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Research Article

Influence of Planting Pattern and Plant Density on the Grain Yield of Hybrid Maize under Field Condition at South Sulawesi, Indonesia

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Abstract

Maize is called king of cereals because of its productivity potential compared to any other cereal crop. Row spacing is crop management tool which affect plant growth and yield. Optimum plant density of maize crop varies considerably depending upon climatic conditions of the growing area and fertility status of the soils. A field experiment was conducted at Bajeng Experimental Station, South Sulawesi, Indonesia from 10th April to 22nd July 2016. Texturally, the soil was silty clay with pH 6.6; 1.06% organic matter, 0.13% total nitrogen, 64.04 mg kg-1 available phosphorus and 0.45 mg kg^{-1} available potassium. The experiment aimed to evaluate of various planting patterns and plant density on yield component and grain yield of hybrid maize under field condition. The experiment was conducted in Randomized Complete Block Design arrangement with three replications. Hybrid maize variety Bima-4 was used for the study. The treatment included of two planting patterns i.e. single row and twin rows. Plant density was provided with 5 levels i.e. 71428, 74074, 79365, 88888 and 95238 plants ha^{-1}. The result of the experiment showed that planting pattern and plant density significantly influenced to plant height, leaf chlorophyll, ear length, 1000-grain and grain yield. The twin rows (100-40 cm x 15 cm), its population density of 95238 plants ha^{-1} produced the highest grain yield (10.97 t ha^{-1}).

Keywords: Hybrid Maize; Grain Yield; Plant Density; Planting Pattern

Introduction

Maize is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals. Maize is called "King of Cereals" because of it has very high yield compared to any other cereal on the earth which have so immerse potentiality [1]. Plant distance is an important factor for higher production and gives equal opportunity to the plants for their survival and best use of other input. Maize is a plant with individual productivity; therefore plant density determines yield significantly [2]. Optimal plant density can be affected by the genetic properties and vegetation time of the given hybrid maize, just as by the conditions of the production area, by the extent of water, nutrient supply and capture sunlight as a source of energy. Sárvári., *et al*. [3] found that different hybrids endure production using higher plant densities in different extent. Plant density is a production factor that affects yield to the greatest extent. Parallel to the increasing plant density the individual production of plants decreases but the yield per unit area increases, however to a certain limit. Plant distance is an important factor for higher production and gives equal opportunity to the plants for their survival and best use of other input.

Recent developments in maize genetic have enhanced plant density in the maize production systems by narrowing and intensifying the rows [4]. Yield can be increased with increased plant density up to maximum for some maize genotypes grown under a set of particular environmental and management conditions and declines when plant density is increased further [5]. Hybrids maize developed in recent years are able to withstand higher plant density level and greater grain yield than older hybrids maize [6,7]. Widdicombe and Thelen [8] reported than plant density had a significant effect on grain yield and the highest plant density level evaluated (90000 plant ha^{-1}) resulting in the highest grain yield. Porter., *et al.* [9] reported inconsistent optimal plant density levels ranging from 86000 to 101270 plants ha^{-1} for maize grain yield

in Minnesota. Farnham [10] reported that, maize grain yield was increased from 10.1 to 10.8 t ha^{-1} as plant density increased from 59000 to 89000 plant ha^{-1}.

Roekel and Coulter [11] determined a close relationship between maize grain yield and plant density. The studied hybrid maize produced maximal yield by a plant densities of 81700 plants ha^{-1} or even higher. On the basis of their research work Berzsenyi and Lap [12] have found that optimal plant density varied between 67483 and 70161 plants ha-1 regarding the average of the involved hybrids. Gozübenli., *et al.* [13], just as Lashkari., *et al.* [14] found that plant density has significant effect on yield. Yield showed increasing tendency up to a plant density of 90 000 plants ha-1 (10.97 t ha^{-1}), but by any higher density it decreased. Hoshang [15] also found that there were significant differences between the yields of different plant populations which increased with increasing plant density. In his work Mohseni., *et al.* [16] confirmed that the increase of plant density from 60000 plants ha^{-1} (9.09 t ha^{-1}) to 80000 plants ha^{-1} (11.14 t ha^{-1}) resulted in a yield increment as well.

A relatively recent modification of narrow row (single row) spacing is twin rows. Twin rows planting have gained interest lately as a way to potentially capture benefits of single row maize. In a twin rows configuration, maize is planted in paired rows, usually 15, 18 or 20 cm apart, on 70 cm centers.

One of the most common questions about twin rows maize is whether it will allow growers to increase yield by planting at higher populations than are practical in 70 cm rows. As plant populations increase, the space between plants within a row gets smaller, which has led to concerns that interplant competition may become yield-limiting in 70 cm rows at high populations. A twin rows arrangement has been looked to as a way to alleviate this competition by providing more space between plants, thereby allowing growers to realize the full yield potential of hybrid maize. Twin rows may allow maize roots room to grow to capture nutrients and water, while allowing plants to capture more available sunlight. Light utilization by maize plant improves greatly with twin rows. Maize root mass can also be greatly increased in twin rows. The experiment aimed to evaluate of various plant density and planting method on yield component and grain yield of hybrid maize under field condition.

Materials and Methods

The experiment was conducted in Bajeng Experimental Station, Gowa, South Sulawesi, Indonesia during the dry season from 10th April to 22nd July, 2016. Texturally, the soil was silty clay with pH 6.6; 1.06% organic matter, 0.13% total nitrogen, 64.04 mg kg^{-1} available phosphorus and 0.45 mg kg^{-1} available potassium Variety used was hybrid maize of Bima 4. The treatment included of two planting patterns i.e. single row and twin rows. Plant density was provided with 5 levels i.e. 71428, 74074, 79365, 88888 and 95238 plants ha^{-1}. The land was prepared with gramoxone herbicide sprayed a rate of 4 l ha^{-1}. Every treatment has 8 rows and distance 6 m. Before sowing seeds were mixed with saromil to prevent downy mildew disease a rate of 2.5 g kg ha^{-1} seed. Pests were controlled with furadan 3 G which is applied at the planting time in the hole of the seeds and 15 days after planting (dap) applied in the top of the leaves of plants at 5 kg ha^{-1}, respectively. Irrigation was given at 10 days interval during crop growth. Irrigation was stopped two weeks prior to harvest of the crops. The experiment involved in Randomized Complete Block Design arrangement in three replications. The all P, 50% N and 50% K fertilizers was applied at 10 dap. The rest of N and K were applied at 30 dap. Data were collected includes: plant height (cm), ear height (cm), leaf chlorophyll (g mg-1) and stem diameter (mm) at 75 dap, 1000-grain weight (g) and grain yield (t ha^{-1}) adjusted to 15% moisture content. Data were analyzed using standard Analysis of Variance (ANOVA) technique and means were compared using Duncan's Multiple Range Test (DMRT) at 5% level [17].

Results and Discussion

Plant height

Analyses of variance at 75 dap on plant height showed that the planting pattern and plant density significantly influenced on hybrid maize. The tallest plant height (198.2 cm) was obtained at twin rows (90-50) x 15 cm, while the lowest plant height at twin rows (100-50) cm x 30 cm, 2 plants $hill^{-1}$ (Table 1). Higher plant densities produced taller plant. Plant height strongly influenced by environmental condition during stem elongation as expected [13]. Some researcher reported that taller plant was obtained with high plant densities as consequence of interplant competition [18,19].

Twin rows at highest population density to grow healthy may allow plants to capture more available sunlight, while allowing maize roots to grow to capture nutrient and water.

Ear height

Analyses of variance at 75 dap revealed that planting pattern and plant density not significantly influenced on ear height hybrid maize. The highest ear height (97.5 cm) was obtained at twin rows (90-50) x 15 cm, while the lowest plant height at twin rows (100-50) cm x 30 cm, 2 plants $hill^{-1}$ (Table 1).

Planting Pattern	Planting distance (cm)	Plant Density (plant ha^{-1})	Plant height 75 dap (cm)	Ear height (cm)	Leaf chlorophyll 75 dap (mg g^{-1})
Single row	70 x 20	71428	188.7 ab	88,6 ns	48.8 ab
Twin rows	(100-40)x20	71428	189,2 ab	86.6	52.3 a
Twin rows	(90-50)x20	71428	187.6 ab	92.8	52.6 a
Single row	75 x 18	74074	189.6 ab	90.6	50.2 ab
Twin rows	(100-50)x18	74074	193.8 ab	95.6	49.4 ab
Twin rows	(100-50)x36*	74074	189.4 ab	90.6	50.7 ab
Single row	70 x 18	79365	192.8 ab	92.5	50.6 ab
Twin rows	(100-40)x18	79365	190.3 ab	94.2	51.3 ab
Twin rows	(90-50)x18	79365	189.2 ab	88.3	52.0 a
Single row	75 x 15	88888	192.7 ab	89.7	50.5 ab
Twin rows	(100-50)x15	88888	188.8 ab	89.5	47.1 b
Twin rows	(100-50)x30*	88888	185.0 b	84.7	48.0 ab
Single row	70 x 15	95238	195.8 ab	92.5	50.7 ab
Twin rows	(100-40)x15	95238	186.1 b	88.9	49.7 ab
Twin rows	(90-50)x15	95238	198.2 a	97.5	50.9 ab
CV(%)			5.5	6.3	6.9

Table 1: Plant height, ear height, and leaf chlorophyll of hybrid maize grown in different planting pattern and planting density. South Sulawesi, Indonesia. 2016.

Note. * = 2 plants hill^{-1} ns = not significance

Means within columns with the same letter are not significantly different at 5% level based on DMRT

Leaf chlorophyll

Analysis of variance revealed that planting pattern and plant density was significantly influenced on leaf chlorophyll content. Observation the leaf chlorophyll at 75 dap demonstrated that plant with twin rows (90- 50) x 20 cm is the highest leaf chlorophyll (52.6 mg g^{-1}). The treatment with twin rows (100-50) x 15 cm is the lowest leaf chlorophyll 47.1 mg g^{-1} (Table 1).

According to Effendi., *et al.* [20] the critical level of leaf chlorophyll on maize at V12 is < 51 mg g^{-1}. Based on it at population density > 88888 plant ha^{-1} required more nitrogen supply from nitrogen fertilizer to get maximal yield. Nitrogen is a key element in chlorophyll, therefore is usually a high correlation between them [21]. High rates of photosynthesis are associated with plants that have a healthy, rich green color due to sound crop production practices such as fertilizer applications that encourage chlorophyll development. Knowledge on the relationship between spectral reflectance and chlorophyll content is an important alternative for making decisions related to the nitrogen supply for crops, which is crucial in agriculture. Chlorophyll content has been suggested as the community property most directly relevant to the prediction of productivity [22]. Argenta., *et al.* [23], Mac Kown and Sutton [24] measurement leaf chlorophyll a destructive positively correlates significant to the N chlorophyll.

Stem diameter

Analysis of variance showed that planting pattern and plant density was not influenced on stem diameter. Observation the stem diameter at 75 dap demonstrated that plant with twin rows (90-50) x 20 cm is the highest stem diameter (27.1 mm). The plot with twin rows (100-40) x 15 cm is the lowest stem diameter 25.1 mm (Table 2).

Ear length

Analysis of variance showed that planting pattern and plant density was significantly influenced on stem diameter. Observation of ear length indicated that plant with twin rows (100- 40) x 15 cm is the highest ear length (19.0 cm), while the treatment with twin rows (100-40) x 18 cm is the lowest ear length 16.8 cm (Table 2).

Ear diameter

Analysis of variance showed that planting pattern and plant density was not influenced on ear diameter. Observation the ear

Planting Pattern	Planting distance (cm)	Plant Density (plant ha^{-1})	Stem diameter 75 dap (mm)	Ear length (cm)	Ear diameter (mm)
Single row	70 x 20	71428	26.2 ns	18.3 ab	44.5 ns
Twin rows	(100-40)x20	71428	26.0	18.1 ab	45.7
Twin rows	(90-50)x20	71428	25.8	17.9 ab	45.5
Single row	75 x 18	74074	26.3	18.2 ab	44.8
Twin rows	(100-50)x18	74074	26.5	17.4 ab	45.4
Twin rows	(100-50)x36*	74074	27.0	17.9 ab	46.0
Single row	70 x 18	79365	25.7	17.5 ab	48.5
Twin rows	(100-40)x18	79365	26.0	16.8 b	49.2
Twin rows	(90-50)x18	79365	26.1	18.1 ab	46.1
Single row	75 x 15	88888	26.0	18.7 ab	44.6
Twin rows	(100-50)x15	88888	25.3	17.0 ab	46.3
Twin rows	(100-50)x30*	88888	26.7	18.8 ab	45.8
Single row	70 x 15	95238	27.1	17.6 ab	46.1
Twin rows	(100-40)x15	95238	25.1	19.0 a	47.2
Twin rows	(90-50)x15	95238	26.2	17.9 ab	46.4
CV(%)			4.0	5.9	7.5

Table 2: Stem diameter, ear length, and ear diameter of hybrid maize grown in different planting pattern and planting density. South Sulawesi, Indonesia. 2016

Note. * = 2 plants hill^{-1} ns = not significance

Means within columns with the same letter are not significantly different at 5% level based on DMRT

diameter revealed that plant with twin rows (100- 40) x 18 cm is the highest ear diameter (49.2 mm). The treatment with single row 70 x 20 cm is the lowest ear diameter 44.5 mm (Table 2).

1000-Grains weight

Analysis of variance that indicated that planting pattern and plant density significantly influenced on 1000-grain yield. Twin rows pattern (100-40) x 15 cm produced the highest 1000-grain weight (404 g), while twin rows (100-40) x 20 cm produced the lowest 1000-grain weight (349.5 g) (Table 3).

Grain yield

Analysis of variance showed that plant pattern and plant density significantly influenced grain yield. Twin rows (100-40) x 15 cm, its population density 95328 plant ha^{-1} significantly produced the highest grain yield 10.97 t ha^{-1}, while single row 70x 20 cm (plant density 71428 plant ha^{-1}) significantly produced the lowest grain yield 7.80 ha^{-1} (Table 3).

Gozubenly., *et al*. [13] also reported that plant density and planting method were statistically significantly influenced on grain yield. Grain yield gradually increased with increasing plant densities up to 90000 plants ha^{-1} (10.973 t ha^{-1}), the decreased in higher plant densities. Twin rows planting method out yielded single row and 10.398 t ha^{-1} and 9.986 t ha^{-1} grain yields obtained, respectively.

Twin rows may allow maize roots room to grow to capture nutrient and water, while allowing plants to capture more available sunlight. Light utilization by maize plants improves greatly with twin rows. Sunlight is a source of energy, the more plant can capture, the better. Maize roots mass can also be greatly increased in twin rows.

Planting Pattern	Planting distance (cm)	Plant Density (plant ha^{-1})	1000-Grains weight (g)	Grain yield (t ha^{-1})
Single row	70 x 20	71428	369.3 ab	7.80 b
Twin rows	(100-40)x20	71428	349.5 b	7.89 ab
Twin rows	(90-50)x20	71428	377.5 ab	9.36 ab
Single row	75 x 18	74074	361.3 ab	9,35 ab
Twin rows	(100-50)x18	74074	372.0 ab	9.03 ab
Twin rows	(100-50)x36*	74074	377.5 ab	8.73 ab
Single row	70 x 18	79365	350.2 b	9.36 ab
Twin rows	(100-40)x18	79365	360.2 ab	8.27 ab
Twin rows	(90-50)x18	79365	385.0 ab	8.75 ab
Single row	75 x 15	88888	380.0 ab	9.65 ab
Twin rows	(100-50)x15	88888	351.2 b	9.11 ab
Twin rows	(100-50)x30*	88888	357.6 ab	8.85 ab
Single row	70 x 15	95238	354.2 ab	9.78 ab
Twin rows	(100-40)x15	95238	404.0 a	10.97 a
Twin rows	(90-50)x15	95238	374.7 ab	9.79 ab
CV(%)			7.0	8.9

Table 3: 1000-Grains weight and grain yield of hybrid maize grown in different planting pattern and plant density. South Sulawesi, Indonesia. 2016.

Note. * = 2 plants hill^{-1} ns = not significance

Means within columns with the same letter are not significantly different at 5% level based on DMRT.

Conclusion

Planting method and plant density significantly influenced plant height, leaf chlorophyll, ear length, 1000-grain and grain yield of hybrid maize. Twin rows (100-40 cm x 15 cm), its population density of 95238 plants ha^{-1} produced the highest grain yield (10.97 t ha^{-1}).

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