Asian Research Journal of Agriculture

12(3): 9-16, 2020; Article no.ARJA.55116
ISSN: 2456-561X

Effect of Plant Spacing to Growth and Yield of Hybrid Maize (*Zea mays* L.)

Indra Dwipa[1*], Syafri Karmaini[1] and Irfan Suliansyah[1]

[1]Department of Agronomy, Faculty of Agriculture, Andalas University, Limau Manis Campus, Padang, West Sumatra, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. Author ID designed the research, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SK Performed the research, performed the data. Author IS Read and approved the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2020/v12i330083
Editor(s):
(1) Dr. M. Yuvaraj, Adhiparasakthi Agricultural College, India.
Reviewers:
(1) Moataz Eliw, Al-Azhar University, Egypt.
(2) Bhupen K Baruah, Jagannath Barooah College, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55116

Original Research Article

Received 04 January 2020
Accepted 10 March 2020
Published 25 March 2020

ABSTRACT

Problem: Maize is one of important food for Indonesian people. The problem faced by Indonesian government is the maize is not sufficient to suffice the this country demand.
Aims: The research aimed to study the interaction between several hybrid maize varieties and plant spacing to growth and yield of hybrid maize
Study Design: Factorial design in randomized block design.
Place and Duration of Study: The research was conducted in Siguntur, Sitiung 1, Dharmasraya, West Sumatra and Indonesia from April to July 2018.
Methodology: Factorial design in randomized block design with 2 factors was used in the assay. The first factor was hybrid maize varieties (Pioneer P35 and Pertiwi 3) and the second factor was planting space (75 cm x 20 cm, 75 cm x 30 cm and 75 cm x 40 cm). The data was analyzed by ANOVA.
Results: The result showed that no interaction between planting spacing and varieties to growth and yield of maize. The best hybrid maize variety for growth and yield was Pioneer 35. The best planting space for growth and yield was 75 cm x 20 cm.

**Corresponding author: E-mail: 1965indradwipa@gmail.com;*

Conclusion: The interaction between plant spacing and hybrid maize varieties did not affect the growth and yield of hybrid maize.
Recommendation: The further research are recommended to study the effect of plant spacing and hybrid maize to growth and yield of maize.

Keywords: Hybrid maize; plant spacing; varieties; Zea mays L.

1. INTRODUCTION

Maize (*Zea mays* L.) is main important cereal crop for half world population [1]. In Indonesia, maize was main staple food for eastern population particularly in Nusa Tenggara Timur. This crop has potential to develop due to its demand always increases every year [2]. In addition to be as staple food, maize also used as feed and industrial raw materials [3]. The increasing demand of maize also occurred in Indonesia. Maize plays an important role for Indonesian economy. The demand always increases every year for staple food, feed and raw materials for industrial. Most of domestic maize for feed and industrial fuel. 57% of national requirement was distributed for these sectors and 34% of rest for food and 9% for other industrial [4].

Maize consumption in Indonesia reached 28.4 kilogram per capita per years [5] both for processed or half-finished product such as cake ingredients, instant porridge, coffee mixture and low calories soft drink product. In 100 gram, maize contains 129 cal.energy, 4.1 protein, 1.3 g fat, 30.3 g carbohydrate, 5 mg calcium, 108 mg phosphor, 1.1 mg iron, 117 SI vitamin A, 0.18 mg vitamin B, 9 mg vitamin C and 63.55 g water [6].

The increasing of maize demand in Indonesia is not followed by the increasing of production. This condition become a main problem for maize sufficient in this country. To solve the problem, Indonesia government imports the maize from another countries to suffice the national requirement In 2014-2015, Indonesia imported 3,253,616 ton and 3,267,294 ton respectively [5].

The dependency of Indonesia to maize import should be stooped due to the main producer countries such as United States (US) and China starts to stop their maize export. This condition due to they converts their maize to be ethanol and bio-fuels [7]. In US, there is increasing of ethanol using from maize and 2006, it increased 36% [8]. This condition causes the Indonesian government should find alternative ways to stimulate maize production, minimal for national sufficiency. One of e effort to solve the problem was hybrid maize varieties.

Hybrid maize is the result of two or more maize seedling cross that has superior characteristic and higher productivity in yield and plant growth is more similar [9]. This maize can be used and developed to increase the national productivity. Seen by public demand, maize can be alternative staple food substituting rice.

For increasing the production, planting space is key component. Population of plant per area unit affected the maize production. Population per hectare is suggested different according the variety, planting season and soil condition The effect of population per hectare addition was longer flowering age, plant height and cob height, number of fall plant decreased the mature age [10].

Plant population is main factor affects the plant yield. The population arrangement aimed to minimize the competition between main crop and weeds. The addition of density per area unit caused the morphology and physiology of maize plant characteristic such as silking delay and barren increased. Number of barren was positively correlated to plant density [11]. Otherwise, low population could improve plant individual growth but it provide a space for weed growth. Maize plant and weed growth in same location has a negative impact due to the competition occurrence in absorption of nutrients, water, light and growth space [12]. The research aimed to the interaction between several hybrid maize varieties and planting space to growth and yield of hybrid maize.

2. MATERIALS AND METHODS

2.1 Experimental Site

The research was conducted in Siguntur, Sitiung 1, Dharmasraya, West Sumatra, Indonesia from April to July 2018. The soil type was ultisol. The altitude was 131 m above sea level (asl). The

experimental site is located at 1º01'S and 101º40'E.

2.2 Experimental Design

Factorial design in randomized block design with 2 factors was used in the assay. The first factor was hybrid maize varieties (Pioneer P35 and Pertiwi 3) and the second factor was Planting space (75 cm x 20 cm, 75 cm x 30 cm and 75 cm x 40 cm). The data was analzed by F test in 5% and followed by Duncan's New Multiple Range Test (DNMRT) in 5%.

2.3 Procedure

The research was started by land tillage. It aimed to provide good condition for crop grew well and free from weed and improved soil structure. The tillage was conducted 2 times. The first tillage was conducted by hand tractor. It aimed to improve aeration and drainage of soil. The second tillage was conducted with interval 1 week from first tillage. The planting was conducted according the treatment. The hole was conducted by hole maker in ± 3 cm in depth. Each hole was filled by 2 seeds.

The fertilization was conducted according the criteria, urea 300 kg/ha, Sp-36 150 kg/ha and KCl 100 kg/ha. The fertilization was conducted 2 time during the research. The first fertilization was conducted in planting time. The dose was all part of SP-36 and KCl and half of urea. The second fertilization was conducted in 35 days after planting. The harvesting was conducted in 94-103 days after planting. The observed parameters were plant height, time of silking appearance, length of cob, diameter of cob, number of row, number of grain, weight of 100 grains and productivity per hectare.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The result showed that there was no interaction between maize varieties and plant spacing effect to maize pant height (Table 1). For single factor, the effect also did not occur. This condition due to all planting space were still similar so that there was no significant effect from planting space. Beside growth factor, the other factor that played important role for plant height was genetic factor.

Vegetative phase significantly affected the generative phase. Optimal vegetative phase stimulated the generative growth so that the high yield could be obtained. One of vegetative growth characteristic was plant height. Low dense of plant spacing caused the competition between crop and weed in obtaining the water, nutrients and sunlight. It also caused the high obtained sunlight intensity so that it caused the disrupted growth [13]. High plant could obtain full light intensity so that it increased dry matter supply to leaf, stem and grain that stimulated growth and biomass of plant [14].

3.2 Number of Leaves

According the result, number of leaves were not affected by interaction between maize varieties and plant spacing (Table 2). But, the single factor affected the number of maize leaves. Number of leaves of Pioneer P35 variety is much more than Pertiwi 3. This condition was caused by the maize variety had different ability in using the growth space and adaptation process to environment. The number of maize leaves was affected by genetic and environmental factors [15,16]. The use of 2 varieties caused the potency of number of leaves were not significantly different.

Dense plant population affected the number of maize leaves. More and denser plant population stimulated to absorb water, nutrient and sunlight for plant growth. The plant requirement for optimal plant growth elements stimulated the plant growth and new leaves formation. The new leaves formation and rest of number of leaves in plant caused the number of leaves increasing. Leaves are as photosynthesis occurrence significantly determined the absorption and energy change in photosynthate formation [17]. The number of leaves was affected by genotype and environmental factor. Large number of leaves contributed to photosynthesis activity due to leaves were an organ that played role as photosynthesis process occurred [18].

3.3 Silk Appearance

Silk appearance is important parameter for maize growth. The result showed that the interaction between maize varieties and plant spacing did not affect the silking appearance (Table 3). But, for single factor, the variety affected the silking appearance. For this parameter, Pertiwi 3 was better variety than Pertiwi 3. Silking appearance was significantly affected by genetic factor [15]. This parameter was closely related to flowering

time. Flowering time was affected by nutrients availability, water and sunlight in growth phase so that the plant entered the flowering phase if vegetative growth reached flowering time and environmental factor stimulated the flowering induce. First silking was correlated to plant itself. Sufficient nutrient stimulated faster silking [19].

The vegetative phase always occurred until generative phase and started by silk formation and followed by grain filling, grain formation and ended by maturing phase. The silk appearance in top of plant indicate the end of vegetative phase and the beginning of generative phase [20].

One of factor that influenced flowering age is environment and genetic. The faster panicle and silk appearance age could increase the grain filling due to the earlier flowering age caused the longer grain filling [21]. Phosphorus and potassium fertilizer application could accelerate the silk appearance [22]. The earlier silk appearance could increase the corn yield. Flowering is complex physiological performance where many factors affected the plant until this stage. The mechanism of plant did not occur automatically, but it was stimulated by many factors and one of them was environmental factor. The environmental factor affected the silking appearance was temperature and day length. The different day length and temperature that obtained by plant caused the different response to hormones in plant that played role as silking performance [12].

3.4. Length of Cob and Diameter of Cob

According the result, the interaction between hybrid maize varieties and plant spacing did not affect the length of cob. But, the single treatment affected the length of cob (Table 4). The result showed that the Pioneer P35 variety was better than Pertiwi 3 variety for length of cob (Fig. 1). The result was caused by the Pioner P35 had good adaptability to environment so that the plant could absorb water, nutrient and sunlight. Planting space use could increase the yield and affected the population and light, water and nutrients for photosynthesis. Sabo et al. [23] reported that 25 cm of planting space produced longer cob than 30 cm.

Table 1. Plant height of hybrid maize varieties and various plant spacing (cm)

Varieties	Planting space		
	75 x 20 cm	75 x 30 cm	75 x 40 cm
Pioneer P35	221.42	202.75	198.00
Pertiwi 3	207.17	205.33	214.50
Coefficient of diversity = 8.46%			

Notes : similar letter indicates not significantly different

Table 2. Number of leaves of hybrid maize varieties and various plant spacing

Varieties	Planting space			Average
	75 x 20 cm	75 x 30 cm	75 x 40 cm	
Pioneer P35	11.083	11.417	12.250	11.583 a
Pertiwi 3	10.667	10.417	10.500	10.528 b
Coefficient of diversity = 5.80%				

Notes : similar letter indicates not significantly different

Table 3. Silk appearance of hybrid maize varieties and various plant spacing (day)

Varieties	Planting space			Average
	75 x 20 cm	75 x 30 cm	75 x 40 cm	
Pioneer P35	53.58	53.50	53.67	53.58 b
Pertiwi 3	54.50	54.17	54.00	54.22 a
Coefficient of diversity = 0.61%				

Notes : similar letter indicates not significantly different

Table 4. Length of cob of hybrid maize varieties and various plant spacing (cm)

Varieties	Planting space			Average
	75 x 20 cm	75 x 30 cm	75 x 40 cm	
Pioneer P35	15.46	15.13	15.13	15.236 a
Pertiwi 3	13.13	12.38	12.63	12.708 b
Coefficient of diversity = 6.71%				

Notes : similar letter indicates not significantly different

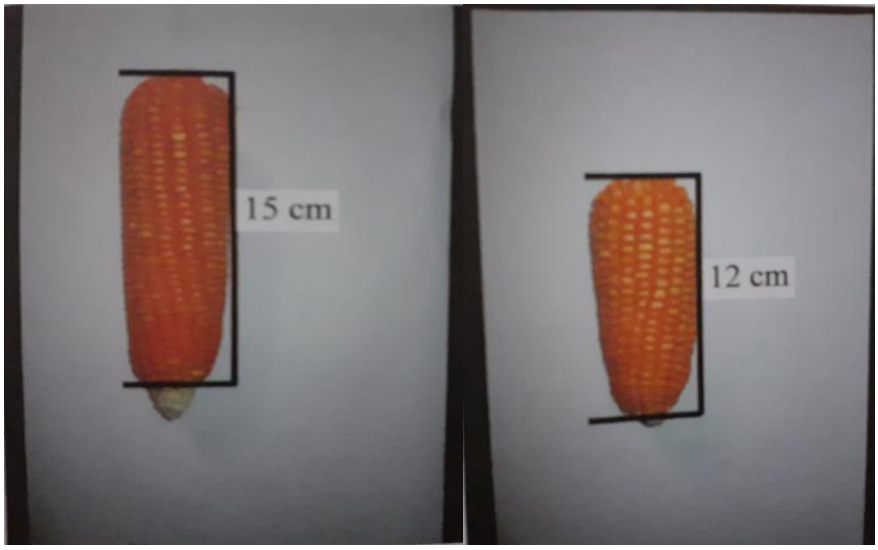

Fig. 1. Length of cob of hybrid maize varieties (a. Pioner P35; b. Pertiwi 3)

Length of cob performance was caused by the difference of division, propagation and enlargement of cell [24]. The significant increasing of plant growth according the photosynthesis efficiency increasing. Optimum photosynthate increased the yield, length of cob and supported by degree of environment fertility [18].

The length of maize cob affected the diameter of cob. The result showed the the diameter of cob was not affected by the interaction between planting space and maize varieties. But, average of single treatment of variety affected the cob diameter. According the result, variety of Pertiwi 3 produced the longer diameter than Pioner P35 variety (Table 5).

The different performance of cob diameter was dominantly caused by genetic factor of variety. The diameter of cob was closely related to photosynthate that was distributed to cob. If the photosynthate on cob was high, the produced cob was high, In this condition, the photosynthate on leaves and stem that was distributed in grain filling played this role. If high photosynthate of laves and stem was high, the transferred photosynthate in grain filling was high [25].

3.5 Number of Row Per Cob

The interaction between plant spacing and maize varieties did not affect the number of row per cob. As the previous result, the single treatment, variety affected the number of row per cob. According the result, Pertiwi 3 had the highest number of row per cob (14.808) (Table 6).

In plant spacing, the competition to obtain the water and nutrients occurred so that the good planting space arrangement could make the competition did not occur. Beside the absorption of water and nutrient, the sunlight absorption was also important in affecting the growth and yield of plant. Good appropriate planting space depended on soil fertility, soil tillage, fertilization and varieties. According the result, for Pioneer 35 variety, the number of row was around 14 rows [26]. This result was similar the description of this variety (14-16 rows/cob). For Pertiwi 3 variety, the number of row per cow was 14-15. This result also was similar to description of the variety [27].

Table 5. Diameter of cob of hybrid maize varieties and various plant spacing (cm)

Varieties	Planting space			Average
	75 x 20 cm	75 x 30 cm	75 x 40 cm	
Pioneer P35	13.65	13.90	13.57	13.706 b
Pertiwi 3	14.93	15.17	14.33	14.808 a
Coefficient of diversity = 5.19%				

Notes : similar letter indicates not significantly different

Table 6. Number of row per cob of hybrid maize varieties and various plant spacing

Varieties	Planting space			Average
	75 x 20 cm	75 x 30 cm	75 x 40 cm	
Pioneer P35	14.33	14.33	14.17	14.278 b
Pertiwi 3	15.33	15.50	15.00	15.278 a
Coefficient of diversity = 3.94%				

Notes : similar letter indicates not significantly different

Table 7.Production per hectare of of hybrid maize varieties and various plant spacing (ton)

Varieties	Planting space		
	75 x 20 cm	75 x 30 cm	75 x 40 cm
Pioneer P35	6.88	4.67	3.40
Pertiwi 3	6.42	4.58	3.20
Average	6.65 A	4.62 B	3.30 C
Coefficient of diversity = 3.94%			

Notes : similar letter indicates not significantly different

3.6 Production Per Hectare

Production per hectare is the goal of plant cultivation. According the result, the interaction between plant spacing and maize varieties did not affect the production per hectare of maize. But, for single factor, planting space affected the production per hectare (Table 7).

The result showed the planting space 75 x 20 cm was the best planting space for production per hectare (6.65 ton). The population of plant per hectare affected the plant production. Plant density was affected by planting space in a row and it affected the plant performance and production particularly light efficiency use. Generally, high production per area unit can be reached by high population due to the light use was maximum in early stage [28].

The 75 x 40 cm treatment was the lowest production among the treatments. This result was caused by the number of population was lowest among the treatments. The wide plant spacing provide the opportunity for weed to develop and the absorbed light and nutrients decreased due to the light fell down to soil surface and the nutrients lost due to evaporation and leaching [29].

The quality of grain was determined by the water content of harvesting. The best water content of grain maize is 15-17%. High water content of grain caused the grain is damaged [30]. According the description, the production per hectare of Pioneer P35 variety is 9.2 ton and water content is 15% with the yield potency is 12.1 ton. For Pertiwi 3 variety, the production per hectare is 9.64 ton and yield potency is 13.74 ton/ha [27]. The lower result than description was caused by the increasing of plant density.

4. CONCLUSION

The result showed that no interaction between planting spacing and varieties to growth and yield of maize. The best hybrid maize variety for growth and yield was Pioneer 35. The best planting space for growth and yield was 75 cm x 20 cm. The interaction between plant spacing and hybrid maize varieties did not affect the growth and yield of hybrid maize. The further research is required to study the interaction between plant spacing and maize varieties.

ACKNOWLEDGEMENTS

The authors would like to thank to all participants who supported this research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Shah TR, Prasad K, Kumar P. Maize, a potential source of human nutrition and health: A review. Journal Cogent Food and Agriculture. 2016;2(1):1-9.
2. Agustiani N, Deng N, Edreira JIR, Girsang SS, Syafruddin, Sitaresmi T, Pasuquin JMC, Agus F, Grassini P. Simulating rice and maize yield potential in the humid tropical environment of Indonesia. European Journal of Agronomy. 2018;101: 10-19.
3. Ferrianta Y, Rifiana. The role of agricultural technology in improving productivity maize: a case from Indonesia. Journal of Biology, Agriculture and Healthcare. 2014;4(1):95-101.
4. Sulaiman AA, Candradijaya A, Syakir M. Technological advancement and the economic benefit of Indonesia rain-fed farming development. Advances in Agriculture. 2019;1-8.
5. Statistics Indonesia. Maize consumption in Indonesia; 2020.
(Accessed 29 January 2020)
Available:https://www.bps.go.id/
6. Truswell AS, Brock JF. The nutritive value of maize protein for man. The American Journal of Clinical Nutrition. 1962;10(2): 142-152.
7. Hochman G, Zilberman D. Corn ethanol and US biofuel policy 10 years later: A quantitative assessment. American Journal of Agricultural Economics. 2018;100(2): 570-584.
8. Hertel TW, Golub AA, Jones AD, O'Hare M, Plevin RJ, Kammen DM. Effect of US maize ethanol on global land use and greenhouse gas emission: Estimating market-mediated responses. BioScience. 2010;60(3):223-231.
9. Fromme DD, Spivey TA, Grichar WJ. Agronomic response of corn (*Zea mays* L.) hybrid to plant populations. International Journal of Agronomy. 2019;3589768:1-8.
10. Sangoi L. Understanding plant density effects on maize growth and development: An important issue to maximize grain yield. Cienca Rural. 2000;31(1):159-168.
11. Borras L, Mazzini LNV. Maize reproductive development and kernel set under limited plant growth environments. Journal of Experimental Botany. 2018;69(13):3235-3243.
12. Varma VS, Durga KK, Keshavulu K, Sunil N. Influence of sowing period on floral characters of maize (*Zea mays* L.) during rainy and spring seasons. Agricultural Science Research Journal. 2015;5(11): 140-145.
13. Gurung DB, Bhandari B, Shrestha J, Tripathi MP. Productivity of maize (*Zea mays* L.) as affected by varieties and sowing dates. International Journal of Applied Biology. 2018;2(2):13-19.
14. Li CF, Luan LM, Yin F, Wang Q, Zhao YL. Effects of light stress at different stages on the growth and yield of different maize genotypes (*Zea mays* L.). Acta Ecologica Sinica. 2005;25(4):824-830.
15. Nannas NJ, Dawe RK. Genetic and genomic toolbox of *Zea mays*. Genetics. 2015;199(3):655-669.
16. Sarvari M, Pepo P. Effect of production factors on maize yield and yield stability. Cereal Research Communications. 2014; 1(1):1-11.
17. Gao J, Zhao B, Dong S, Liu P, Ren B, Zhang J. Response of summer maize photosynthate accumulation [and distribution to shading stress assessed by using $^{13}CO_2$ stable isotope tracer in the field. Frontiers Plant Science. 2017;8(1821):1-12.
18. Chikov VI, Abdrakhimov FA, Batasheva SN, Khamidullina LA. Characteristics of photosynthesis in maize leaves (C4 plants) upon changes in the level of illuminance and nitrate nutrition. Russian Journal of Plant Physiology. 2016;63(5):620-625.
19. Ning P, Yang L, Li C, Fritschi FB. Post-Silking carbon partitioning under nitrogen deficiency revealed sink limitation of grain yield in maize. Journal of Experimental Botany. 2018;69(7):1707-1719.
20. Strable J, Borsuk L, Nettleton D, Schnable PS, Irish EE. Microaaray analysis of vegetative phase change in maize. The Plant Journal. 2008;56(6):1045-1057.
21. Alter P, Bircheneder S, Zhou LZ, Schluter U, Gahrtz M, Sonnewald U, Dresselhaus T. Flowering time regulated genes in maize include the transcription factor ZmMADS1. Plant Physiology. 2016;172(1):389-404.
22. Sadiq G, Khan AA, Inamullah, Rab A, Fayyaz H, Naz G, Nawaz H, Ali I, Raza H, Amin J, Ali S, Khan HA, Khan AA, Khattak WA. Impact of phosphorus and potassium

levels on yield and yield components of maize. Pure App. Biology. 2017;6(3):1071-1078.
23. Sabo MU, Wailare MA, Aliyu M. Effect of variety and spacing on growth and yield of maize (*Zea mays* L.) in Bauchi State, Nigeria. International Journal of Plant Soil Science.2016;9(6):106.
24. Enaku OO, Kaankuka FG, Shaahu DT. The effect of maize cob meal (MCM) on performance and economy of feed conversion of growing rabbits. Nigerian Journal of Animal Science. 2017;19(1):1-9.
25. Probowati RA, Guritno B, Sumarni T. The effect of cover crop and spacing of weed and maize yield. Jurnal Produksi Tanaman. 2014;2(8):639-647.
26. Setyamidjaja D. Fertilizer and fertilization. Jakarta. Simpleks; 2006.
27. Ministry of Agriculture of Indonesia. Superior maize varieties description; 2020.
(Accessed 31 January 2020)
Avaiable:https://www.pertanian.go.id/
28. Greenwood EAN, Boundy CAP, Boer E, Power TR. Effect of planting time and plant spacing on maize production on the Swan Coastal Plain of Western Australia. Australian Journal of Experimental Agriculture and Animal Husbandry. 1974; 14(69):547-552.
29. Warisno.Jagung Hibrida. Yogyakarta. Kanisius; 2009.
30. Sabetha ET, Modi AT, Owoeye LG. Maize seed quality in response to different management practices and sites. Journal of Agricultural Science. 2015;7(1): 215-223.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55116