Increasing Planting Density of Maize Trough Double Row Cropping System to Improves Seed Yield

A Saryoko, Y Giamerti, Z Yursak*, P N Susilawati, S Kusumawati, Kardiyono and N Winanti

Banten Assessment Institute for Agricultural Technology (Banten AIAT), Indonesian Agency for Agricultural Research and Development (IAARD), Jl. Ciptayasa km.01 Ciruas Serang Banten Indonesia

E-mail: zyursak@yahoo.co.id

Abstract. Maize as the second major crop in Indonesia has an important role in the national economy. Maize production in Indonesia is potentially to be improved by the use of appropriate cultivars and cropping system. The aims of study were to evaluate the yield performance of high-yielding maize cultivars under two different cropping system. An RCBD field experiment using five high-yielding maize cultivars, namely NK212, P21, BISI 2, BISI 18 and Bima 14 were conducted at Banjar Sub-district, Pandeglang District, Banten Province, Indonesia from April to July 2020. The plants were arranged into a single row (70 x 25 cm; 5.7 plant m-2; J1) or double row (25 x 25 x 90 cm; 6.9 plant m-2; J2) cropping system. Plant growth, yield and yield components for each cultivars and cropping system were observed. Across the cultivars, the seed yield of J2 (1.34 kg m-2) was higher than that of J1 (1.71 kg m-2) due to higher number of plant m-2 that resulted greater ear number and seed number m-2. Even though J2 resulted smaller ear size (weight, length, diameter and seed weight ear-1) as compared to J1, but those were offset with greater ear number per m2 of J2. Across two cropping system, cultivar NK212 (1.75 kg m-2) was superior in seed yield, and followed with BISI 18 (1.57 kg m-2). All cultivars were consistently better under J2 than that of J1. We concluded that increasing planting density using double row cropping system, in combination with high-yielding cultivars resulted better seed yield, which is a promising way to improve maize production in Indonesia.

1. Introduction
The increase in plant density has been one of the main managements contributed to maize grain yield improvements [1][2], which remarkably increase resources use efficiency when combination with high density tolerance maize cultivars [3]. It has been shown that varying the maize planting density greatly affects the grain-filling process, yield and yield components [3]. However, Intraspecific competition is evident under high planting density [4]. Light availability per plant decreases with increasing planting density, the yield per plant decreases with increasing planting density [2]. The optimum sowing density for obtaining the highest maize yield in different regions was different, ranged from 67.000 to 104.000 plants ha-1 [3]. At the very specific densities, plant could have a positive effect on yield components, thus achieve maximum grain yield. In the period of 2012 – 2016, Indonesia is the 8th world largest maize producing country, accounting for half maize production in South East Asia [5]. The maize yield in Indonesia need to be improve due to higher demand of maize grain for food and feed as well. Recently, high yielding maize cultivars has
been released by private seed company and governmental research institute. However, yield gaps between actual and potential yield still remarkable wide. This experiment aimed to evaluate the yield performances of high-yielding maize cultivars under two different cropping system.

2. Material and Methods

2.1. Cultivar and agronomical practices

A randomized complete block design (RCBD) experiment with 3 replications was conducted at the dry season from April to July 2020. Seeds of five cultivars, namely NK212 (V1), P21 (V2), BISI 2 (V3), BISI 18 (V4) and Bima 14 (V5) were sown at Banjar Sub-district, Pandeglang District, Banten Province, Indonesia (lat. 6°22’ S, long. 106°74’ E). The plants were arranged into a single a row system (70 × 20 cm, 5.7 plant m⁻², J1) or a double row system (25 × 25 × 90 cm, 7.1 plant m⁻², J2). The soil was fertilized with N in the form of urea with the dose of 20 g m⁻², and also with N, P, and K in the form of compound fertilizer (15 : 15 : 15 w/w of N, P₂O₅ and K₂O) with the dose of 30 g m⁻². Urea was applied three times at 2, 4, and 7 week after sowing as much as 30, 50, 20 %, respectively. In the same time, the compound fertilizer was applied as much as 50, 25, 25 %, respectively. Regional recommended management programs were employed for weed, pest and disease control to optimized growth condition.

2.2. Agronomical traits, yield and yield components

The flowering date, day from sowing to tassel completely appear, was recorded and plant height was measured. Plant height was observed as the height from the soil to the highest part of the plant. At the maturity stage, a sub-plot with the size of 1.4 m² for J1 and J2 were created for each plot. The sub-plot consist of 8 or 10 plants for J1 and J2, respectively. Five plants for each sub-plot were taken, and the ears from each plant were separated.

Yield potential was determined by yield components. Ear density, as the number or ear per unit area was counted. Ear weight and morphology from each samples was measured. Further, seed number was counted and weighted, and seed water content was measured. Seed yield was expressed as a seed weight at 14% moist content. The seed-cob thickness ratio was determined as the ratio of seed length and the radius of cob.

2.3. Data Analysis

In order to better understand the relationship between seed yield and yield components in J1 and J2, correlation analysis was performed between seed yield per unit area with yield components in ear base. A one way ANOVA analysis using MINITAB 16 was performed to evaluate the effect of cultivar, planting density and its interaction on yield and yield components, and followed with a Tukey’s test.

3. Results and Discussion

3.1. Maize yield under different planting density

In this experiment, we use two different planting density, single row system and double row system which was resulted 5.7 and 7.1 plants m⁻², respectively. Across all cultivars, the seed yield produced using single row system was 1.34 kg m⁻² (Fig. 1). In contrast, the seed yield produced under double row system was 1.71 kg m⁻² or 25.7 % higher than that produced under single row system (Fig. 1). The ear density under double row system was 12.4 or 26.1 % greater than that produced under single row system (Fig. 1). A close correlation was found between seed yield with ear density (r = 0.89). This result showed that increasing planting density from 5.7 plant m⁻² to 7.1 plant m⁻² through double row system increased the seed yield by the increased of ear density. The above results in line with that reported by [1] in China Plateau where density stress tolerance hybrids could achieve higher grain yield and water use efficiency with higher plant density when water is not a limiting factor.
Figure 1. Seed yield performance (a) and ear density (b) of maize under single row system (J1) and double row system (J2).

3.2. Cultivars variability

Variation in yield performance was occurred. Across the planting pattern, seed yield ranged from 1.30 to 1.75 kg m$^{-2}$. Cultivar NK212 (V1) was the highest in seed yield followed with BISI 18 (V4) and P21 (V2) with the seed yield of 1.75, 1.57 and 1.53 kg m$^{-2}$, respectively (Fig. 2a). Variation in yield components were also evident. Seed yield was determined by yield components; ear number, ear weight and morphology and seed weight. Across the planting pattern, cultivar P21 (V2) showed the highest in ear density (10.8 ear m$^{-2}$) followed by cultivar NK212 (10.6 ear m$^{-2}$) (Fig. 2b).

Figure 2. Seed yield performance (a), ear density (b), 1000-seed weight (c) and seed-cob thickness ratio (d) of five maize cultivars. Bars are average from two planting density and its standard error. V1=NK212, V2=P21, V3=BISI 2, V4=BISI 18, V5=BIMA 14.
Other yield component determined yield performance was seed weight. Two cultivars, BISI 2 (V3) and NK212 (V1) were the biggest in 1000-seed weight. The seed size of tested cultivars ranged from 299 to 318 g 1000–1 (Fig. 2c). In this experiment, the terms of seed-cob thickness ratio was used to describe ear morphology. The thickness ratio ranged from 41 – 46 %, which mean that as much of 41 – 46 % of the ear diameter was filled with the seeds. We found some variation in the thickness between cultivars. The cultivar BISI 18 (V4) was the most efficient in the seed-cob thickness ratio (46 %) followed by cultivar BISI 2 (V3) and NK212 (V1) (Fig. 2d).

3.3. Relationship between yield and yield components

Seed yield was linearly correlated with individual ear weight ($R^2=0.80$) (Fig. 3a), and seed number per ear ($R^2=0.63$) (Fig. 3c). In addition, seed yield was also correlated with seed-cob thickness ratio ($R^2=0.84$) (Fig. 3b). The above results showed that higher yield can be achieved by producing bigger individual ear size and greater seed number per ear. However, quadratic correlation between yield with seed-cob thickness ratio indicated that a best yield was achieved when the ratio is around 43.5 % (Fig. 3b).

![Figure 3](image-url). Correlation between seed yield with individual ear weight (a), seed-cob thickness ratio (b), and seed number per ear (c). V1=NK212, V2=P21, V3=BISI 2, V4=BISI 18, V5=BIMA 14.

Increasing planting density from J1 (single row, 5.7 plant m$^{-2}$) to J2 (double row, 7.1 plant m$^{-2}$) improved seed yield by the increase of ear number per unit area, then followed by the increase of ear weight per unit area. However, higher planting density induced higher competition within plants[2] [6]. As a consequence smaller ear in size and weight was evident for all cultivars under J2 as compared with that of J1 (Fig. 4a). Seed yield under J1 ranged from 1.1 – 1.4 kg m$^{-2}$ with the individual ear weight ranged from 183 – 228 g. In contrast, smaller individual ear weight was found under J2, ranged from 172 – 213 g, but resulted greater seed yield ranged from 1.4 – 2.0 kg m$^{-2}$.

The smaller individual ear size and weight was offset with a greater ear number per unit area. Therefore, positive correlations were found between seed yield with the multiplication of ear density and individual ear weight (Fig. 4b). Although the increase of planting density resulted smaller ear size and weight, the above results indicated that double row system is still reliable to be applied to produce better seed yield for all tested cultivars.

4. Conclusion

Cultivar NK212 and BISI 18 was superior in seed yield under double row cropping system due to better individual ear size and weight, and greater seed number. Increasing planting density using double row cropping system increased ear density for all tested cultivars that improved seed yield. Application of double row cropping system, in combination with high-yielding cultivars resulted better seed yield that could be an approach to improve maize production in Indonesia.
Figure 4. Correlation between seed yield with individual ear weight (a), ear density × individual ear weight (b) under single row system (J1) and double row system (J2).

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