The growth and yield of hybrid corn on different plant spacing

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Abstract. Plant spacing affects the number of plants, the process of receiving sunlight, water and nutrients which also affect the process of photosynthesis and assimilation between plants. The aim of this research was to examine the effect of different plant spacing and to evaluate plant spacing that could increase the growth and yield of hybrid corn. This research was conducted in UNS experimental field Jumantono, Karanganyar from June-November 2019. Design utilization was experimental method with Randomized Complete Block Design (RCBD) of 1 factor, consist of 4 levels, the treatment was 60 cm × 30 cm (J1); 60 cm × 40 cm (J2); 60 cm × 50 cm (J3); and 60 cm × 60 cm (J4). There was replicated 6 times. The result showed that plant spacing of 60 cm × 60 cm has increase on cob weight with husk, cob weight without husk, number of cobs per plant and grain yield per plant compared with plant spacing of 60 cm × 30 cm. The plant spacing treatment of 60 cm × 60 cm can improve quality of yield per crop but have not been able to increase the quantity of hybrid corn yield.

1. Introduction
Corn is the most important food crop in the world besides rice and wheat. Residents in various countries including Indonesia make corn as one of the staple foods and animal feed. National demand for corn is increasing every year. The national corn needs in 2016 amounted to 16.30 million tons. Indonesia still imports corn by 2.40 million tons to meet the needs and demand for corn at 8.90 million tons [1]. Demand for corn increases along with the income and purchasing power in the community [2]. The increase in population causes the need for residential land and agricultural land-use change will also continue to increase [3]. In addition to that, the low productivity of corn is caused by non-intensive cultivation techniques. Efforts to increase corn production can be done by applying technologies such as the use of high yielding varieties and fertilizing. An equally important factor in influencing the growth and yield of corn is the plant spacing.

The use of superior varieties plays an important role in efforts to increase corn production. Hybrid corn has advantages in terms of potential yield due to the growth of the same plant. Utilization of hybrid varieties is one of the efforts that can be done to overcome the existing corn cultivation problems. In addition to the use of superior varieties in an effort to increase corn production, another factor to consider is the spacing or planting density. Plant spacing is one of the factors that can affect crop production. Plant spacing affects the number of plants, the process of receiving sunlight, water
and nutrients which will also affect the process of photosynthesis and assimilation between plants. Effective application of plant spacing aims to promote growth well without experiencing much competition in the availability of water, nutrients, and optimal sunlight on each plant [4].

2. Materials and methods
This research was conducted from June to November 2019 in the UNS experimental field Jumantono, Karanganyar. Laboratory analysis was carried out in the Laboratory of Chemistry and Soil Fertility and Laboratory of Ecology and Management of Plant Production, Faculty of Agriculture, Universitas Sebelas Maret Surakarta.

Design utilization was experimental method with Randomized Completed Block Design (RCBD) of 1 factor, consist of 4 levels, the treatment was 60 cm × 30 cm (J1); 60 cm × 40 cm (J2); 60 cm × 50 cm (J3); and 60 cm × 60 cm (J4), there was replicated 6 times so there were 24 experimental units. The hybrid corn seed used is BISI-2. Observed variables included plant height, stem base diameter, number of leaves, leaf area index, fresh weight, dry weight, cob weight with husk, cob weight without husk, number of cobs per plant, grain yield per plant, grain yield per plot, 100 seeds weight and number of seeds per plant. The data were analyzed by using analysis of variance (ANOVA) 5% using the SPSS program, then followed by Duncan’s Multiple Range Test (DMRT) 5%.

3. Results and discussion
3.1. General condition of land
Corn cultivation was carried out in the UNS experimental field Jumantono, Karanganyar at an altitude of 170 meters above sea level. The study was conducted in the dry season. Table 1 showed results of environmental conditions in Jumantono’s experimental field.

Table 1. Environmental conditions

| Variables              | Morning | Afternoon | Evening |
|------------------------|---------|-----------|---------|
| Light intensity (Lux)  | 2,150   | 3,890     | 2,780   |
| Relative humidity (RH) | 66      | 50        | 60      |
| Temperature (C)        | 27      | 45        | 30      |

Note: Measurement of light intensity using a lux meter, measurement of relative humidity using a thermohygrometer, temperature measurement using a thermometer.

Research field have alfisol soil types. Table 2 showed results of soil chemical analysis on dry land.

Table 2. Results of initial soil analysis

| Variables      | Value    | Explanation |
|----------------|----------|-------------|
| N total (%)    | 0.29     | Medium      |
| P total (ppm)  | 247.24   | High        |
| K total (%)    | 0.20     | Low         |
| C organic (%)  | 1.45     | Low         |
| Organic matter (%) | 2.50 | Low         |
| C/N ratio      | 5.00     | Low         |
| Soil pH        | 5.26     | Acid        |

Source: Laboratory of Chemistry and Soil Fertility.

3.2. Corn growth and yield
Plant spacing is essentially regulating plant populations that affect competition in the absorption of nutrients, water and sunlight, so that if not properly regulated it will affect plant growth and yield. A variety of spacing gives different results to the observation variables (Table 3).
Table 3. Effects of plant spacing on growth and yield parameters

| Observed variables                  | J1          | J2          | J3          | J4          |
|-------------------------------------|-------------|-------------|-------------|-------------|
| Plant height (cm)                   | 98.78a      | 103.50a     | 110.61a     | 99.61a      |
| Stem base diameter (mm)             | 13.88a      | 16.32a      | 15.61a      | 15.60a      |
| Number of leaves (blade)            | 11.00a      | 12.27a      | 11.72a      | 11.16a      |
| Leaf area index                     | 0.91b       | 0.78ab      | 0.69ab      | 0.64a       |
| Fresh weight (g)                    | 100.99a     | 121.63a     | 156.96a     | 180.69a     |
| Dry weight (g)                      | 40.10a      | 48.70a      | 63.63a      | 69.47a      |
| Cob weight with husk (g)            | 108.69a     | 142.63ab    | 169.04ab    | 207.87b     |
| Cob weight without husk (g)         | 96.32a      | 130.47ab    | 148.99ab    | 175.81b     |
| Number of cobs per plant (seed)     | 1.00a       | 1.05ab      | 1.11ab      | 1.22b       |
| Grain yield per plant (g)           | 79.03a      | 101.05ab    | 118.23ab    | 142.56b     |
| Grain yield per plot (tons/ha)      | 1.19a       | 1.27a       | 1.09a       | 1.08a       |
| 100 seeds weight (g)                | 20.08a      | 23.55a      | 25.61a      | 27.30a      |
| Number of seeds per plant (seed)    | 304.11a     | 355.00a     | 382.06a     | 416.39a     |

Note: J1 = 60 cm × 30 cm plant spacing, J2 = 60 cm × 40 cm plant spacing, J3 = 60 cm × 50 cm plant spacing, J4 = 60 cm × 60 cm plant spacing. Numbers followed by the same letter on the same line show no difference based on Duncan’s Multiple Range Test at 5% significance level.

3.2.1. Plant height. The height of hybrid corn plants in each treatment has increased every week.

![Figure 1](image.png)

**Figure 1.** Plant height chart of hybrid corn until the maximum vegetative phase.

Corn plant height ranges from 98.78 cm (J1) to 110.61 cm (J3) (Figure 1). The increase in plant height along with an increase in plant density at narrow plant spacing [5]. This is caused by increased competition between plants in getting sunlight and due to the canopy, that covers the plant parts reduces the decomposition of auxin so plant height can increase.

Plant height is also influenced by nutrients contained in the soil. The low value of plant height can be caused by several factors, one of which is the excess P. If the P level is excessive then the absorption of other elements in the soil will be disturbed so that it will inhibit the growth of plant height [6].

3.2.2. Stem base diameter. Plant stems base continue to grow from the beginning of growth until the time of the last measurement. Increasing the diameter of the stem increases every week (Figure 2).
The stem base diameter ranges from 13.88 mm (J1) to 16.32 mm (J2). The application of spacing did not give a real difference to the diameter of hybrid corn stems. The narrow spacing and high plant density that affect morphological and physiological changes [7]. This results in plant height, stem diameter and length of the cob being low and yields being reduced. High plant density will increase competition between plants for light, water and nutrition. Wide plant spacing makes the roots of plants grow better and can utilize nutrients in the soil. The element nitrogen is used in the formation of chlorophyll, protein synthesis and other important ingredients [8]. When the N elements are fulfilled, new cell formation can be achieved so that it can increase the diameter of the stem. Element P will stimulate plant roots so that roots become better at absorbing nutrients which are then used by plants in the formation of new tissues including the increase of stem base diameter.

3.2.3. Number of leaves. The number of leaves in hybrid corn plants continues to grow as growth continues to increase (Figure 3).

The average number of leaves ranged from 11.00 blades (J1) to 12.27 blades (J2). The use of narrow plant spacing causes the number of leaves produced lower [9]. That is because the use of narrow spacing will overlap between plant leaves. Then the plant will respond by reducing leaf formation.
3.2.4. Leaf area index. Application of plant spacing treatment gives a real difference to the value of leaf area index (LAI). Table 3. shows that treatment J1 has the largest LAI value of 0.91 while treatment J4 has the smallest value of 0.64. Application of plant spacing treatment that has a different density can be a cause of differences in LAI values. The high leaf area index was caused by the narrow plant spacing so that the canopy covered each other and covered an area of land [10].

Another thing that also affects the size of the leaf area index in addition to plant density is the supply of nutrients, especially nitrogen and leaf area. Increased of total leaf area related to the elements N and P [11]. The N elements are very influential on the growth and development of leaves. High nitrogen concentration results in a greater total leaf area. Nitrogen is the main element in the formation of vegetative parts of plants such as leaves, while phosphorus has a function as a constituent of proteins and magnesium as a constituent of chlorophyll molecules that play a role in the process of photosynthesis.

3.2.5. Fresh weight. The measurement of fresh stover weight is carried out immediately after harvesting because it can avoid a lot of water loss. Fresh weight ranges from 100.99 g (J1) to 180.69 g (J4). The increased spacing in rows will reduce competition between plants, including the absorption of sunlight and nutrients that can make the photosynthesis process run optimally and produce fresh weight that is also optimal [12]. Wider plant spacing makes the roots of plants grow better so that they are able to absorb water and nutrients optimally. Fresh weight relates to the accumulation of photosynthate yields and water content in plants [13]. The fresh weight of plants is influenced by the absorption of water and nutrients by plants so that the roots play an important role in increasing the fresh weight of plant.

3.2.6. Dry weight. The dry weight ranging from 40.10 g (J1) to 69.47 g (J4). Narrower plant spacing in fact it affects the loss of dry weight [14]. The narrower plant spacing and the higher the population makes the dry weight per plant lower, while the wider plant spacing and the low populations provide opportunities for plants to absorb nutrients, water and sunlight.

The dry weight reflects the net results of photosynthesis. Plants that grow at wider spacing can use sunlight, water and nutrients better so that photosynthesis and biomass formation are more optimal. The availability of nutrients N, P and K will cause the photosynthesis process to run well [15]. Nitrogen in plants has the function to increase the size of the leaves and increase the amount of protein thereby increasing the dry weight of the plant.

3.2.7. Cob weight with husk. Based on the results of the study, the largest weighted cobs was shown by J4 treatment with a weight of 207.87 g while J1 treatment had the lowest value of 108.69 g. The J4 treatment had the widest spacing with a population of 24 plants. While the J1 treatment had the narrowest plant spacing with 42 plants. Wide spacing increases reception of light and nutrients so that they are able to grow and experience a better assimilation process [16]. Spacing that is too narrow makes plants lush and cover each other so that the process of photosynthesis is inhibited and seed production is not optimal, even though the plants are given enough fertilizer to contain phosphorus.

3.2.8. Cob weight without husk. The J4 treatment had the highest weight without husk which was 175.81 g while the J1 treatment had the lowest weight which was 96.32 g. Cobs that produced by corn plants at wide plant spacing with low population have a higher size and weight compared to plants at a narrow plant spacing.

The increasingly narrow plant spacing caused very tight competition between plants, resulting in suboptimal plant growth [17]. High competition makes the level of availability of potassium absorbed by plants for organ formation to be lower. The potassium element regulates water in cells and transfers cations through the membrane. Increased weight of the cob is determined by the process of photosynthesis and photosynthate translocation to the effective part of the cob.
3.2.9. **Number of cobs per plant.** The J4 treatment has the highest value producing 1.22 cobs while the J1 treatment has the lowest value producing 1.00 cobs. The average treatment of J4 and J3 produced two cobs per plant although not the same in all samples. While J2 and J1 treatments on average only produce one cob per plant. This can be caused by the wide spacing makes plants able to get sunlight, water and nutrients with more leverage compared to a narrower spacing.

The spacing affects the number of plants in a certain area, it will affect the number of cobs that can be produced and harvested [18]. The number of cobs is also influenced by nutrient content, especially P in the soil. Plant roots at wide spacing can grow better so that they can absorb nutrients better. The number of cobs is influenced by the element of phosphorus contained in the soil [19]. The high phosphorus content causes the formation of female flowers to be better so that it can produce a high number of cobs as well.

3.2.10. **Grain yield per plant.** The real difference in the treatment of plant spacing was seen in the grain yield per plant. The J4 treatment gave the highest yield with a weight of 142.56 g, significantly different from the J1 treatment which had the lowest weight seed value of 79.03 g. The increase in grain yields in wide spacing with a low number of plants due to the availability of more resources (nutrition, moisture and light) so that competition between plants is low, while at narrow plant spacing with higher density produces weak plants when before silking [20].

Grain yield weight is also influenced by the availability of nutrients in the soil, especially N, P and K. The availability of N nutrients in the soil will support seed formation [21]. Nitrogen uptake is also influenced by the supply of elements P and K. The elements N and P are absorbed by the plant to near maturity, while K is needed when silking or female flowers appear. Most N and P are taken to the point of growth, stems, leaves and male flowers, then transferred to seeds.

3.2.11. **Grain yield per plot.** The yield of seeds is 1.19 tons/ha (J1), 1.27 tons/ha (J2), 1.09 tons/ha (J3) and 1.08 tons/ha (J4). The treatment with a wider spacing has lowest plants than the treatment of a narrow spacing. The J2 treatment has 36 plants with optimal results so that the grain yield per plot can reach higher values. J4 treatment has better results when viewed from plantations, but when viewed from the yields of plots it turns out that the amount is not enough because of the small population of only 24 per plant.

Corn plants with spacing that are wider get enough nutrition because there is no competition but with too low population will affect plot production [22]. Planting corn in high plant populations is a strategy to increase crop yields [23]. This strategy prioritizes an increase in per unit hybrid corn yields rather than an increase in crop yields. High density planting is less suitable for land with low soil fertility, because the supply of nutrients through fertilization in particular N is not sufficient to increase yields [24].

3.2.12. **100 seeds weight.** Application of spacing did not show significant differences in the 100 seeds weight. The 100 seeds weight ranges from 20.08 g (J1) to 27.30 g (J4). Wide plant spacing causes sunlight to be absorbed to the maximum by plants because the canopy does not shade each other [25]. As a result there is no competition against sunlight for photosynthesis so that plants get maximum energy for the growth of generative organs at 100 seeds weight.

3.2.13. **Number of seeds per plant.** The treatment of different plant spacing on corn did not produce any significant difference in the number of seeds per plant. Number of seeds ranged from 304.11 seeds (J1) to 416.39 seeds (J4). The increase in population at very narrow spacing affects corn production when filling seeds [26]. High plant density will reduce the weight and number of seeds due to competition during flower bud formation. High plant density also makes photosynthesis more distributed for vegetative growth or respiration than seed growth. Using wider spacing makes the root growth better so that the utilization of nutrients becomes more optimal.
Nutrients also play an important role in seed formation. Corn cobs filling influenced by the supply of nutrients to be able to form assimilates during the growth period and filling of cob [27]. If the assimilate supply is sufficient, the growth of cob and seed filling will be optimal so that it can increase corn productivity.

4. Conclusions
Based on research, it can be concluded that plant spacing treatment of 60 cm × 30 cm has increase on Leaf Area Index compared by 60 cm × 60 cm. Plant spacing treatment of 60 cm × 60 cm has increase on cob weight with husk, cob weight without husk, number of cob per plant and grain yield per plant compared with plant spacing of 60 cm × 30 cm. The plant spacing treatment of 60 cm × 60 cm can improve quality of yield per plant but have not been able to increase the quantity of hybrid corn yield. Spacing of 60 cm × 40 cm tended to give the highest yield, namely 1.27 tons/ha, 6.5% higher than 60 cm × 30 cm and 17.5% than 60 cm × 60 cm.

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