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The Effect of Planting Distance and Number of Seeds on Growth, Production, and Quality of Local Maize (*Zea mays L.*), Manado Kuning

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Abstract

Local maize, Manado Kuning, may contain more carotene than other maize varieties, but low production. This study was carried out to pursue the effect of planting distance and number of seeds per planting hole on the plant growth and the corn production. The study used a Group Randomized Design and the experiment was factorial, with two factors. Results showed that both factors individually affected the plant height, the leaf width, and the dry weight of the maize plant at all observations. These also inluenced the net assimilation rate and the chlorophyll level. There was strong interaction of planting distance and number of seeds per planting hole on corn production.

Keywords: maize, Manado Kuning, planting distance, number of seeds per planting hole, growth. production.

INTRODUCTION

Maize (Zea mays L) has enough nutrition and crude fibers as a substitute of rice, besides it is used for animal feed ingredients (feed) and industrial raw materials (Ditjen PPHP, 2005a). Local maize (*Zea mays indurate*), called Manado Kuning, has mostly been developed in North Sulawesi; the corn with strong yellow color that may contain more carotene than other corns, but low production.

According to Watson (2006), the crop is, in reality, a result of various factors and ecological conditions during its growth, and therefore, growth-directly related major factors need to be understood. Total crop is a direct impact of photosynthetic level and duration. Number of photosynthetic output produced and trans-located to the plant organs is dependent upon water, sun light, nutrients, oxygen, and carbohydrate (Wittwer, 2005). Planting distance, fertilization, variety utilization and soil processing are also important need to be considered to be able to gain those ingredients. Those factors cannot be taken apart due to interacting one and another. Planting distance of the plant is very important for achieving optimal crops. Implementation of optimal and *regular* planting distance on the land could enable the plant to grow well without having competition in light intensity acceptance, water and nutrient absorption so that fertilization will become effective (Harjadi, 2002).

According to Amir *et al.* (2001), number of plants per area unit highly affects the corn production. Number of plant population suggested is different based on the plant variety and soil condition. Nevertheless, farmers are used to having Manado Kuning population about 60,000 plants/Ha with planting distance varying between 30-50 cm x 50- 75 cm producing 1-2 ton dry corn/Ha.

Larger population level can possess positive impact, more planted plants, or negative impact, competition occurrence, on the crop (Chapman and Carter 1997). Number of plants per Ha can influence the crop, so that the achievement of maximum crop requires an optimum population through establishing number of population in the row. Basically, implementing number of planted population per area unit is one of the ways that highly influence the plant growth, the quality of corn and the crop expected. The closer the planting distance is the more plants fail to have the crop. Number of plant population also influences the competition level for water and nutrients that will consequently affect the crop.

Based on the information, a study on setting the planting distance and the number of seed per hole was carried out to increase the maize growth and crop quality of Manado kuning.

MATERIALS AND METHOD

Local maize, *Manado Kuning*, urea and KCl were used in this study. Soil samples of the study site were also analyzed for nutrients and several chemicals. Other equipment used were altimeter, meter line, borer, hoe, pH-meter, analytical balance, plastic bag, thermometer, spectrophotometer, centrifuge, HPLS (High Performance Liquid Chromatography), oven and a series of measuring tubes and writing equipment. Experiments were conducted in the experimental land of Wawo, Walian village, South Tomohon district, North Sulawesi, at 500 M above sea level and air temperature of 23 -25 ^{0}C.

This experiment was a factorial one, with two factors, planting distance and number of seed per hole, and used a Group Randomized Design. The former had three distance levels: J1 = 75 X 20 cm, J2 = 75 X 30 cm, and J3 = 75 X 40 cm. The latter consisted of three levels: 1 seed (B1), 2 seeds (B2), and 3 seeds (B3) per planting hole, each of which had 3 replications.

This field experiment was done in June, 2012. The plot had an area of 4 M x 7 M. Plant maintenance included fertilizing, weeding, soil piling as well as pest and disease control. Planting the seed was carried out by digging 3-5 cm deep-holes. Growth observations were focused on the plant height, leaf width, chlorophyll content, and dry weight, and conducted at the 28th, 42th, 56th and 70th day. Maize production was recorded on total grains per cob, dry weight of 1,000 grains, dry weight per Ha, the starch content in grain, sugar and carotene levels.

RESULTS

ANOVA indicated no significant interactions in the plant height, leaf width and maize plant dry weight resulted from different planting distances and number of seeds per hole. These factors individually affected the plant height, the leaf width, and the dry weight of the maize plant at all observations.

Table 1. Mean height of maize plant (cm) resulted from planting distance and number of seeds treatments at various observations.

Treatments	**Days after planting (DAP)**				
	14	**28**	**42**	**56**	**70**
Planting Distance					
J_1 (75 cm x 20 cm)	5,86 a	25,56 a	84,25 a	214,58 a	299,25 a
J_2 (75 cm x 30 cm)	5,87 a	25,96 a	90,81 b	222,17 a	304,83 ab
J_3 (75 cm x 40 cm)	7,21 b	27,94 b	97,56 c	242,14 b	308,75 b
LST 5%	**0,42**	**1,11**	**3,87**	**7,98**	**6,30**
No. of seeds per hole					
B_1 (1 seed)	8,82 b	27,11 b	95,83 b	233,97 b	309,86 b
B_2 (2 seeds)	6,21 a	26,75 b	91,97 b	229,03 b	304,92 b
B_3 (3 seeds)	5,92 a	25,59 a	84,81 a	215,89 a	298,06 a
LST 5%	**0.42**	**1,11**	**3,87**	**7,98**	**6,30**

Note : Values in the same column with similar alphabetic indicates no significant difference at 5% level.

Table 9 shows that both treatments significantly influence the plant height at all observation. Planting distance of 75 cm x 20 cm (J1) and 75 cm x 30 cm (J2) resulted in lower plant height than the other one at the 14th, 28th, 56th and 70th day after planting, while the planting distance of 75 cm x 20 cm produce the lowest plant height at the 42nd day. Maize planted at the planting distance of 75 cm x 40 cm gave the highest plant at 14 to 70 days after planting.

For number of seeds planted per hole, 3 seeds (B3) produced the lowest plant height at 14 days after planting. From 28-70 days after planting, 1 seed per hole (B1) did not gave different plant height from that of 2 seeds per hole (B2) and lower than that of 3 seeds per hole (B3). One seed per planting hole (B1) showed the highest plant in 14 to 70 days.

Table 2. Mean leaf width (cm^2) resulted from the planting distance resulted from planting distance and number of seeds treatments at various observations.

Treatments	**Days After Planting (DAP)**			
	28	**42**	**56**	**70**
Planting Distance				
J_1 (75 cm x 20 cm)	8,50 a	32,23 a	61,00 a	75,05 a
J_2 (75 cm x 30 cm)	9,45 ab	36,18 a	65,44 a	76,69 a
J_3 (75 cm x 40 cm)	10,72 b	43,75 b	73,69 b	92,71 b
LST 5%	**1,30**	**3,77**	**6,12**	**7,05**
No. seeds per hole				
B_1 (1 seed)	10,26 b	40,06 b	74,77 b	84,66 b
B_2 (2 seeds)	10,17 b	39,81 b	64,94 a	83,96 b
B_3 (3 seeds)	8,97 a	32,98 a	6 ,42 a	75,83 a
LST 5%	**1,30**	**3,77**	**6.12**	**7.05**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Table 2 shows that the planting treatment J3 resulted in the highest leaf width at all observations. In 14-70 days after planting, the J1.treatment did not give different leaf width from that of J2. One and 2 seeds per hole (B1 and B2) treatments did not also result in different leaf width, but wider than that of 3 seeds (B3) in 28, 42, 56 and 70 days after planting. Three seeds per planting hole (B3) treatment resulted in the narrowest leaf in 28 - 70 days.

Both treatments J and B highly affected the dry weight of the corn (Table 3). The J1 and J2 treatments resulted in lower dry weight than J3 at all observations. The J3 treatment showed the highest dry weight in 28 - 70 days after planting. The treatment of 3 seeds per planting hole (B3) gave the lowest dry weight. The treatment B1 did not result in different dry weight of the plant from that of B2.

Table 3. Mean dry weight of maize plant (g) resulted from treatments of planting distance (J) and number of seeds (B) at various observations.

Treatments	**Days After Planting (DAP)**			
	28	**42**	**56**	**70**
Planting Distance				
J_1 (75 cm x 20 cm)	12.30 a	64.72 a	309.19 a	511.96 a
J_2 (75 cm x 30 cm)	13.44 ab	72.98 a	328.01 a	525.86 a
J_3 (75 cm x 40 cm)	14.15 b	92.05 b	381.54 b	590.90 b
LST 5%	**1.45**	**11.18**	**30.41**	**57.42**
No. seeds per hole				
B_1 (1 seed)	14.36 b	82.35 b	364.71 b	584.46 b
B_2 (2 seeds)	13.94 b	79.08 b	349.88 b	555.59 b
B_3 (3 seeds)	11.60 a	68.08 a	304.15 a	408.67 a
LST 5%	**1.45**	**11.18**	**30.41**	**57.42**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Table 4 shows that the closer the planting distance is the higher the leaf width index. The J1 treatment gave the highest leaf width index in 28 - 70 days after planting. The leaf width index of the J2 treatment was not different from that of J3 in 28, 56 and 70 days after planting.

Table 4. Mean leaf width index of maize plant resulted from planting distance and number of seeds treatments at various observation ages.

Treatments	**Days After Planting (DAP)**			
	28	**42**	**56**	**70**
Planting Distance				
J_1 (75 cm x 20 cm)	0,57 b	2,12 b	4,07 c	5,00 b
J_2 (75 cm x 30 cm)	0,41 a	1,61 a	2,91 b	3,41 a
J_3 (75 cm x 40 cm)	0,36 a	1,46 a	2,46 a	3,09 a
LST 5%	**0,06**	**0,24**	**0,28**	**0,38**
No. seeds per hole				
B_1 (1 seed)	0,47 b	1,86 b	3,52 b	3,99 b
B_2 (2 seeds)	0,48 b	1,84 b	3,03 a	3,96 b
B_3 (3 seeds)	0,38 a	1,48 a	2,88 a	3,55 a
LST 5%	**0,06**	**0,24**	**0,28**	**0,38**

Note: Values in the same column with similar alphabet code indicates no significant difference at 5% level.

The treatment B3 gave the lowest leaf width index in 28, 42, 56 and 70 days after planting, but it was not different from that of B2 in 56 days after planting. Lower number of seeds had the highest leaf width index. There was no difference in leaf width index between B1 and B2.

Table 5. Mean growth rate (MGR) (g.m^{-2}/d) of the maize plant resulted from planting distance and number of seeds treatments at various observations.

Treatments	**Days After Planting (DAP)**		
	28 – 42	**42 – 56**	**56 – 70**
Planting Distance			
J_1 (75 cm x 20 cm)	24,63 b	116,36 c	96,61 b
J_2 (75 cm x 30 cm)	18,83 a	80,96 b	62,81 a
J_3 (75 cm x 40 cm)	18,55 a	68,93 a	49,85 a
LST 5%	**3,40**	**10,61**	**22,20**
No. seeds per hole			
B_1 (1 seed)	22,46 b	93,96 b	87,78 b
B_2 (2 seeds)	21,29 b	91,28 ab	70,47 ab
B_3 (3 seeds)	18,26 a	81,00 a	51,02 a
LST 5%	**3,40**	**10,61**	**22.20**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Table 5 shows that treatment J1 gave the highest growth rate at all observations. The growth rates were not different between treatment J2 and J3. Maize planting with 1 and 2 seeds per planting hole (B1 and B2) showed higher growth rate than that with 3 seeds per planting hole (B3).

Table 6. Mean net assimilation rate (g.m^{-2}/d) of the maize plant resulted from planting distance and number of seeds per hole at various observations.

Treatments	Days After Planting (DAP)		
	24 – 42	**42 – 56**	**56 – 70**
Planting Distance			
J_1 (75 cm x 20 cm)	24.03 b	40.36 b	24.91 c
J_2 (75 cm x 30 cm)	21.82 a	38.31 b	18.85 b
J_3 (75 cm x 40 cm)	21.63 a	33.84 a	15.56 a
LST 5%	**1.85**	**3.15**	**2.22**
No. seeds per hole			
B_1 (1 seed)	25.88 b	39.32 b	21.15 b
B_2 (2 seeds)	21.40 a	38.01 ab	19.96 ab
B_3 (3 seeds)	20.21 a	35.16 a	18.21 a
LST 5%	**1.85**	**3.15**	**2.22**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Table 6 shows that the wider the planting distance is the lower the net assimilation rate of the plant. The J1 treatment resulted in the highest net assimilation rate in 28-42 days and 56 – 70 days after planting, while in 42 – 56 days after planting, The J1 and J2 treatments did not have different net assimllation rate. The J3 treatment indicated the lowest net assimilation rate in 28 - 70 days after planting.

Moreover, planting more seeds per hole would decrease the net assimilation rate of the plant. Planting 1 seed per hole (B1) resulted in the lowest net assimilation rate in 28 - 42 days after planting, but it was not different from that of treatment B2 in 42 - 70 days after planting, but higher than that of treatment B3.

Table 7. Mean chlorophyll content (mg/g) of the maize plant resulted from planting distance and number of seeds treatments at various observations.

Treatments	Days After Planting (DAP)			
	28	**42**	**56**	**70**
Planting Distance				
J_1 (75 cm x 20 cm)	0.74 a	0.89 a	1.02 a	1.01a
J_2 (75 cm x 30 cm)	0.77 a	0.94 a	1.37 b	1.27 b
J_3 (75 cm x 40 cm)	0.97 b	1.07 b	1.50 b	1.33 b
LST 5%	**0.09**	**0.07**	**0.19**	**0.19**
No. seeds per hole				
B_1 (1 seed)	1.07 b	1.28 c	1.62 c	1.64 c
B_2 (2 seeds)	0.74 a	0.88 b	1.36 b	1.17 b
B_3 (3 seeds)	0.67 a	0.73 a	0.92 a	0.80 a
LST 5%	**0.09**	**0.07**	**0.19**	**0.19**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

ANOVA shows no significant interactions between maize planting distance and number of seeds per planting hole on the chlorophyll level of the plant. The planting distance and number of seeds per planting hole individually highly affected the leaf chlorophyll of the plant (Table 7). The farther the planting distance is the higher the leaf chlorophyll. In 28 - 42 days after planting, the J1 and the J2 treatments revealed lower chlorophyll level than that of the J3. In 56 and 70 days, the J1 gave the lowest chlorophyll level. Treatment J3 obtained the highest chlorophyll level in 28 and 42 after planting, but in 56 and 70 days after planting it was not different from that of the J2, but higher than that given in treatment J1.

The treatment of 1 seed per planting hole (B1) bestowed the highest chlorophyll level at all observations. Addiing more seeds (B2 and B3) resulted in lower chlorophyll level in 28 days after planting. In 42 - 70 days after planting, the treatment B3 gave the lowest chlorophyll level.

ANOVA shows that difference in planting distance and number of seeds per planting hole showed strong interactions on the dry weight of 1,000 corns, but no strong interaction on the dry weight of grains per plant and number of grains per cob. Farther planting distance increased the corn weght per cob and number of grains per cob (Table 8).

Dealing with number of seeds per planting hole, the B3 treatment produced the lowest corn weight per cob and number of grains per cob among those treatments. The B1 treatment resulted in the highest weight of corn per cob, but it was not different from the number of grains per cob in B2, but more than that in B3.

Table 8. Corn production resulted from planting distance and number of seeds per hole.

Treatments	**Weight of corns per cob (g)**	**Number of corns per cob**
Planting Distance		
J_1 (75 cm x 20 cm)	30.93 a	204,29 a
J_2 (75 cm x 30 cm)	32.71 a	215,90 a
J_3 (75 cm x 40 cm)	43.17 b	257,29 b
LST 5%	**9.35**	**33,08**
No. seeds per hole		
B_1 (1 seed)	55.41 c	259,72 b
B_2 (2 seeds)	30.18 b	226,15 b
B_3 (3 seeds)	21.22 a	191,61 a
LST 5%	**9.35**	**33,08**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Table 9 shows that there is strong interaction bertween planting distance and number of seeds per planting hole on dry weight of corns per Ha. The J1 treatment did not give different grain weight with number of seeds planted per hole. The J3 and B2 treatment combination resulted in increased the grain weight, but not in the J3 and B3 treatment combination. The lowest corn production per Ha was recorded at the J2 and B1 treatment combination and the highest was recorded at the J3 and B2 treatment combination.

Table 9. Corn weight per Ha (ton) resulted from planting distance and number of seeds treatments.

Treatments	**B1 (1 seed per hole)**	**B2 (2 seeds per hole)**	**B3 (3 seeds per hole)**
J1 (75 cm x 20 cm)	3,38 cd	3,39 cd	3,32 cd
J2 (75 cm x 30 cm)	2.09 a	2.47 b	3.10 c
J3 (75 cm x 40 cm)	2.28 ab	3,49 d	2,38 ab
LST 5%		**0,37**	

Note: Values in the same column with similar alphabet code indicates no significant difference at 5% level.

ANOVA reveals that there is significant interaction on the dry weight of 1,000 grains as a result of planting distance and number of seeds per planting hole. Table 10 shows that for treatment B1 and B3, increase in planting distance did not result in significantly different weight of 1,000 grains. The combination of treatment B2 and J3 resulted in the highest weight increment of 1,000 grains. Lower increment was recorded in other treatment combinations.

Table 10. Dry weight of 1000 grains resulted from planting distance and number of seeds per planting hole.

Treatments	**B1 (1 seed per hole)**	**B2 (2 seeds per hole)**	**B3 (3 seeds per hole)**
J1 (75 cm x 20 cm)	194,02 b	116,06 a	100,39 a
J2 (75 cm x 30 cm)	227,44 b	121,89 a	104,59 a
J3 (75 cm x 40 cm)	227,55 b	226,68 b	133,32 a
LST 5%		**44.24**	

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

There is no significant interaction on starch and total sugar levels due to the planting distance and number of seeds per planting hole treatments. These treatments individually had significant influence on the starch and the total sugar levels. Both treatments did not also highly affect the carotene level.

Table 11. Corn starch, sugar and carotene levels as a result of planting distance and number of seeds per planting hole treatments.

Treatments	Starch (%)	Total sugar(%)	Carotene (mg/g)
Planting Distance			
J_1 (75 cm x 20 cm)	44.88 a	2.75 a	0.64
J_2 (75 cm x 30 cm)	46.32 b	2.84 a	0.73
J_3 (75 cm x 40 cm)	48.13 c	3.19 b	0.75
LST 5%	**1.17**	**0.08**	**Ns**
Number of seeds per planting hole			
B_1 (1 seed)	49.68 c	3.18 c	0.79
B_2 (2 seeds)	47.467 b	2.97 b	0.71
B_3 (3 seeds)	42.18 a	2.63 a	0.62
LST 5%	**1.17**	**0.08**	**Ns**

Note: Values in the same column with similar alphabetic code indicates no significant difference at 5% level.

Increase in planting distance lifted up the corn starch and the total sugar levels (Table 11). Maize planted at the distance of 75 cm x 20 cm (J1) resulted in the lowest starch level, and that of 75 cm x 40 cm (J3) produced the highest starch level. Treatment J3 resulted in the highest sugar content, while J1 and J2 did not give different sugar content**.**

The less the number of seeds per planting hole is the higher the starch and the total sugar content. Table 11 shows that the use of 1 seed per planting hole (B1) gave the highest starch and total sugar content. Increase in number of seeds per planting hole reduced the starch and the total sugar content.

DISCUSSION

Planting distance and number of seeds per planting hole individually gave significant effect on plant height, leaf width and plant dry weight.

Planting distance significantly influenced the Manado Kuning plant growth. Increase in planting distance to 75 cm x 40 cm (J_3) resulted in better growth rate, since it results from gives better rooting distance and reduces competition between plants for growth factors, such as light, water and nutrient, while narrower planting distance will raise inter-plant competition. One of the important climatic elements and often competed is sunlight, since maize plant needs full sunlight. Enough growth factor caused the plant be able to grow optimally. Harjadi (1986 In Johu *et al*., 2002) found that planting distance did not only influence the plant population and light utilization efficiency, but also affected the inter-plant competition for water and nutrients that eventually affect the plant growth. The less the inter-plant competition is the higher the plant growth.

Local maize, *Manado kuning,* had better growth at a wide planting distance. This study found that the planting distance of 75 cm x 40 cm (J_3) gave the highest growth rate. Since this local maize has tall stem, long leaf and long harvest time, the planting distance of 75 cm x 40 cm (J_3) causes enough availability of space for growth that makes it can optimally grow. The wide planting distance makes also the growth factors be more met for water, light and nutrients. This fulfilment could increase the leaf width of the plant. Table 2 shows that the leaf width of 75 cm x 40 cm (J3) planting distance produces the largest leaf width. Increase in the leaf width is also dealt with increase in leaf chlorophyll (Table 7**.** It results in the phosynthesis working well so that the formation of dry materials increase and augment the cell size causing increase in the plant height. The study was carried out in rainy season, in which the maize grew faster than that in dry season. It agrees with Sangakkara *et al*. (2004) that the maize planted in rainy season has higher upper part of the plant than that in dry season, so that it will be better to plant at the wider distance**.** Beside that, with 75 cm x 40 cm planting distance, the local maize could compete with weeds, since high crown of the maize plant and many leaves could reduce the sunlight penetration onto the soil surface that inhibits the weed growth. The planting distance of 75 cm x 40 cm for Manado kuning maize planted in rainy season gave also better growth, since a wide planting distance helps the sunlight reach the soil surface and could boost the soil temperature and reduce the soil humidity. The local maize, *Manado Kuning,* is feeble to albino disease (*Sclerospora maydis*), and it easily disperses in humid condition and water flooding. Low soil humidity could lessen this infection.

Closer planting distance results in lower growth rate. Close planting distance causes the plant grow taller and increases inter-plant competition. It occurs due imbalanced growth factor distribution, such as water, nutrient and sunlight. Table 7 shows that the planting distance of 75 cm x 20 cm (J_1) and 75 cm x 30 cm (J_2) results in slimer leaf than that of wider planting distance. It is indicated by low number of growing leaves. It could happen due to close planting distance that inhibits the plant to get the growth factors. Competition for sunlight is very important factor in setting the planting distance. Number and size of growth factors are influenced by sunlight, humidity and number of nutrients available. According to Dewani (2004), leaf enlargement is a result of leaf cell development affected by the availability of protoplasms made of organic compounds and carbohydrates, so that increase in phosporous and nitrogen content will enlarge the tissue size, including leaf. Close planting distance (J_1 and J_2) gave narrow leaves causing low sunlight absorption. Narrow leaves reduce also the leaf chlorophyll level cutting the phosynthetic process. Both narrow leaf and low chlorophyll content result in low photosyntat accummulation into dry materials and inhibit the height development of the plant.

Number of seeds per planting hole affects the growth rate. Table 1, 2 and 3 shows no different growth given between 1 and 2 seeds per planting hole. It could result from that 2 seeds per hole do not have enough competition for growth factors and still exhibit good growth. According to Effendi *et al*. (2008), the growth of 2 adjacent plants will not compete if there is enough groundwater, nutrients and sunlight penetration available for each plant. Planting 2 seeds per hole (B_2) does not give different leaf width from that of 1 seed (B_1). Indifferent leaf width causes indifferent sunlight acceptance on the leaf surface despite lower chlorophyll content than that of 1 seed per hole (B_1). Consequently, formation of dry material and plant height is not different.

The more the seeds per hole are the lower the plant growth rate. Table 1, 2 and 3 show that planting 3 seeds per hole (J_3) gives the lowest plant height, leaf plant, dry weight of the plant. It occurs since planting 3 seeds per hole (J_3) will increase plant density in a hole, so that the competition for growth factors will be very strong. Shafi *et al*. (2012) suggested that the leaf width is usually affected by genotype, plant density, climate and soil fertility. High plant density will reduce the leaf width and the plant chlorophyll content. Table 2 and 7 show that planting 3 seeds per hole gives the lowest leaf width and chlorophyll content. Low leaf width and chlorophyll content will inhibit the plant photosynthetic process so that the photosyntat stored in the dry material will be less and the development of plant height is also inhibited.

The denser the planting distance is the higher the plant leaf width index. It results from that the closer the planting distance is the narrower the space inhabited, and the higher the leaf width index will be. High leaf width index reflects that the plant possesses overlapping leaves, and vise versa. Close planting distance will cause the leaves are shading one and another so that the shaded leaves get less light, and eventually get lower photosynthetic rate than those unshaded. The chlorophyll content is also lower than that of close planting distance (Table 7). From 28 to 56 days after planting the leaf width index develops fast, then slows down. It results from having generative phase after 56 days old and the photosyntat is more directed to fruit formation and less to leaf formation.

The width leaf index decreases with increase in number of seeds per hole. Table 4 exhibits that the use of 3 seeds per hole results in the lowest leaf width index in all observations. Planting 3 seeds per hole will lift up the plant population density, and it will significantly affect the plant acceptance of light intensity. The higher the population density is the lower the light intensity reached. High density will cause leaves of adjacent plants be shading each other so that the assimilation rate and the growth rate become lower and the leaf width index is also lower.

Planting 1 and 2 seeds per hole resulted in higher leaf width index, growth rate, and net assimilation rate. With 1 and 2 seeds per planting hole, the density is low and not many leaves are shading. The sunlight will have enough space to penetrate the leaf which could increase the leaf width, and therefore the leaf width index becomes higher. Wider leaf width will raise the number of chlorophyll in the leaf. Table 7 shows that planting 1 seed (J_1) gives the highest leaf chlorophyll, and high chlorophyll content increases the photosynthesis, and therefore, lifts up the dry materials as well. High leaf width index indicates shading leaf structure which supports the light catch of the leaf. The light uncatchable on the upper part will be taken by the leaves below, so that it could hoist the growth rate and the net assimilation rate of the plant.

Close planting distance gave higher growth rate than that the wide one did. The present study reflects that the planting distance of 75 cm x 20 cm (J_1) gives the highest growth rate**,** since at the close planting distance, the area used is narrower. The growth rate reflects the soil ability to produce the biomass per time unit. Table 5 shows that the plant initially grows slow and then faster up to 56 days after planting and slow down again. According to Sitompul and Guritno (1995), the growth rate will go slow after reaching the maximum due to age increment. Growth rate is influenced by the leaf width index. Table 4 shows that the planting distance of 75 cm x 20 cm (J_1) gives a high leaf width index. It firstly rose fast and therefore the plant grew fast as well, but when the leaf width index decreases, the plant will grow slow. The leaf width index at the planting distance of 75 cm x 20 cm (J_1) causes the net assimilation rate increase.

Wide planting distance gives lower net assimilation rate and growth rate, since the area inhabited by the plant is larger. Growth rate of the plant is an increment of dry weight per are unit per time unit. The planting distance of J_2 and J_3 results in wider leaf than that of J_1, but since the area inhabited is bigger, the leaf width index becomes low. Low leaf width index reflects that much sunlight energy passing to the soil surface, so that the net assimilation rate become lower and the growth rate goes slower. At early growth, the growth rate and the net assimilation rate increase very fast up to 56 days after planting.

Number of seeds per hole influences the net assimilation rate and growth rate (Table 5 and 6). The more number of seeds per hole will raise the competition among plants for growth factors causing less leaf formation. The net assimilation output and the dry material increment is determined by the width of the photosynthesizing surface leaf.

Planting 3 seeds per hole gives the lowest leaf width (Table 2) and the lowest chlorophyll content (Table 7). These cause the photosynthetic process be not maximum, and eventually result in low net assimilation rate, and slow growth (Table 5 and 6).

Increase in leaf width index to certain level will reduce the growth rate and the net assimilation rate. High width leaf index value imbalanced with increased growth rate and net assimilation rate indicates that the optimum leaf width index is reached. Higher leaf width index than the optimum reflects many leaves shaded bringing about low sunlight acceptance in lower part and decreased growth and net assimilation rate. In addition, the photosynthesis, through the generative phase, will be more directed to the formation of generative organs.

ANOVA shows significant interaction between planting distance and number of seeds per planting hole on corn production. It is highly correlated with population gained in association with the combination of planting distance and number of seeds per hole. Number of maize populations planted per area unit strongly affects the production. Table 16 shows that increase in population from 33.333 to 66.000 plants per Ha results in corn production, but higher population will trim it down. It reveals that Manado Kuning population of 60.000 - 66.666 plants is optimum. This study supports Shafi *et al*. (2012) that population enlargement from 45,000 to 65,000 plants per Ha could increase the corn production with the highest reached in 65,000 plants. According to Sitompul and Guritno (1995), increased number of plants per area unit is firstly accompanied with proportional production increment, but the next additional population will reduce the production due to competition. Higher competition among plants results in production reduction per area unit with population addition. Higher corn production per Ha is obtained at treatment J1 and B_1 combination and J_3 and B_2), 2,94 t ha^{-1} and 2,97 ha^{-1}, respectively.

Low plant population results in large mass and low weight per Ha. Table 8 shows that planting 33,333 (J_3B_1) and 44,444 (J_2B_1) plants results in higher weight per plant, but lower weight per Ha. Lower population produces higher weight per plant due to low competition among plants for growth factors. Sufficient availability of growth factors could result in higher weight per plant. It, however, does not bring about higher weight per Ha, because the plant population per Ha is below the optimum population. The planting distance and the number of seeds combinations (J_2B_1 and J_3B_1) could increase the corn production per plant, 63.30 g and 84.32 g, respectively, and 2.81 tons per Ha.

Close planting distance and number of seed addition will reduce the production. Table 8 shows that the planting distance of J_1 and B_3 combination results in the lowest corn weight per plant, corn weight per Ha, weight of 1,000 grains and number of grains. It occurs since the population is too big, 199,988 plants. Very big plant population unbalanced with sufficient availability of growth factors could enhance the competition among plants, so that their growth declines. In the soil, the plant rooting will be competing for nutrients and water. Increase in plant density could inhibit the sunlight penetration into the crown reducing the photosynthesis. It causes the assimilat proportion allocated to the seed corn decline, so that the seed size becomes small and not many, and results in the lowest weight of 1,000 seeds, the lowest weight per plant, the lowest weight per Ha and the lowest number of seeds (Tabel 8). In addition, according to Goldsworthy and Fisher (1992: *In* Johu *et al*., 2002), enormously high population could also make more plants be warren that reduces the plant production.

Manado Kuning seeds usually originate from hereditary seeds. Therefore, setting the planting distance and the number of population is intended not only to amplify the production, but also to maintain the seed quality for the next planting. Good seeds are those of medium size. Excessively big seeds will cause the seed need become more, while excessively small seeds will bring about low quality plants and lower the germination. To obtain seeds for the next planting, it is more appropriate to use seeds from the treatment combination of J_3 and B_2 . This suggestion results from higher number of seeds per cob produced with ideal weight (Table 8). Tabri (2009) suggested to use an optimal population, 66,667 tanaman ha^{-1} to get good quality seeds.

As food materials, the seed corn should meet human-needed nutrients, and therefore, maize study is not only oriented to production increment, but to quality development as well. According to Suarni and Widowati (2007), as food materials, corns should meet sufficient nutritions, such as carbohydrates, proteins, sugar and vitamins. Manado Kuning maize is potential to develop due to nutritive content higher than white grains. In addition, yellow grains have carotene content that is able to increase human immunity and hold back cell generative damages.

Planting distance significantly affects the starch and the sugar content of the grains. Maize planted at a wide planting distance produces higher starch and sugar content. In this study, the planting distance of J_3 gave the highest starch and the total sugar content. A wide planting distance enables the plant to better take nutrients needed, especially K^+ necessary for the grain quality. Sufficient K^+ available could lift up the corn quantity and quality, such as addition of sugar and carbohydrate content of the grain (Dewani, 2004). Potassium is highly required to push the carbohydrates in plant metabolism process. Manado Kuning maize planted on the distance of J_3 produces the highest starch and total sugar content,48.13% and 3.19%, respectively. The starch content is lower than nutrition standard for corns, but the sugar content is higher than the nutrition standard. According to Suarni and Widowati (2007), corns have 72-73% starch content, 25-30% amylose and amylopectine ratio% : 70 – 75% ?, and 1-3% simple sugar content (glucose, fructose and sucrose).

Number of seeds per planting hole influences the starch and the total sugar content. Planting 1 seed per hole (B_1) gave the highest starch and total sugar content among the treatments. Planting one-seed per hole enables the plant to gain more nutrients than planting more seeds per hole. Nutrients, especially potassium, are very crucial for increasing the sugar and the starch content of the maize plant. Total sugar content is closely correlated with carbohydrate formation and utilization. Nyakpa *et al*. (1988) found that potassium could raise the starch content of the grain. An adequate accessibility of potassium could support the plant height, the leaf width and the chlorophyll content. The higher the chlorophyll content of the leaf is the better the photosynthesis process works and more carbohydrates are produced. Low sugar and stach content in 3 seeds per hole-produced corns could result from high inter-plant competition for the nutrients. Insufficient potassium utilized by the plant results in low sugar and starch content.

All planting treatments do not significantly influence the carotene content of the seed corn. It could result from insufficient nutrient availability for carotene production of the corn. To increase the carotene content of the seed corn, enough nutrients, particularly potassium, are needed.

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