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Effect of Plant Geometry on Growth and Yield of Corn in the Rice-Corn Cropping System

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ABSTRACT

The rice-corn cropping system is increasing in Asia in response to increased demand of corn for feed. A field study was conducted to evaluate the effect of plant geometry (row and plant to plant spacing: 50 × 20, 50 × 30, 75 × 20, and 75 × 30 cm) on growth and yield of corn. Plant height and leaf production per plant were not influenced by the plant geometry. Spacing, however, influenced leaf area, aboveground shoot biomass, and yield of corn per unit area. Highest leaf area, shoot biomass, and yield (8.2 $t \cdot ha^{-1}$) were produced by plants grown at 50 × 20 cm spacing. The results of this study suggest that narrow rows and plant to plant spacing may increase grain yield by increasing crop growth rates. Plant geometry could be modified to improve yield of corn in the rice-corn cropping system, and thereby increase productivity of the system.

Keywords: Row Spacing; Plant to Plant Spacing; Leaf Area; Rice-Corn Cropping System

1. Introduction

Rice (*Oryza sativa* L.) is the most important crop in tropical Asia. However, the increasing scarcity of water could lead to changes in production systems, which use less water (for e.g., dry-seeded rice) or more crop diversification [1]. Corn (*Zea mays* L.) is one such crop which is more water efficient than rice and produces high yield. The rice-corn cropping system is already gaining importance in Asia in response to the increasing demand of corn for biofuel and feed [2]. In this cropping system, rice in the wet season and corn in the dry season can provide high yield and it is more water-efficient than the rice-rice cropping system. In the Philippines, corn is grown on around 2.6 $M \cdot ha^{-1}$ and around 0.12 $M \cdot ha^{-1}$ is under rice-corn cropping system [2].

Glyphosate-resistant corn is already available and grown in the Philippines, where it is planted at 60 cm row spacing. In other environments, narrow row spacing has been shown to increase corn yield [3-5]. Narrow row spacing may enhance available soil moisture to the crop [6]. Narrow rows may also increase light interception by the crop, for example, corn and soybean (*Glycine max* L.) and therefore lead to increased crop growth [7-9]. Narrowing crop rows may also result in early canopy closure and reduced weed growth (by increased shading of weeds), and thereby improvement in yield [10,11].

In the literature, however, data are very limited on the effect of row spacing on corn growth and yield in the Philippines. Therefore, a study was designed to evaluate the effect of row spacing and plant to plant spacing on the growth and yield of corn in the rice-corn cropping system.

2. Materials and Methods

This study was conducted at the Experimental Station of the International Rice Research Institute, Los Baños, Laguna, Philippines. The soil at the experimental site had a pH of 6.8, organic carbon of 1.2, and sand, silt, and clay contents of 23%, 47%, and 30%, respectively. The site was dry cultivated using a twin axle tractor before corn planting.

There were four spacing treatments (row spacing x plant to plant spacing within the row): 50 × 20 cm, 50 × 30 cm, 75 × 20 cm, and 75 × 30 cm. The experiment was arranged in a randomized complete block design with three replications. The crop was planted by hand on January 21, 2013 and immediately surface-irrigated with a light irrigation. Phosphorus and potassium were incorpo-

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rated before crop planting at 40 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}, respectively. Nitrogen was applied as urea in four splits: 40 kg·N·ha^{-1} at 2 weeks after planting (WAP), 40 kg·N·ha^{-1} at 4 WAP, 40 kg·N·ha^{-1} at 6 WAP, and 40 kg·N·ha^{-1} at 8 WAP. The size of each plot was 7.2 × 5.2 m.

Weeds were controlled by using pendimethalin at 1.0 kg ai ha^{-1} at 1 d after planting and glyphosate (1.4 kg ai ha^{-1}) application at 4 WAP. Herbicides were applied with a knapsack sprayer that delivered around 320 L·ha^{-1} of spray solution through flat fan nozzles. No measures were taken for other pests.

Immediately after crop emergence, six consecutive plants were tagged. Height and leaf numbers were measured for these tagged plants at 2, 4, 6, 8, and 11 WAP. In addition, leaf area and shoot biomass (aboveground) were measured for another six consecutive plants at 4 and 8 WAP, and converted to leaf area (cm^2) m^{-2} and biomass (g) m^{-2}. Corn was harvested on May 14, 2013 from an area of 12 m^2 (4 m × 3 m). Grain yield was converted to t·ha^{-1} at 16% moisture content.

The data of height and leaf number plant^{-1} at different times were fitted to a functional three-parameter sigmoid model (SigmaPlot 10.0). The model was

$$y = a / \{1 + e[-(x - W_0)/b]\}$$

where y is the plant height or leaf number at time x, a is the maximum height (cmplant^{-1}) or leaf number (plant^{-1}), W_0 is the time (WAP) required to reach 50% of the maximum height or leaf number, and b is the slope. The other data (leaf area, biomass, and grain yield) were presented using standard error of mean.

3. Results and Discussion

Plant height of corn was not influenced by the spacing (**Figure 1**). Although the maximum height (a) was observed at 50 × 30 cm spacing, it was statistically similar with the height at other spacing (**Table 1**). Similarly, the slope was also not influenced by the spacing. The time taken to reach 50% of the maximum height (W_0) was shortest at 50 × 20 cm (4.5 WAP) and longest at 75 × 30 cm (5.0 WAP). However, these differences were statistically non-significant.

The maximum number of leaves plant^{-1} was observed when the crop was planted at the narrowest spacing, that is 50 × 20 cm, and least numbers were observed at the widest spacing, that is 75 × 30 cm (**Figure 2**, **Table 1**). The maximum number of leaves at different spacing ranged from 14.6 to 17.6 leaves plant^{-1}; however, these differences were statistically non-significant. Similarly, the rate of leaf development (b) was also similar among different spacing. The plants at 75 × 30 cm spacing took 2.0 WAP to reach 50% of the maximum leaf number

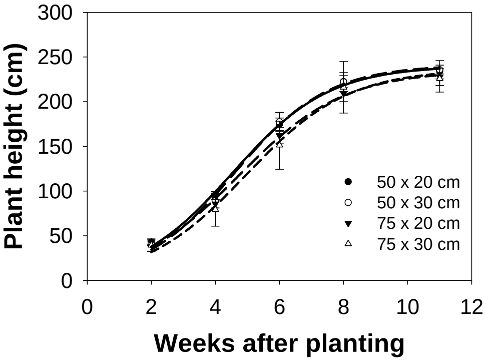

Figure 1. Effect of plant geometry (row and plant to plant spacing: 50 × 20, 50 × 30, 75 × 20, and 75 × 30 cm) on the height of corn. A three-parameter sigmoid model was fitted to the height data over different times.

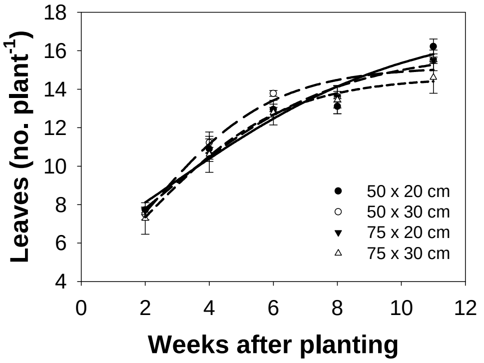

Figure 2. Effect of plant geometry (row and plant to plant spacing: 50 × 20, 50 × 30, 75 × 20, and 75 × 30 cm) on leaf production (number plant^{-1}) of corn. A three-parameter sigmoid model was fitted to the data.

Table 1. Parameter estimates (± standard error) of the three-parameter sigmoid model fitted to the plant height and leaf number data. The fitted model was $y = a/\{1 + e[-(x - W_0)/b]\}$, where y is the plant height or leaf number at time x, a is the maximum height (cmplant^{-1}) or leaf number (plant^{-1}), W_0 is the time (WAP) required to reach 50% of the maximum height or leaf number, and b is the slope.

Spacing (cm)	a	b	W_0	R^2
		Plant height		
50 × 20	240 (6)	1.51 (0.13)	4.5 (0.15)	0.99
50 × 30	241 (8)	1.46 (0.16)	4.6 (0.19)	0.99
75 × 20	235 (8)	1.64 (0.16)	4.7 (0.19)	0.99
75 × 30	237 (13)	1.59 (0.25)	5.0 (0.31)	0.99
		Leaf number plant^{-1}		
50 × 20	17.6 (3.2)	3.82 (1.94)	2.6 (1.37)	0.95
50 × 30	15.2 (0.8)	1.96 (0.57)	2.0 (0.39)	0.97
75 × 20	16.0 (0.8)	2.89 (0.59)	2.2 (0.35)	0.99
75 × 30	14.6 (0.4)	2.14 (0.27)	2.0 (0.18)	0.99

plant^{-1} and the plants at 50 × 20 cm took 2.6 WAP (**Table 1**). Although there was a difference of 0.6 weeks between the treatments, the difference was statistically similar. The results of height and leaf numbers plant^{-1} suggest that the tested plant geometry may not influence the development of height and leaf production in corn.

In contrast to plant height and leaf numbers, the leaf area and shoot biomass of corn were greatly influenced by the plant geometry. At 4 and 8 WAP, highest leaf area was produced by plants grown at 50 × 20 cm spacing (**Table 2**). The plants grown at 75 × 30 cm spacing produced lowest leaf area m^{-2} and this was significantly lower than the leaf area at other three spacing. Leaf area, however, was not influenced between plants grown at 50 × 30 cm and 75 × 20 cm. A similar response was observed for the aboveground biomass (**Table 2**). Plants grown at 50 × 20 cm produced the highest shoot biomass and plants grown at 75 × 30 cm produced the least shoot biomass at 4 and 8 WAP. At 8 WAP, for example, corn produced 1295 and 623 g·m^{-2} of biomass when grown at 50 × 20 cm and 75 × 30 cm, respectively. At both timings (*i.e.*, 4 and 8 WAP), the plants produced similar biomass at 50 × 30 cm and 75 × 20 cm spacing.

Plant geometry influenced the grain yield of corn. Highest grain yield (8.2 t·ha^{-1}) was produced by plants grown at the narrowest spacing, that is, 50 × 20 cm (**Figure 3**). However, the yield at 50 cm row spacing was not influenced (7.8 - 8.2 t·ha^{-1}) by the plant to plant spacing. Similarly, plant to plant spacing at 75 cm rows did not influence grain yield and it ranged from 6.1 to 6.4 t·ha^{-1}.

The results of our study suggest that narrowing row may lead to increased leaf area and crop biomass per unit area. Earlier studies hypothesized that narrow rows increased light interception in the early growing season and this led to increased crop growth rates and earlier canopy closure [3,9,12]. An earlier study reported that leaf area increases and light transmittance to the soil surface declines as corn plant population increases [13]. Although we did not evaluate the effect of row spacing on weed growth, various studies suggest that narrow row spacing significantly suppresses weed growth due to earlier canopy closure compared with wider rows [11,12,14, 15]. Teasdale suggested the importance of the early canopy closure in a reduction of the critical period for weed competition by one week [12]. Therefore, our study also suggests that growing corn in narrow rows may have the potential for improving weed management in reduced-herbicide systems [12,16]. As crop cultivars differ in their growth traits (e.g., height, leaf morphology, etc.), more research is needed in tropical conditions to clearly demonstrate the effect of narrow rows on growth and yield of corn.

Table 2. Effect of spacing (row and plant to plant) on leaf area and corn biomass at 4 and 8 weeks after planting (WAP).

Spacing (cm)	Leaf area (cm^2·m^{-2})		Biomass (g·m^{-2})	
	4 WAP	8 WAP	4 WAP	8 WAP
50 × 20	18947 (625)	53900 (1900)	115 (7)	1295 (104)
50 × 30	12645 (419)	38000 (1700)	72 (9)	900 (125)
75 × 20	11567 (524)	38600 (3200)	69 (6)	833 (81)
75 × 30	7249 (727)	25600 (900)	42 (6)	623 (27)

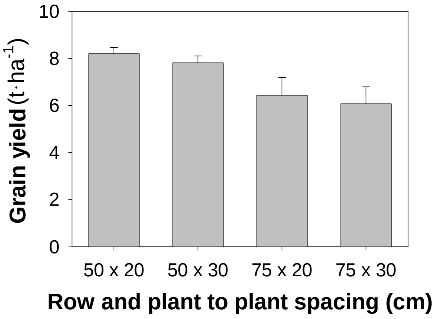

Figure 3. Effect of plant geometry (row and plant to plant spacing: 50 × 20, 50 × 30, 75 × 20, and 75 × 30 cm) on grain yield of corn.

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