38 |
| 22  | AVLN 118-2/AVLN 100-1 | 7.33 | 3.08 | 5.21 | 0.39 | P | 58.05 |
| 23  | MAL 04/AVLN 100-1 | 8.68 | 3.51 | 6.10 | 0.53 | MT | 59.58 |
| 24  | AVLN 83-1/AVLN 100-1 | 7.64 | 4.76 | 6.20 | 0.63 | MT | 37.74 |
| 25  | AVLN 83-6/AVLN 86-2 | 7.05 | 4.66 | 5.85 | 0.57 | MT | 33.92 |
| 26  | AVLN 124-4/AVLN 83-6 | 3.71 | 2.83 | 3.27 | 0.18 | P | 23.86 |
| 27  | AVLN 83-6/AVLN 122-2 | 8.50 | 5.08 | 6.79 | 0.75 | MT | 40.22 |
| 28  | AVLN 83-6/AVLN 100-1 | 9.06 | 4.78 | 6.92 | 0.75 | MT | 47.26 |
| 29  | AVLN 118-2/AVLN 83-6 | 8.30 | 5.18 | 6.74 | 0.74 | MT | 37.62 |
| 30  | MAL 04/AVLN 83-6 | 7.74 | 3.56 | 5.65 | 0.48 | P | 53.97 |
| 31  | AVLN 83-1/AVLN 83-6 | 7.31 | 3.97 | 5.64 | 0.50 | MT | 45.77 |
| 32  | AVLN 124-4/AVLN 86-2 | 8.44 | 5.37 | 6.90 | 0.78 | MT | 36.40 |
| 33  | AVLN 122-2/AVLN 86-2 | 8.52 | 3.37 | 5.95 | 0.50 | MT | 60.39 |
| 34  | AVLN 86-2/AVLN 124-9 | 7.92 | 3.95 | 5.94 | 0.54 | MT | 50.10 |
| 35  | AVLN 118-2/AVLN 86-2 | 8.16 | 4.05 | 6.11 | 0.57 | MT | 50.34 |
| No. | Genotype               | Chlorophyll Value |
|-----|------------------------|-------------------|
| 36  | MAL 04/AVLN 86-2       | 8.37              |
| 37  | AVLN 83-1/AVLN 86-2    | 7.07              |
| 38  | AVLN 122-2/AVLN 124-4  | 8.54              |
| 39  | AVLN 124-4/AVLN 124-9  | 5.18              |
| 40  | AVLN 118-2/AVLN 124-4  | 6.75              |
| 41  | MAL 04/AVLN 124-4      | 7.74              |
| 42  | AVLN 83-1/AVLN 124-4   | 7.11              |
| 43  | AVLN 122-2/AVLN 124-9  | 7.15              |
| 44  | AVLN 118-2/AVLN 122-2  | 7.59              |
| 45  | MAL 04/AVLN 122-2      | 6.63              |
| 46  | AVLN 83-1/AVLN 122-2   | 7.22              |
| 47  | AVLN 118-2/AVLN 124-9  | 7.80              |
| 48  | MAL 04/AVLN 124-9      | 7.85              |
| 49  | AVLN 83-1/AVLN 124-9   | 8.60              |
| 50  | MAL 04/AVLN 118-2      | 7.41              |
| 51  | AVLN 83-1/AVLN 118-2   | 7.87              |
| 52  | AVLN 83-1/MAL 04       | 7.75              |

| Check | Chlorophyll Value |
|-------|-------------------|
| 53 ADV 777 (a) | 8.92 4.99 6.95 0.77 MT 44.02 |
| 54 Bisi 18 (b) | 8.39 4.61 6.50 0.67 MT 45.02 |
| 55 P-27(c) | 8.59 4.66 6.63 0.69 MT 45.69 |
| 56 JH-37 (d) | 7.85 4.06 5.95 0.55 MT 48.35 |

|       | Average | LSD 5% | CV  |
|-------|---------|--------|-----|
|       | 7.60    | 1.82   | 26.2 |

Note: the numbers followed by the letters a b c d in the column mean that they are significantly higher than the inbred genotypes ADV777 (a), Bisi 18 (b), P-27 (c) and JH 37 (d) based on the 5% LSD test.

There was a different response between genotypes to chlorophyll and a decrease in chlorophyll genotype from normal N fertilization (200 kg N/ha) to low N (100 kg N/ha). Based on the decrease in leaf chlorophyll value, the tolerance level of maize genotypes to low N can be grouped into Sensitive/P (ITC≤0.5), medium tolerant/MT (0.1≤ITC<0.5), and Tolerant/T (ITC≥1). Tolerance group has chlorophyll in the normal dose of fertilizer was 40.01-56.68 units, and the application of low N fertilizer had a chlorophyll meter value of 41.23-56.84 units (Table 2). The different genotypes were significantly higher than the controls of Bisi 18 and P-27, namely AVLN 86-2/AVLN 100-1 (Table 2). There are 32 genotypes that are significantly higher than the P-27 control, namely AVLN 83-4/AVLN 32-3, AVLN 32-3/AVLN 100-1, AVLN 32-3/AVLN 86-2, AVLN 124-4/AVLN 32-3, AVLN 122-2/AVLN 122-2, AVLN 122-2/AVLN 83-4, AVLN 83-6/AVLN 100-1, AVLN 124-4/AVLN 100-1, AVLN 122-2/AVLN 100-1, AVLN 118-2/AVLN 100-1, MAL 04/AVLN 100-1, AVLN 83-1/AVLN 100-1, AVLN 83-6/AVLN 86-2, AVLN 124-4/AVLN 86-2, AVLN 122-2/AVLN 86-2, AV LN 118-2/AVLN 86-2, MAL 04/AVLN 86-2, AVLN
122-2/AVLN 124-4, AVLN 118-2/AVLN 124-4, MAL 04/AVLN 124-4, AVLN 83-1/AVLN 122-2, AVLN 118-2/AVLN 124-9, MAL 04/AVLN 124-9, AVLN 83-1/AVLN 124-9, MAL 04/AVLN 118-2 and AVLN 83-1/MAL 04.

The 1000 kernel weight of genotype, both at 200 kg N/ha and 100 kg N/ha fertilization were significantly different. There were three genotypes that were significantly higher than all the control varieties ADV 777, Bisi 18, P-27 and JH-37, namely AVLN 83-4/AVLN 124-4, AVLN 83-4/AVLN 124-9 and AVLN 122-2. Four different genotypes were significantly higher than the control varieties Bisi-18 and JH-37, namely AVLN 122-2/AVLN 83-4, AVLN 118-2/AVLN 83-4, AVLN 122-2/AVLN 86-2 and AVLN 122-2/AVLN 124-9. One genotype that was significantly different from the control variety JH-37 was AVLN 86-2/AVLN 83-4. Higher grain weight indicates that the transfer of photosynthetic products to grains is better.

Table 2. Leaf chlorophyll and weight of 1000 kernel weight from several genotypes under nitrogen fertilization stress conditions in IP2TP Bajeng, 2020.

| No. | Hybrid            | N (kg/ha) | N 200 | N 100 | N 200 | N 100 | 1000 kernel weight |
|-----|------------------|-----------|-------|-------|-------|-------|-------------------|
|     |                  | SPAD      |       |       |       |       |                   |
| 1   | AVLN 83-4/AVLN 32-3 | 49.21     | 54.05 | c     | 311.28| 304.52|
| 2   | AVLN 32-3/AVLN 100-1 | 46.16     | 51.88 | c     | 292.53| 264.35|
| 3   | AVLN 83-6/AVLN 32-3 | 50.29     | 49.18 |       | 291.50| 246.74|
| 4   | AVLN 32-3/AVLN 86-2 | 44.87     | 50.70 | c     | 300.68| 260.21|
| 5   | AVLN 124-4/AVLN 32-3 | 46.46     | 50.82 | c     | 322.16| 301.80|
| 6   | AVLN 122-2/AVLN 32-3 | 45.02     | 54.86 | c     | 316.73| 266.98|
| 7   | AVLN 32-3/AVLN 124-9 | 43.72     | 47.15 |       | 344.19| 266.37|
| 8   | AVLN 118-2/AVLN 32-3 | 44.61     | 48.76 |       | 270.39| 278.64|
| 9   | MAL 04/AVLN 32-3    | 50.53     | 49.40 |       | 277.19| 260.05|
| 10  | AVLN 83-4/AVLN 100-1 | 52.19     | 49.47 |       | 335.12| 311.08|
| 11  | AVLN 86-2/AVLN 83-4 | 51.79     | 50.27 |       | 357.60| 216.57|
| 12  | AVLN 83-4/AVLN 124-4 | 47.83     | 47.80 |       | 415.05| 325.83|
| 13  | AVLN 122-2/AVLN 83-4 | 51.91     | 52.89 | c     | 362.49| 324.34|
| 14  | AVLN 83-4/AVLN 124-9 | 46.67     | 50.27 |       | 374.16| 332.04|
| 15  | AVLN 118-2/AVLN 83-4 | 53.31     | 47.68 |       | 363.54| 326.14|
| 16  | AVLN 83-4/AVLN 83-1  | 53.31     | 49.30 |       | 326.14| 279.12|
| 17  | AVLN 83-6/AVLN 100-1 | 46.42     | 50.62 | c     | 315.46| 265.05|
| 18  | AVLN 86-2/AVLN 100-1 | 49.51     | 56.84 | bc    | 331.66| 236.33|
| 19  | AVLN 124-4/AVLN 100-1 | 50.33     | 51.27 | c     | 346.98| 316.55|
| 20  | AVLN 122-2/AVLN 100-1 | 46.28     | 54.81 | c     | 287.78| 288.81|
| 21  | AVLN 100-1/AVLN 124-9 | 46.14     | 50.18 |       | 332.54| 277.58|
| 22  | AVLN 118-2/AVLN 100-1 | 53.13     | 52.02 | c     | 288.97| 269.68|
| 23  | MAL 04/AVLN 100-1   | 56.68     | 51.79 | c     | 279.96| 255.84|
| 24  | AVLN 83-1/AVLN 100-1 | 51.46     | 54.25 | c     | 294.46| 297.29|
| 25  | AVLN 83-6/AVLN 86-2  | 52.67     | 51.73 | c     | 332.28| 253.58|
| 26  | AVLN 124-4/AVLN 83-6  | 47.38     | 50.99 | c     | 347.18| 307.77|
| 27  | AVLN 83-6/AVLN 122-2  | 46.61     | 49.76 |       | 316.38| 261.94|
|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 28 | AVLN 83-6/AVLN 100-1 | 44.67 | 51.07 | c | 352.60 | 287.69 |
| 29 | AVLN 118-2/AVLN 83-6 | 50.22 | 53.98 | c | 296.29 | 298.62 |
| 30 | MAL 04/AVLN 83-6 | 51.62 | 52.20 | c | 293.43 | 182.71 |
| 31 | AVLN 83-1/AVLN 83-6 | 48.21 | 52.33 | c | 304.56 | 281.10 |
| 32 | AVLN 124-4/AVLN 86-2 | 50.74 | 51.98 | c | 341.44 | 300.30 |
| 33 | AVLN 122-2/AVLN 86-2 | 49.98 | 53.15 | c | 361.40 | 290.09 |
| 34 | AVLN 86-2/AVLN 124-9 | 49.33 | 41.23 | 50.74 | 51.98 | c | 293.43 | 182.71 |
| 35 | AVLN 118-2/AVLN 86-2 | 55.07 | 51.62 | c | 315.94 | 295.65 |
| 36 | MAL 04/AVLN 86-2 | 53.54 | 52.23 | c | 279.40 | 229.90 |
| 37 | AVLN 83-1/AVLN 86-2 | 51.46 | 49.48 | 352.60 | 287.69 |
| 38 | AVLN 122-2/AVLN 124-4 | 47.11 | 54.18 | c | 386.12 | 328.00 |
| 39 | AVLN 124-4/AVLN 124-9 | 43.88 | 50.28 | 335.51 | 272.90 |
| 40 | AVLN 118-2/AVLN 124-4 | 45.24 | 52.40 | c | 340.36 | 306.59 |
| 41 | MAL 04/AVLN 124-4 | 50.00 | 52.73 | c | 324.66 | 278.26 |
| 42 | AVLN 83-1/AVLN 124-4 | 45.53 | 52.25 | c | 298.63 | 277.31 |
| 43 | AVLN 122-2/AVLN 124-9 | 45.59 | 47.20 | 358.82 | 309.55 |
| 44 | AVLN 118-2/AVLN 122-2 | 56.27 | 48.34 | 319.74 | 277.52 |
| 45 | MAL 04/AVLN 122-2 | 51.53 | 48.86 | 278.31 | 264.87 |
| 46 | AVLN 83-1/AVLN 122-2 | 40.01 | 50.96 | c | 292.90 | 289.44 |
| 47 | AVLN 118-2/AVLN 124-9 | 48.39 | 53.40 | c | 328.21 | 284.27 |
| 48 | MAL 04/AVLN 124-9 | 48.51 | 53.04 | c | 296.99 | 255.10 |
| 49 | AVLN 83-1/AVLN 124-9 | 51.72 | 53.92 | c | 323.58 | 271.26 |
| 50 | MAL 04/AVLN 118-2 | 52.49 | 52.02 | c | 289.47 | 279.47 |
| 51 | AVLN 83-1/AVLN 118-2 | 43.04 | 45.99 | 300.39 | 267.11 |
| 52 | AVLN 83-1/MAL 04 | 49.99 | 54.14 | c | 261.57 | 264.56 |

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|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 53 | ADV 777 | 55.06 | 51.73 | 327.86 | 271.08 |
| 54 | Bisi 18 | 49.93 | 47.04 | 319.51 | 280.29 |
| 55 | P-27 | 56.38 | 41.67 | 326.79 | 295.77 |
| 56 | JH-37 | 53.92 | 50.30 | 317.00 | 267.51 |

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| Average | 49.36 | 50.87 | 320.80 | 279.08 |
| LSD 5% | 7.96 | 8.84 | 38.62 | 65.33 |
| CV | 10.0 | 14.1 | 7.4 | 14.5 |

Note: the numbers followed by the letters a b c d in the column mean that they are significantly higher than the inbred genotypes ADV777 (a), Bisi 18 (b), P-27 (c) and JH 37 (d) based on the 5% LSD test.

### 3.2 General combining ability (GCA)

Analysis of variance showed that maize grain yields were significantly different between hybrid maize genotypes, so that the combined value of the parents could be calculated. In the yield character, general affinity was not significantly different between genotypes, while the specific affinity was significantly different. This shows that there are lines that have better Specific Combining Ability (SCA) than other lines.
The interaction between GCA under stress conditions was not significant. Genotypes that have high GCA under normal conditions tend to be high under conditions of low N stress than genotypes that have low GCA under normal conditions. This indicates that the selection of genotypes that have high GCA under normal conditions can be used as hybrid parents tolerant of low N stress.

Table 3. Combining ability of the 11 genotypes of maize under conditions of low N stress, Bajeng, South Sulawesi, 2020.

| Source                        | df | Sum Square | Mean Square | F Value | Pr(>F) |
|-------------------------------|----|------------|-------------|---------|--------|
| Stress condition (SC)         | 1  | 851.16     | 851.16**    | 27.82   | 0.01   |
| Replication (R)               | 4  | 122.4p     | 30.60       | 26.01   | 0.00   |
| Genotype                      | 54 | 178.89     | 3.31**      | 2.20    | 0.00   |
| Genotype x SC                 | 54 | 81.38      | 1.51 tn     | 1.28    | 0.12   |
| GCA                           | 10 | 28.22      | 2.82 tn     | 1.72    | 0.20   |
| SCA                           | 44 | 150.67     | 3.42**      | 2.32    | 0.00   |
| GCA x SC                      | 10 | 16.36      | 1.64 tn     | 1.39    | 0.19   |
| SCA x SC                      | 44 | 65.02      | 1.48 tn     | 1.26    | 0.15   |
| Error                         | 192| 225.89     | 1.18        |         |        |

Table 4. GCA values of 11 maize genotypes for yield characters under low and normal N stress conditions, Bajeng, South Sulawesi, 2020.

| Code | Lines     | GCA Low N (100 kg N/ha) | GCA Normal (200 kg N/ha) |
|------|-----------|-------------------------|--------------------------|
| A    | AVLN 100-1| -0.44                   | -0.05                    |
| B    | AVLN 118-2| -0.10                   | 0.14                     |
| C    | AVLN 122-2| 0.06                    | 0.06                     |
| D    | AVLN 124-4| 0.33                    | -0.35                    |
| E    | AVLN 32-3 | -0.12                   | -0.53                    |
| F    | AVLN 83-1 | 0.18                    | 0.03                     |
| G    | AVLN 83-4 | 0.55                    | 0.38                     |
| H    | AVLN 83-6 | -0.12                   | -0.28                    |
| I    | AVLN 86-2 | -0.16                   | 0.17                     |
| J    | MAL 04    | 0.06                    | 0.46                     |
| K    | AVLN 124-9| -0.24                   | -0.03                    |

Genotypes with good GCA values have good ability to combine with other genotypes to form superior hybrid maize. A good GCA for the character of the grain yield variable is one that has a large value. The results of the combining analysis showed that the AVLN83-4 strain had a significantly higher GCA value for the yield variable under conditions of low N stress, namely 0.55 and 0.38 under normal conditions (Table 4).

3.3 Specific combining ability (SCA)
Genotype pairs that had significantly positive SCA values under conditions of low and normal N fertilization stress were AVLN 118-2/AVLN 83-6, AVLN 122-2/AVLN 124-4, AVLN 122-2/AVLN 83-6, AVLN 124-4/AVLN 83-4, AVLN 124-4/AVLN 86-2, AVLN 83-1/AVLN 124-9 (Table 5). Hybrids that are tolerant under conditions of low N stress are shown by the AVLN 83-4/AVLN 124-4
genotype pair which has a yield of 6.29 under conditions of low N stress Table (6). The genotype yield was significantly higher than the Bisi 18 and JH 37 varieties, which only produced 4.61 t/ha and 4.06 t/ha under conditions of low N stress. The yield of maize is a complex character controlled by many interacting genes or characters whose expression is strongly influenced by the environment.

Table 5. Values of special combining ability of inbred pairs for grain yield variables under low N conditions (LN), normal conditions (Normal), and combining conditions. Bajeng, South Sulawesi, 2020.

| Crosses | LN     | Normal | Combine |
|---------|--------|--------|---------|
| A x B   | -0.68  | -0.26  | -0.47   |
| A x C   | 0.65   | -1.04  | -0.20   |
| A x D   | -0.90  | 0.36   | -0.27   |
| A x E   | 0.26   | -1.45  | -0.59   |
| A x F   | 0.72   | 0.16   | 0.44    |
| A x G   | -0.87  | -0.09  | -0.48   |
| A x H   | 0.16   | 1.06   | 0.61    |
| A x I   | 0.30   | 0.29   | 0.30    |
| A x J   | -0.41  | 0.77   | 0.18    |
| A x K   | 0.77   | 0.20   | 0.49    |
| B x C   | -0.46  | -0.12  | -0.29   |
| B x D   | 0.04   | -0.56  | -0.26   |
| B x E   | -0.01  | -0.54  | -0.28   |
| B x F   | -1.63  | 0.19   | -0.72   |
| B x G   | -0.28  | 0.53   | 0.13    |
| B x H   | 1.11 **| 0.93   | 1.02    |
| B x I   | 0.02   | 0.35   | 0.18    |
| B x J   | 1.44   | -0.70  | 0.37    |
| B x K   | 0.46   | 0.18   | 0.32    |
| C x D   | 0.64 **| 1.32   | 0.98    |
| C x E   | 0.04   | -0.13  | -0.05   |
| C x F   | 0.09   | -0.38  | -0.15   |
| C x G   | -0.67  | 0.14   | -0.27   |
| C x H   | 0.85 **| 1.21   | 1.03    |
| C x I   | -0.83  | 0.78   | -0.02   |
| C x J   | -0.38  | -1.40  | -0.89   |
| C x K   | 0.08   | -0.38  | -0.15   |
| D x E   | 0.18   | 0.88   | 0.53    |
| D x F   | 0.72   | -0.08  | 0.32    |
| D x G   | 1.12 **| 1.93 **| 1.52    |
| D x H   | -1.67  | -3.16  | -2.41   |
| D x I   | 0.90 **| 1.12   | 1.01    |
| D x J   | 0.85   | 0.12   | 0.49    |
|   |   |   |   |
|---|---|---|---|
| D x K | -1.90 | -1.94 | -1.92 |
| E x F | -0.10 | 0.36 | 0.13 |
| E x G | 0.87 | -0.29 | 0.29 |
| E x H | 0.10 | 0.28 | 0.19 |
| E x I | -0.79 | -1.24 | -1.01 |
| E x J | -0.36 | 1.74 | 0.69 |
| E x K | -0.20 | 0.40 | 0.10 |
| F x G | -0.62 | -0.51 | -0.57 |
| F x H | -0.38 | 0.05 | -0.16 |
| F x I | -0.56 | -0.63 | -0.59 |
| F x J | 0.86 | -0.25 | 0.30 |
| F x K | 0.91 | ** | 1.09 | 1.00 |
| G x H | -0.29 | 0.35 | -0.32 |
| G x I | 0.04 | -0.84 | 0.40 |
| G x J | -0.27 | -0.49 | -0.38 |
| G x K | 0.98 | -0.03 | 0.48 |
| H x I | 0.64 | -0.35 | 0.15 |
| H x J | 0.67 | 0.06 | -0.31 |
| H x K | 0.15 | 0.27 | 0.21 |
| I x J | 0.22 | 0.23 | 0.23 |
| I x K | 0.05 | 0.28 | 0.17 |
| J x K | -1.30 | -0.08 | -0.69 |

**= significantly different based on the Critical Difference test at the 1% level (P < 0.01)

*= significantly different at the 5% level (P < 0.05)

A= AVLN 100-1, B= AVLN 118-2, C= AVLN 122-2, D= AVLN 124-4, E= AVLN 32-3, F= AVLN 83-1, G= AVLN 83-4, H= AVLN 83-6, I= AVLN 86-2, J= MAL 04, dan K= AVLN 124-9
Table 6. Grain yield of several genotypes of hybrid maize from cross combinations using the half-diallel method under low N stress conditions. Maros, South Sulawesi, 2020.

| Crosses | Tolerance criteria | Yield (t/ha) |
|---------|--------------------|-------------|
| A x B   | P                  | 3.08        |
| A x C   | P                  | 4.56        |
| A x D   | P                  | 3.29        |
| A x E   | P                  | 4.00        |
| A x F   | P                  | 4.76        |
| A x G   | P                  | 3.53        |
| A x H   | P                  | 4.78        |
| A x I   | P                  | 4.01        |
| A x J   | P                  | 3.51        |
| A x K   | P                  | 4.39        |
| B x C   | P                  | 3.79        |
| B x D   | P                  | 4.56        |
| B x E   | P                  | 4.06        |
| B x F   | P                  | 2.73        |
| B x G   | P                  | 4.46        |
| B x H   | P                  | 5.18        |
| B x I   | P                  | 4.05        |
| B x J   | P                  | 5.69        |
| B x K   | P                  | 4.42        |
| C x D   | MT                 | 5.32        |
| C x E   | P                  | 4.28        |
| C x F   | P                  | 4.62        |
| C x G   | P                  | 4.23        |
| C x H   | P                  | 5.08        |
| C x I   | P                  | 3.37        |
| C x J   | P                  | 4.04        |
| C x K   | P                  | 4.20        |
| D x E   | P                  | 4.68        |
| ADV 777 | MT                 | 4.99        |
| Bisi 18 | P                  | 4.61        |
| P-27    | P                  | 4.66        |
| JH-37   | P                  | 4.06        |

Average 4.27

LSD 5% 1.66
CV 23.8

Note: T= tolerant, MT= moderate tolerant, P= susceptible
4. Conclusion
Our findings indicated one hybrid pair i.e. AVLN 83-4/AVLN 124-4 performed a good tolerance to low N stress. This hybrid is comparable with the two commercial varieties Bisi-18 and JH 37 with average yield at normal and low N stress was 7.87 t/ha. Inbred maize genotypes classified as medium tolerant (MT) were AVLN 83-4/AVLN 124-9, AVLN 124-4/AVLN 86-2, AVLN 122-2/AVLN 124-4, AVLN 83-1/AVLN 124-9, has the same yield potential as all control varieties.

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