*Original Research Article*

INFLUENCE OF PLANT DENSITY ON THE GROWTH AND YIELD OF TWO HYBRID VARIETIES OF CORN (*Zea mays* L.) IN DSCHANG, WEST CAMEROON

ABSTRACT

|  |
| --- |
| **Aims:** Maize (*Zea mays* L.) is vital to Cameroon's agricultural sector, supporting food security and economic stability. Despite production efforts, yields remain low, necessitating agronomic interventions. This study assessed the effect of sowing density on the growth and yield of two hybrid maize varieties, Pannar 12 and Kabamanoj F1, in Dschang, Cameroon. **Study design:** A completely randomized block design with a split-plot arrangement and three replications was used, with variety as the main plot and sowing density as the subplot.**Place and Duration of Study:** The study was conducted at the Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon, from February to June, 2023.**Methodology:** Four sowing densities were tested: 62,500 plants/ha, 83,333 plants/ha, 62,500 plants/ha, and 71,428 plants/ha. Growth parameters, including plant height, collar diameter, and number of leaves per plant, were recorded at different growth stages. Yield components such as ear diameter, ear length, grain weight, and total yield were also assessed. Statistical analyses included ANOVA, LSD tests for mean separation, and Pearson correlation analysis.**Results:** Sowing density significantly influenced the number of leaves per plant (P < 0.05), with the highest at 62,500 plants/ha (11.60) and the lowest at 83,333 plants/ha (9.58) at 42 days after sowing. Variety significantly affected ear diameter (P < 0.01), with Pannar 12 (51.70 mm) outperforming Kabamanoj F1 (50.34 mm). Grain weight was variety-dependent but unaffected by sowing density. Correlation analysis showed significant positive relationships between yield and growth parameters such as leaf length (r = 0.54\*\*), stalk height (r = 0.55\*\*), and collar diameter (r = 0.56\*\*). **Conclusion:** Higher sowing densities reduced individual plant growth but optimized total plot yield. The Pannar 12 variety at 62,500 plants/ha is recommended for maximizing maize productivity in Dschang. These findings provide valuable agronomic insights for optimizing maize production in similar agro-ecological zones. |

*Keywords: Maize, Hybrid Varieties, Plant Density, Agronomic Performance, Yield Components, West Cameroon*

1. INTRODUCTION

Like most sub-Saharan African countries, Cameroon's economy is heavily dependent on agriculture for the vitality of its growth process, contributing around 22.2% to its gross domestic product (GDP) and employing around 45% of the working population (INS, 2016). In addition, agriculture plays an essential role in stimulating growth in other sectors of the economy, reducing poverty and contributing to food security. Agriculture in Cameroon is mainly practised by small-scale farmers, who control around 70% of total agricultural land (Yengoh and Jonas, 2014). With its five agro-ecological zones offering a variety of landscapes and climates, the country offers great diversity in terms of agricultural production (Abossolo, 2017).

Maize (Zea mays L.) plays an important role in the agricultural sector. Like rice and wheat, it has a strategic and priority role in world food security (Ngoucheme *et al*., 2020). Total world maize production is 1,210.2 million tonnes, with an average yield of 5.8 tonnes per hectare (FAO, 2021). Maize is grown for its starch-rich grains for human and animal consumption, but also for numerous uses in the textile and pharmaceutical industries, and in the production of biodegradable plastic and biofuel (Kaho *et al*., 2011; Useni *et al*., 2014). In Africa, maize consumption is high, partly because of the rapid increase in population (3% per year) and changing eating habits (Seck *et al*., 2013). Maize is the third most important crop for humans, after wheat and rice (Sarr and Atta, 2011).

In Cameroon, maize, along with other cereals (rice, sorghum, millet, wheat) and tubers (cassava, plantain, macabo), are the main staple food for the population. Indeed, among the cereals grown in Cameroon, maize ranks first in terms of production area, ahead of wheat and rice. National production is 2 million tonnes, with a yield of 1.7 tonnes per hectare (FAO, 2021), and the demand is 3 million tonnes to meet local consumption needs (MINADER, 2021). However, productivity remains low, while demand remains high in the face of a growing population.

The difficulties hampering maize production in Cameroon include the constant decline in soil fertility, poor use of and access improved seeds, the high price of synthetic chemical inputs (Nyembo *et al*., 2010; Useni *et al*., 2012), pest pressure linked to the effects of climate change (Kalonji *et al*., 2004; Issa *et al*., 2011), climatic hazards, unavailability of quality seed, poor cultivation practices and farming methods that are less suited to the local context. Faced with these difficulties, the adoption of new improved maize varieties with high agronomic potential is a serious alternative for helping to increase maize yields.

Over the years, the area under maize cultivation in Cameroon has continued to increase, rising from 846,130 ha in 2012 to 1,186,193 ha in 2021. However, yields have not kept pace, falling from 1.97 t/ha to 1.7 t/ha over the same period (FAO, 2021). This is due to the large-scale production of traditional varieties adapted to agro-ecological conditions but with low production potential by these producers (Kaho *et al*., 2011). The West Cameroon region alone accounts for almost 60% of national maize production (INS, 2010). In addition, increasing demographic pressure is leading to greater demand for food, housing and other items. This translates into additional pressure on the land available for agriculture, leading to an intensification of farming practices and an extension of cultivated areas. As a result, there is a reduction in the fallow period and a decline in soil fertility, leading to lower crop yields (Konan *et al*., 2018). In addition, with the climate change observed in recent decades, the maize genotypes sought must have both good tolerance to associated stress and good grain yield potential (Nyembo, 2010). In the United States, of the 100% increase in maize yield, 60% is linked to genetic improvement, and maize yields rose from 1 tonne per ha in the 1930s to 7 tonnes per ha in the 1990s. In France, 58% of the progress in maize yields is due to genetic improvement. So, the adoption of new improved varieties of maize with high agronomic potential is a serious alternative to help increase maize yields (Konan *et al*., 2018).

Sowing density is one of the main factors affecting crop growth and yield. In general, higher sowing densities can lead to a reduction in the growth of individual plants, but an increase in production at plot level. This can be explained by the fact that in a higher seeding density, plants have to compete for access to resources such as water, nutrients and sunlight, which can limit individual growth but increase overall yield (Argenta, 2001; Caliskan, 2007). Studies have shown that some varieties are more tolerant to high sowing densities, while other varieties grow better at lower densities (Kouassi *et al*., 2017). As the sowing densities of these varieties have not yet been studied in the study area, it is necessary to determine the optimal sowing density for each variety. To this end, this study assesses the influence of sowing density on growth and yield parameters of two hybrid maize varieties in Dschang. This study will help to optimise maize yields in order to ensure food security and improve the incomes of maize growers through the use of new, improved varieties. On a scientific level, it will provide technical knowledge to growers by informing them about the diversity of sowing densities and also guide them in their choice of varieties when setting up their farms. It will also enable new maize varieties to be promoted, with recommendations for optimum sowing densities.

2. material and methods

**2.1 Description of the study site**

This study was carried out at the Faculty of Agronomy and Agricultural Sciences (FASA) Research and Application Farm at the University of Dschang (UDs), 5°20' latitude North and 10°03' longitude East altitude of 1407 m, in the Menoua Division of the West Region of Cameroon; from the11th of February to the 2nd of June 2023. The site (FAR) is located in zone III of Cameroon's five agro-ecological zones, known as the Western Highlands zone.

The climate in Dschang is tropical and humid, with a rainy season from mid-March to mid-November (8 months) and a dry season from mid-November to mid-March (4 months). Average annual rainfall is between 1,800 and 2,000 mm (Metambou, 2016). Annual temperatures vary between 13.02°C and 26.73°C, with an average of 19.87°C and an average thermal amplitude of 13.71°C; relative air humidity is above 60% (Metambou, 2016). Sun exposure is highest during the dry season, when it accounts for 8.5 hours per day, whereas in the rainy season it falls to 2.2 hours per day. Total annual sunshine is 1,864 hours (Metambou, 2016). The dominant vegetation on the site is made up of the following species: *Tithonia diversifolia*, *Mimosa pudica*, *Ageratum conyzoides*, *Cyperus esculentus* and *Pennisetum purpureum* (Metambou, 2016). The type of soil encountered in the study area belongs to the group of brown or red soils on basic rocks, otherwise known as Oxisol (according to the US Soil classification) or red ferralitic soil according to the French classification (Orstom, 1965).

**2.1.2 Plant materials**

The plant material studied consisted of two hybrid maize varieties, Kabamanoj F1 and Pannar 12 from Arysta Lifesciences Cameroun, the characteristics of which are presented in Table 1 below.

**Table 1: Characteristics of the different varieties**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Varieties** | **Cycle (days)** | **Potential yield/ha** | **Special features** | **Grain characteristics** |
| **Pannar 12** | 115-120 | 8 tons | Very high drought tolerance;Resistant to leaf diseases. | Hard dark yellow grain, tolerant to insect attack |
| **Kabamanoj F1** | 85-90 | 10 tons | Plant resistance to lodging; Better tolerance to drought stress;disease resistance. | Yellow-orange grain, horny and toothed;Protein-rich maize ideal for feed and poultry farming. |

**2.3 Phytosanitary materials used**

Throughout the trial, several phytosanitary products were used to treat the plot, alternating products for each treatment. Table 2 shows these products with some information marked on their labels.

**Table 2: Phytosanitary materials**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Insecticides** | **Commercial names** | **Active ingredient** | **Nature** | **Target pest** |
| K-OPTIMAL | Lambda-cyhalothrine 15 g/l + Acetamipride 20 g/l | Systemic  | defoliator caterpillars, noctuid moths, leaf miners, the borers and the aphids |
| CAÏMAN B | Emamectine benzoate 50 g/kg | Contact and systemic | Army worm |
| PYRIFORCE | Chloropyriphos-ethyl 600 g/l | Contact and systemic | Defoliating caterpillars, aphids, whitefly |

Organic fertiliser was not used in this study because soil analyses showed that the organic matter on site was high. Only mineral fertilisers were used, in particular NPK14-23-14 at a rate of 300 kg/ha and urea at a rate of 100 kg/ha, taking into account the quantities already present in the soil.

**2.4 Land preparation**

Land preparation consisted firstly of clearing the plot using machetes, then delimiting the trial area. A flat ploughing was also carried out, followed by the preparation of the different experimental units on which the seeds were to be sown. The experiment followed a completely randomized block design with a split-plot arrangement and three replicates. Variety served as the main plot factor, randomly distributed within each block, while density was the subplot factor. This classic Fischer block design ensured randomization and replication for robust statistical analysis. Each sub-block was randomly divided based on the density factor, with each block representing a replicate where all treatments appeared once. The design included three (3) blocks, each containing eight (8) experimental units, resulting in a total of twenty-four (24) experimental units. Each experimental unit covered an area of 2.5 m × 2.5 m (6.25 m²). The experimental layout included 50 cm spacing between units, 1 m spacing between blocks and sub-blocks, and a 1 m outer margin for passage. The total area of the experimental plot was 299 m² (Figure 1). The trial required 387 g of seed for each variety.

The treatment descriptions were as follows:

V1D1: Variety Pannar 12 + Density 80cm x 40cm

V1D2: Variety Pannar 12 + Density 80cm x 20cm

V1D3: Variety Pannar 12 + Density 60cm x 20cm

V1D4: Variety Pannar 12 + Density 70cm x 20cm

V2D1: Variety Kabamanoj F1 + Density 80cm x 40cm

V2D2: Variety Kabamanoj F1 + Density 80cm x 20cm

V2D3: Variety Kabamanoj F1 + Density 60cm x 20cm

V2D4: Variety Kabamanoj F1 + Density 70cm x 20cm

**2.5 Sowing**

The seeds were sown manually, with the number of seeds per pocket determined by the spacing. For 80 cm × 40 cm spacings, two seeds were sown per pocket, while for 80 cm × 20 cm, 60 cm × 20 cm, and 70 cm × 20 cm spacings, one seed was sown per pocket.

This resulted in plant densities per experimental unit as follows:

* 80 cm × 40 cm: 24 plants per unit (62,500 plants/ha),
* 60 cm × 20 cm: 50 plants per unit (83,333 plants/ha),
* 80 cm × 20 cm: 40 plants per unit (62,500 plants/ha),
* 70 cm × 20 cm: 40 plants per unit (71,428 plants/ha).

**2.6 Fertilisation**

The first fertilization was conducted 14 days after sowing, using a formulated mineral fertilizer (NPK 14-23-14). The fertilizer was applied 5 cm from the sowing line at a depth of 2–3 cm, with a dose of 300 kg/ha, corresponding to 70.95 g per experimental unit. The second fertilization, using urea, was applied 52 days after sowing, immediately following the second weeding. This application was also placed 5 cm from the seed line at a depth of 2–3 cm, with a dose of 100 kg/ha, equivalent to 62.5 g per experimental unit.

**2.7 Phytosanitary treatment**

The insecticide CAÏMAN B WG, as detailed in Table 2, was applied to control armyworms upon their appearance on the maize crop. Additionally, K-OPTIMAL and PYRIFORCE insecticides were used to manage infestations of aphids and borers when they appeared.

**2.8 Harvesting**

Harvesting was performed manually in a single operation, 15 weeks and 6 days after sowing.

**2.9 Data collection**

Data were collected from 8, 12, and 15 plants located at the center of each experimental unit, depending on the plant density. Sampling was conducted at four intervals, spaced two weeks (14 days) apart, beginning two weeks after seedling emergence. Plants for data collection were randomly selected from the center of the plot to minimize border effects.

**2.9.1 Growth variables**

*2.9.1.1 Plant Height*

Height was measured from the crown to the tip of the last fully opened leaf using a wooden ruler graduated to the nearest centimeter. The average plant height was calculated from the heights of the plants sampled in each experimental unit.

*2.9.1.2 Crown Diameter*

The crown diameter, corresponding to the ring between the roots and the stem, was measured using a caliper. This measurement served as an indicator of plant growth. The average crown diameter (mm) was calculated from the diameters of the sampled plants in each experimental unit.

*2.9.1.3 Number of Leaves per Plant*

The number of leaves on each sampled plant was counted manually. The average number of leaves was obtained from the sampled plants within each experimental unit.

*2.9.1.4 Leaf Length and Width*

Leaf length and width were measured with a ruler graduated to the nearest centimeter. The leaf area (LA) was calculated using the formula from Ruget et al. (1996):

LA= L × W × 0.75……………………………………………………………………………………(1)

Where LA = leaf area, L = length and W = width

**2.9.2 Yield variables**

*2.9.2.1 Ear diameter*

The diameter of the dry, destemmed ear was measured after harvest. It was measured on all the sampled spikes from each experimental unit. The instrument used to measure this variable was a vernier caliper.

*2.9.2.2 Ear length*

After harvesting the spikes from the sampled plants in each experimental unit, the length of the dry, destemmed spikes was measured using a ruler graduated in centimetres.

*2.9.2.3 Seed weight of ears and 1000 seeds*

After harvesting the cobs from the sampled plants in each experimental unit, they were dehulled and the seeds from these cobs were weighed using an electronic balance, along with the weight of 1000 seeds.

*2.9.2.4 Dry grain yield at 15% moisture*

To determine this, the ears of the sampled plants were harvested from each experimental unit, then destemmed and oven-dried at a temperature of 25°C. Once removed from the oven, the ears were dehulled and the total weight of the seeds was weighed using an electronic balance. The yield was calculated using the following formulae:

$RT=\frac{10 000 ×PT}{S.U}=\frac{Number of plants per hectare×PT}{Number of plant sample}$……………………………….(2)

Where: E.A = Spacing × Number of sampled plants

$PT=\frac{PT at Y×(100-Y)}{100-15}$………………………………………………………………(3)

*RT* = Total Yield of maize grains (t/ha); *PT* = Total Weight of maize grains at 15% moisture; *S.U* = Effective Area ; *PT at Y* = The total weight of maize grains at moisture content Y%; *Y* = The actual moisture content of the maize grains during measurement; *15* = The desired standard moisture content (15%).

**2.10 Data analysis**

The data collected was entered into a Microsoft Excel version 2013 spreadsheet. The data was then imported into the R software, which was used to perform the statistical analyses. The following tests were carried out: the Shapiro-Wilk normality test to check whether the data conformed to the normal distribution, the ANOVA test to check for significant differences and the LSD (Smallest Significant Difference) test to separate the means. A correlation analysis was also performed between growth and yield parameters.

3. results and discussion

**3.1 Results**

**3.1.1 Effect of variety and plant density on growth variables**

*3.1.1.1 Number of leaves per plant*

The main effect of variety was significant (*P* < .01) on the number of leaves per plant at 14 days after sowing while the main effect of plant density was not significant (*P* > .05) on the number of leaves per plant throughout the experiment. The variety x plant density (V x D) interaction significantly affected the number of leaves per plant at 42 days after sowing (Table 3).

**Table 3:** **Main and interaction effect of variety and plant density on the number of leaves per plant**

|  |  |  |
| --- | --- | --- |
| **Source of variation**  | **Degree of freedom** | **P-value** |
|  |  | **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Variety (V) | 1 | .009\*\* | .24 | .41 | .37 |
| Density (D) | 3 | .28 | .64 | .28 | .65 |
|  V x D  | 3 | .65 | .47 | .02\* | .81 |

*Significance levels, \*P<.05; \*\*P<.001. DAS: Days after sowing.*

At 42 days after planting, the highest number of leaves per plant was recorded by Pannar 12 at the D1 (80 cm x 40 cm) plant density while the lowest number of leaves per plant was recorded by Kabamanoj F1 at the D3 (60 cm x 20 cm) plant density (Table 4).

**Table 4:** **Variation in the mean number of leaves per plant for the variety x density interaction**

|  |  |  |
| --- | --- | --- |
| **Variety** | **Density** | **Mean number of leaves per plant** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Pannar 12 | D1 | 4.00 ± 0.00a | 7.95 ± 1.04a | 11.60 ± 1.22a | 14.20 ± 0.31a |
| D2 | 3.91 ± 0.14a | 7.80 ± 0.42a | 10.88 ± 0.59ab | 14.16 ± 1.49a |
| D3 | 3.93 ± 0.11a | 7.66 ± 0.35a | 9.93 ± 0.52c | 14.08 ± 0.49a |
| D4 | 4.00 ± 0.00a | 8.28 ± 0.25a | 11.23 ± 1.56a | 13.57 ± 0.35a |
| Kabamanoj F1 | D1 | 3.25 ± 0.43a | 7.08 ± 0.68a | 10.17 ± 1.30c | 13.59 ± 0.36a |
| D2 | 3.05 ± 0.09a | 7.22 ± 0.96a | 9.97 ± 0.67c | 13.91 ± 1.12a |
| D3 | 3.02 ± 0.03a | 6.68 ± 0.67a | 9.58 ± 0.80c | 13.61 ± 1.14a |
| D4 | 3.05 ± 0.09a | 7.05 ± 0.75a | 9.94 ± 0.93c | 13.64 ± 1.25a |
| P-value |  | .13 | .06 | .04\* | .15 |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other.* ***Significance levels:*** *\*P <.05;* ***DAS:*** *Days after sowing.* *Mean ± SD = Mean values ± Standard deviation of means*

At 14 days after sowing, Pannar 12 significantly (*P* < .01) outperformed Kabamanoj F1 in terms of number of leaves per plant, with Pannar 12 recording an average of 3.96 as oppose to 3.09 leaves per plant for Kabamanoj F1(Table 5).

**Table 5:** **Variation in the mean number of leaves per plant across varieties**

|  |  |
| --- | --- |
| **Variety** | **Mean number of leaves per plant** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Pannar 12 | 3.96 ± 0.08a | 7.92 ± 0.57a | 10.91 ± 1.11a | 14.00 ± 0.74a |
| Kabamanoj F1 | 3.09 ± 0.21b | 7.01 ± 0.69a | 9.91 ± 0.84a | 13.69 ± 0.89a |
| Significance | .001\*\* | .77 | .26 | .81 |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other.* ***Significance levels:*** *\*\*P<.01;* ***DAS:*** *Days after sowing.* *Mean ± SD = Mean values ± Standard deviation of means*

*3.1.1.2 Plant height*

The main effect of variety was significant (*P* = .05) on plant height at 28 days after sowing and 56 days after sowing. The main effect of plant density and the interaction effect of variety x plant density (V x D) were not significant on plant height throughout the experiment (Table 6).

**Table 6: Main and interaction effect of variety and plant density on the mean plant height**

|  |  |  |
| --- | --- | --- |
| **Source of variation** | **Degrees of freedom** | **P-value** |
|  |  | **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Variety (V) | 1 | .06 | .002\*\* | .17 | .03\* |
| Density (D) | 3 | .51 | .59 | .50 | .79 |
|  V x D  | 3 | .65 | .99 | .52 | .60 |

*Significance levels: \*P<.05; \*\*P<.01; DAS: Days after sowing.*

At 28 days after sowing, Pannar 12 significantly (*P* = .05) outperformed Kabamanoj F1 in terms of plant height, with Pannar 12 recording an average plant height of 59.48cm as oppose to 51.57cm for Kabamanoj F1. A similar result was recoded at 56 days after sowing, in which Pannar 12 significantly outperformed Kabamanoj F1, with Pannar 12 recording an average height of 174.82cm as oppose to Kabamanoj F1which recorded an average plant height of 152.49cm (Table 7).

**Table 7: Variation in the mean plant height across varieties**

|  |  |
| --- | --- |
| **Variety**  | **Mean plant height (cm)** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Pannar 12 | 17.88 ± 2.65a | 59.48 ± 4.11a | 113.37 ± 23.61a | 174.82 ± 11.98a |
| Kabamanoj F1 | 14.57 ± 0.84a | 51.57 ± 4.87b | 91.96 ± 10.93a | 152.49 ± 5.99b |
| P-value | .08 | .004\*\* | .06 | .03\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*P<.05; \*\*P<.01; DAS: Days after sowing. Mean ± SD = Mean values ± Standard deviation of means*

*3.1.1.3 Collar diameter*

The main effect of variety was significant (*P* = .05) on collar diameter at 14, 28 and 56 days after sowing while the main effect of plant density was significant collar diameter at 42 and 56 days after sowing. The interaction effect of variety and plant density (V and D) was not significant (P > 0.05) on the collar diameter (Table 8).

**Table 8: Main and interaction effect of variety and plant density on the collar diameter**

|  |  |  |
| --- | --- | --- |
| **Source of variation**  | **Degrees of freedom**  | **P-value** |
|  |  | **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Variety (V) | 1 | .02\* | .049\* | .53 | .02\* |
| Density (D) | 3 | .24 | .66 | .046\* | .03\* |
|  V x D  | 3 | .81 | .81 | .08 | .83 |

*Significance levels: \*P<.05; DAS: Days after sowing.*

At 14 days after sowing, Pannar 12 significantly (*P* = .05) outperformed Kabamanoj F1 in terms of collar diameter, with Pannar 12 recording an average collar diameter of 5.45mm as oppose to 3.63mm for Kabamanoj F1. A similar observation was made at 28 days after sowing, in which Pannar 12 significantly outperformed Kabamanoj F1, with Pannar 12 recording an average collar diameter of 11.23mm as oppose to Kabamanoj F1which recorded an average plant height of 8.50mm (Table 11). A similar trend was equally recorded at 56 days after sowing, in which Pannar 12 significantly outperformed Kabamanoj F1, with Pannar 12 recording an average collar diameter of 23.63mm as oppose to Kabamanoj F1 which recorded an average collar diameter of 8.50mm (Table 9).

**Table 9: Variation in collar diameter across varieties**

|  |  |
| --- | --- |
| **Variety** | **Collar diameter (mm)** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Pannar 12 | 5.45 ± 0.67a | 11.23 ± 1.29a | 21.37 ± 5.09a | 23.63 ± 1.23a |
| Kabamanoj F1 | 3.63 ± 0.25b | 8.50 ± 0.57b | 18.69 ± 2.04a | 21.19 ± 1.11b |
| P-value | .03\* | .04\* | .65 | .02\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*P<.05; DAS: Days after sowing. Mean ± SD = Mean values ± Standard deviation of means*

At 42 days after sowing, the highest (22.37mm) collar diameter was recorded for the D1 (80 cm x 40 cm) plant density while the lowest (19.04mm) was recorded for the D3 (60 cm x 20 cm) plant density. On the other hand, at 56 days after sowing, the highest (23.18mm) collar diameter was recorded for the D1 (80 cm x 40 cm) plant density while the lowest (19.04mm) was recorded for the D3 (60 cm x 20 cm) plant density (Table 10).

**Table 10: Variation in collar diameter across plant densities**

|  |  |
| --- | --- |
| **Density** | **Collar diameter (mm)** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| D1 | 4.89 ± 1.15a | 10.03 ± 1.73a | 22.37 ± 6.33a | 23.18 ± 1.28a |
| D2 | 4.27 ± 1.05a | 9.98 ± 2.01a | 19.32±2.8b | 22.92 ± 1.70ab |
| D3 | 4.56 ± 1.26a | 9.92 ± 1.99a | 19.04 ± 3.19b | 21.51 ± 1.93c |
| D4 | 4.45 ± 0.91a | 9.54 ± 1.44a | 19.38 ± 2.80b | 22.02 ± 1.66bc |
| P-value | .74 | .67 | .02\* | .04\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*P<.05; DAS: Days after sowing. Mean ± SD = Mean values ± Standard deviation of means*

*3.1.1.4 Leaf area*

The main effect of variety on the leaf area was significant (*P* = .05) at 14, 28 and 56 days after sowing while the main effect of plant density and the interaction effect of variety and plant density (V and D) on the leaf area was not significant (*P* = .05) throughout the experimental period (Table 11).

**Table 11: Main and interaction effect of variety and plant density on the leaf area**

|  |  |  |
| --- | --- | --- |
| **Source of variation**  |  **Degrees of freedom** | **P-value** |
| **14 DAS** | **28 DAS** | **42 DAS** | **56 DAS** |
| Variety (V) | 1 | .045\* | .02\* | .46 | .02\* |
| Density (D) | 3 | .31 | .47 | .27 | .31 |
|  V x D  | 3 | .19 | .97 | .20 | .87 |

*Significance levels: \*P<.05; DAS: Days after sowing.*

At 14 days after sowing, Pannar 12 significantly (*P* = .05) outperformed Kabamanoj F1 in terms of leaf area, with Pannar 12 recording an average leaf area of 17.02cm2 as oppose to 13.43cm2 for Kabamanoj F1. Similarly, at 28 days after sowing, Pannar 12 significantly (*P* = .05) outperformed Kabamanoj F1 in leaf area, with Pannar 12 recording an average leaf area of 176.79cm2 as oppose to Kabamanoj F1which recorded an average leaf area of 123.47cm2 (Table 11). Furthermore, a similar trend was recorded at 56 days after sowing, in which Pannar 12 significantly (*P* = .05) outperformed Kabamanoj F1, with Pannar 12 recording an average leaf area of 720.17cm2 as oppose to Kabamanoj F1which recorded an average leaf area of 616.62cm2 (Table 12).

**Table 12: Variation in leaf area across varieties**

|  |  |
| --- | --- |
| **Variety**  | **Leaf area (cm2)** |
| **14DAS** | **28DAS** | **42DAS** | **56DAS** |
| Pannar 12 | 17.02 ± 1.59a | 176.79 ± 21.94a | 402.58 ± 85.74a | 720.17 ± 50.04a |
| Kabamanoj F1 | 13.43 ± 1.45b | 123.47 ± 22.67b | 325.59 ± 61.09a | 616.62 ± 48.81b |
| P\_value  | .02\* | .01\* | .08 | .04\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*P<.05; DAS: Days after sowing. Mean ± SD = Mean values ± Standard deviation of means*

**3.1.2 Effect of variety and sowing density on yield variables**

*3.1.2.1 Ear diameter*

The main effect of variety was significant (*P* < .01) on the ear diameter while the main effect of plant density and the interaction effect of variety and plant density were not significant (*P* = .05) on the ear diameter (Table 13)

**Table 13: Main and interaction effect of variety and plant density on the ear diameter**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of variation**  |  **Degrees of freedom**  | **Sum of squares** | **Medium squares** | **F** | **P-value** |
| Variety (V) | 1 | 11.09 | 11.09 | 184.14 | .005\*\* |
| Density (D) | 3 | 3.98 | 1.33 | 2.46 | .11 |
|  V x D  | 3 | 1.55 | 0.52 | 0.96 | .45 |

***Significance levels:*** *\*\*P<.01.*

The ear diameter varied significantly (*P* < .01) across varieties, with Pannar 12 outperforming Kabamanoj F1 as indicated by an ear diameter of 51.70mm as oppose to 50.34mm respectively (Table 14).

**Table 14: Variation in ear diameter across varieties**

|  |  |
| --- | --- |
| **Varieties** | **Ear diameter (mm)** |
| Pannar 12 | 51.70 ± 0.95a |
| Kabamanoj F1 | 50.34 ± 0.65b |
| P-value | .002\*\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*\*P<.01. Mean ± SD = Mean values ± Standard deviation of means*

*3.1.2.2 Ear length*

The main effects and the interaction effect of variety and plant density on ear length were not significant (*P* = .05) (Table 15).

**Table 15: Main and interaction effect of variety and plant density on the ear length**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of variation**  |  **Degrees of freedom** | **Sums of squares** | **Medium squares** | **F** | **P-value** |
| Variety (V) | 1 | 0.140 | 0.140 | 0.061 | .82 |
| Density (D) | 3 | 3.414 | 1.138 | 0.433 | .73 |
|  V x D  | 3 | 5.819 | 1.940 | 0.738 | .55 |

*3.1.2.3 Number of rows per cob*

The main effect of plant density and the interaction effect of variety and plant density on the number of rows per cob was significant (*P* = .05) while the main effect of variety on the number of rows per cob was not significant (*P* = .05) (Table 16).

**Table 16: Main and interaction effect of variety and plant density on the number of rows per cob**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of variation**  |  **Degrees of freedom** | **Sums of squares** | **Medium squares** | **F** | **P-value** |
| Variety (V) | 1 | 0.073 | 0.073 | 0.346 | .62 |
| Density (D) | 3 | 2.354 | 0.785 | 17.396 | <.001\*\*\* |
|  V x D  | 3 | 0.542 | 0.181 | 4.006 | .04\* |

*Significance levels: \*P<.05; \*\*\*P<.001*

Kabamanoj F1 significantly (*P* = .05) outperformed Pannar 12 at plant density D2 (80 cm x 20 cm) in terms of the number of rows per cob, with Kabamanoj F1recording an average of 14.44 rows per cob as oppose to an average of 13.41 rows per cob for Pannar 12 (Table 17).

**Table 17: Variation in the number of rows per cob for the variety x density interaction**

|  |  |
| --- | --- |
| **Varieties** | **Number of rows per cob** |
| **D1** | **D2** | **D3** | **D4** |
| Pannar 12 | 13.50 ± 0.25bc | 13.83 ± 0.52 b | 13.50 ± 0.25bc | 13.33 ± 0.14c |
| Kabamanoj F1 | 13.33 ± 0.14c | 14.44 ± 0.16 a | 13.41 ± 0.14c | 13.41 ± 0.14c |
| P-value | .89 | .04\* | .90 | .97 |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*P<.05. Mean ± SD = Mean values ± Standard deviation of means*

The number of rows per cob varied significantly (*P* < .001) across plant densities with the highest number of rows per cob recorded for D2 (80 cm x 20 cm) (14.13 rows per cob) and the lowest was recorded for D4 (80 cm x 40 cm) (13.37 rows per cob) (Table 18).

**Table 18: Variation in the number of rows per cob across plant densities**

|  |  |
| --- | --- |
| **Density** | **Number of rows per cob** |
| D1 | 13.41 ± 0.20b |
| D2 | 14.13 ± 0.47a |
| D3 | 13.45 ± 0.18b |
| D4 | 13.37 ± 0.13b |
| P-value | <.001\*\*\* |

***NB:*** *Values that share the same superscript letter along the same column are not significantly different from each other. Significance levels: \*\*\*P<.001. Mean ± SD = Mean values ± Standard deviation of means*

*3.1.2.4 1000-grain weight*

The main and interaction effects of variety and plant density were not significant (*P* = .05) on 1000-grain weight (Table 19).

**Table 19: Main and interaction effect of variety and plant density on 1000-grain weight**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of variation**  | **Degrees of freedom** | **Sums of squares** | **Medium squares** | **F** | **P-value** |
| Variety (V) | 1 | 1683.0 | 1683.0 | 1.7418 | .32 |
| Density (D) | 3 | 2389.1 | 796.4 | 0.5089 | .68 |
|  V x D  | 3 | 9679.9 | 3226.6 | 2.0618 | .16 |

*3.1.2.5 Grain yield*

The main and interaction effects of variety and plant density were not significant (*P* = .05) on 1000-grain weight (Table 20).

**Table 20: Main and interaction effect of variety and plant density on grain yield**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of variation**  | **Degrees of freedom**  | **Sums of squares** | **Medium squares** | **F** | **P-value** |
| Variety (V) | 1 | 5.196 | 5.196 | 13.918 | .07 |
| Density (D) | 3 | 0.555 | 0.185 | 0.202 | .89 |
|  V x D  | 3 | 1.515 | 0.505 | 0.553 | .67 |

**3.1.3 Correlation between growth variables and yield**

Pearson’s correlation analysis results (Table 21) showed that yield had a significant (*P* < .01) moderate positive correlation with leaf length (r = 0.54), collar diameter (r = 0.56) and plant height (r = 0.55).

**Table 21: Pearson’s correlation coefficient for the correlation between growth parameters and yield**

|  |  |
| --- | --- |
| **Growth parameter** | **Correlation coefficient (r)** |
| Leaf width | 0.4 |
| Leaf length | 0.54\*\* |
| Collar diameter | 0.56\*\* |
| Plant height | 0.55\*\* |
| Number of leaves | 0.36 |

*Significance levels: \*\*P<.01*

**3.2 Discussion**

The findings of this study provide critical insights into the impact of sowing density on the growth and yield characteristics of two hybrid maize varieties in Dschang. The results demonstrate that sowing density significantly affected the number of leaves per plant at 42 days after sowing, with Pannar 12 recording the highest number of leaves at the lowest plant density (80 cm x 40 cm). However, other growth parameters, including plant height, collar diameter, and leaf area, were largely unaffected by plant density, suggesting that within the tested range, maize growth was more strongly influenced by genetic factors than by spacing. These findings align with previous studies, including those of Taffouo et al. (2008) and Mahmudul et al. (2019), who reported that higher planting densities led to greater competition for resources, limiting growth potential.

Yield components, particularly ear diameter and grain weight, were significantly affected by variety but not by sowing density. Pannar 12 outperformed Kabamanoj F1 in terms of ear diameter (51.70 mm vs. 50.34 mm) and overall plant height. These findings align with previous research indicating that hybrid maize varieties exhibit different responses to agronomic factors, including plant density and soil conditions (Kouassi et al., 2017). The non-significant effect of plant density on yield may be attributed to the ability of maize plants to adapt to different spacing arrangements by modifying their architecture and resource allocation, as observed by Taffouo et al. (2008) and Mauad et al. (2010). These findings align with previous research by Kouassi et al. (2017) and Essy et al. (2022), which emphasize the importance of selecting optimal varieties and planting densities for maize production.

A key outcome of this study is the significant correlation between specific growth parameters and yield. Leaf length, stalk height, and crown diameter were positively correlated with yield, reinforcing their potential as early indicators for yield estimation. The strong correlation between collar diameter (r = 0.56\*\*) and grain yield suggests that robust stem development contributes to improved nutrient and water uptake, leading to better productivity. Similar trends have been reported by Essy et al. (2022), indicating that growth parameters can serve as reliable predictors of maize yield.

These findings highlight the need for localized agronomic recommendations that consider both genetic potential and environmental conditions. Farmers in Dschang and similar agro-ecological zones should prioritize selecting high-performing varieties like Pannar 12 while adopting optimal planting densities to maximize resource efficiency and yield potential. Additionally, further research should explore the interaction of sowing density with soil fertility and irrigation management to improve maize productivity (Konan et al., 2018).

4. Conclusion

This study assessed the influence of sowing density on the growth and yield parameters of two hybrid maize varieties in Dschang, West Cameroon. The results indicate that while sowing density significantly affects the number of leaves per plant, it does not significantly impact other growth and yield parameters. Variety played a more critical role in determining plant height, ear diameter, and grain weight, with Pannar 12 consistently outperforming Kabamanoj F1.

The positive correlation between specific growth variables (leaf length, stalk height, and crown diameter) and yield underscores their potential as early indicators for maize productivity estimation.

Based on the study's outcomes, the Pannar 12 variety at a density of 80 cm x 40 cm (62,500 plants/ha) is recommended for maximizing maize production in Dschang. Future research should explore the interaction of sowing density with soil fertility management and irrigation practices to further optimize maize productivity in the region, ensuring that farmers can make data-driven agronomic decisions to enhance food security.

References

1. INS (National Institute of Statistics). (2016). Fourth Cameroon Household Survey ECAM4: Trends, profile, and determinants of poverty between 2001–2014. Republic of Cameroon.
2. Yengoh, G. T., & Jonas, A. (2014). Crop yield gaps in Cameroon. Ambio, 43(2), 175–190.
3. Abossolo, S. A., Amougou, J. A., & Tchindjang, M. (2017). Climate disruptions and agricultural practices in Cameroon's agro-ecological zones: Socio-economic changes and adaptation challenges. Knowledge and Insights.
4. Ngoucheme, M., Tabi, F., Lontsi, M., & Fouadou, J. (2020). Combined effects of sowing dates and mineral fertilization on the performance of NERICA L56 rice in the Mbo plain, Cameroon. Journal of Applied Biosciences, 148, 15190-15201.
5. FAO. (2021). Available at: http://www.fao.org.
6. Kaho, F., Yemefack, M., Feujio-Tegwefouet, P., & Tchanthaouang, J. C. (2011). Combined effect of Tithonia diversifolia leaves and inorganic fertilizers on maize yield and properties of a ferrallitic soil in Central Cameroon. Tropicultura, 29(1), 39-45.
7. Useni, S. Y., Baboy, L. L., Nyembo, K. L., & Mpundu, M. M. (2014). Effects of combined application of biowaste and inorganic fertilizers on the yield of three maize (Zea mays L.) varieties grown in the Lubumbashi region. Journal of Applied Biosciences, 54, 3935–3943.
8. Seck, P., Togola, A., Touré, A., & Diagne, A. (2013). Proposals for optimizing the performance of rice production in West Africa. Cahiers Agriculture, 22, 361-368.
9. Sarr, B., Kafando, L., & Atta, S. (2011). Identification of climate risks in maize cultivation in Burkina Faso. International Journal of Biological and Chemical Sciences, pp. 1659-1675.
10. MINADER (Ministry of Agriculture and Rural Development). (2021). National maize production report.
11. Nyembo, K. L. (2010). Increase in maize (Zea mays L.) yield by exploiting heterosis effects of hybrids produced in Katanga, Democratic Republic of Congo. University of Lubumbashi, Faculty of Agricultural Sciences.
12. Kalonji, M. A., Nyembo, K., & Milambo, B. (2004). Effect of sowing date and variety on maize behavior and yield under Lubumbashi's edaphoclimatic conditions. Annals of the Faculty of Agricultural Sciences, 1(1), 12-19.
13. Issa, U. S., Afun, J. V. K., Mochiah, M. B., Owusu-Akyaw, M., & Braimah, H. (2011). Resistance status of some maize lines and varieties to the maize weevil, Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidae). Journal of Animal & Plant Sciences, 11(31), 1466-1473.
14. Konan, K., Faniegue, L. C., Laopé, S., Conde, M., & Mamadou, K. (2018). Effects of mineral and organic fertilizer inputs on the yield and economic profitability of a hybrid maize variety (Zea mays), grown in the Korhogo region, Côte d’Ivoire. International Journal of Agronomy and Agricultural Research, 13(6), 10-23.
15. Argenta, G., Silva, P. R. F., & Sangoi, L. (2001). Plant arrangement in maize: State-of-the-art analysis. Science Rural, 31(6), 1075–1084.
16. Caliskan, S. M., Aslan, M., Uremis, I., & Caliskan, M. E. (2007). Effect of row spacing on yield and yield components of full-season and double-crop soybeans. Turk. J. Agric. For, 31, 147-154.
17. Kouassi, N. J., Koffi, A. M. H., Yah, N. M., Kouakou, Y. I. J., & Yatty, K. J. (2017). Influence of sowing density on agronomic parameters of three cowpea varieties (Vigna unguiculata (L.) Walp, Fabaceae) cultivated in Côte d’Ivoire. Afrique SCIENCE, 13(4), 327–336.
18. Metambou, J. (2016). Thesis of Master's of Engineering Degree in Agronomy, Soil Science, Agriculture, Agricultural exploitation, and related sciences, University of Dschang.
19. ORSTOM (1965). Office of Overseas Scientific and Technical Research.
20. Taffouo, V. D., Ndongo, D. J. E., Nguelemeni, M. P., Eyambe, Y. M., Tayou, R. F., & Akoa, A. (2008). Effects of plant density on growth parameters, yield components, and organic compound contents in five cowpea (*Vigna unguiculata* (L.) Walp) varieties. Journal of Applied Biosciences, 12, 623-632.
21. Mauad, M., Silva, T. L. B., Almeida-Neto, A. I., & Abreu, V. G. (2010). Influence of sowing density on the agronomic characteristics of soybean. Agrarian Magazine, 3(9), 175-181.
22. Essy, F. J. K., Kouassi, N. J., Kouame, N., & Kouadio, J. Y. (2022). Effects of organic fertilization and sowing density on agronomic performance of a maize variety (f8128) grown in the Gbeke region (Central Côte d'Ivoire). International Journal of Biological and Chemical Sciences, 16(6), 2869-2880.

Definitions, Acronyms, Abbreviations

**DAS**: Days After Sowing

**FAO**: Food and Agriculture Organization

**ha**: Hectare

**mm**: Millimeters

***P***: Probability value

**r**: Pearson’s correlation coefficient