The growth and yield of hybrid maize on shaded agroecosystem

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Abstract. The development of maize in shade areas is one of the efforts to increase the national maize production.The study objective was to determine the growth and yield adaptation of hybrid maize in shaded areas. The study was conducted in the sengon forest area of Kalices Village, Patehan District, Kendal Regency from March to September 2020. The study was designed using a randomized block design with split-split plots with treatments including: a) shade density (0%, 20% and 40%) as the main plot; b) cultivation technology (PTT and existing farmers) as sub-plots; and c) varieties (JH 37, Nasa 29 and Bisi 18) as sub-plots. Each treatment was replicated 3 times in order to obtain 18 treatment combinations and each replication was planted in a plot with a size of 350 m². The parameters observed included the percentage of plants growing, plant height at harvest, age 50% male flowers, age 50% female flowers, cob height, cob length, cob weight, cob diameter, number of rows per cob, number of seeds per row, weight of dry seeds, seed moisture content, yield per plot and yield per hectare. The data were processed by analysis of variance and if there is a significant difference, it was further tested with DMRT at the 5% level. The results showed that the shading had a very significant effect on most of the yield components, namely cob length, number of seed rows per cob, wet and dry shell weight per 10 cobs, wet stubble weight per 10 plants, wet stubble weight, and dry shell weight. However, there is no significant effect on the growth components of growth power, cob circumference and cob position. The growth and yield adaptation of maize was better at 20% shade density compared to 40% shade density. On land with a shade density of 20%, the highest productivity was obtained in the Bisi 18 of 5.9 t/ha with a potential yield of 62.7%, followed by Nasa 29 of 5.8 t/ha with a potential yield of 58.41%, and JH 37 as much as 5.2 t/ha with a potential yield of 25%.

1 Introduction

Maize is an agricultural commodity that has an important role in the national economy and can be a source of foreign exchange through the export market. Maize is one of the main secondary crops in Indonesia, both as food and feed [1], and has great potential and opportunities to be utilized in the perspective of economic development, food security and

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energy security [2]. The need for maize for food, feed, and industrial raw materials continues to increase. The average need for maize for consumption in 2018 reached 23.25 million tons with a production target of 29.93 million tons, resulting in a surplus of 6.68 million tons [3]. In 2019, maize production reached 27.8, and in 2020 it increased to 28.63 million tons [4].

Efforts to increase production and productivity of maize continue to be carried out in line with the reduction of land and the advancement of location-specific maize cultivation technology innovations, for a sustainable supply of maize. Maize development is directed at dry land agroecosystems such as the use of community forest areas. Central Java is the second national maize center after East Java [5; 6]. Development of agricultural areas on dry land in Central Java covering an area of ± 955,587 ha with a maize production target in 2021 of 3.69 million tons [7].

Maize development in Central Java is mostly done on dry land. In Grobogan Regency, maize is grown on dry land at the beginning of the rainy season and the beginning of the dry season [8]. Maize farming on dry land in Wonosobo Regency is profitable and efficient [9]. The development of maize cultivation areas on dry land is predicted to increase the GRDP of the agricultural sector by 5.94% (10].

Dry land for maize development in a number of areas in Central Java is land under stands such as stands of teak, sengon, rubber, coconut, and eucalyptus. Planting maize as an intercrop among plantation crops is often done by farmers to utilize the available land, especially on immature staple crops [11]. The extent of control of the sengon forest by farmers in Central Java has the potential to expand the maize development area. The land between the sengon forest area is identical to shade stress, so it is necessary to innovate shade-stress tolerant maize technology. In exploring the potential of dry land in each region, it is necessary to select a technology package that is in accordance with site-specific conditions [12].

The main problem with maize cultivation in dry land is that water requirements are completely dependent on rainfall, variations in soil fertility, reduced soil fertility due to erosion [8], and shade stress on land under stands. Currently, there are many varieties of hybrid maize that can be used as references for farmers, but not much is known about their adaptability and production if they are developed in dry land agroecosystems under shade stress. The aim of the study was to determine the adaptation to growth and yield of hybrid maize in shaded areas.

2 Materials and method

The rescobch was conducted in the community forest land of Kalices Village, Patean District, Kendal Regency, from March to September 2020. The rescobch area used is a sengon forest area of 20,000 m² (2 ha). Prior to the rescobch, the characteristics of the rescobch location were observed.

The study was carried out using a split-split plot randomized design with shade treatment (0%, 20% and 40%) as the main plot, fertilizer (integrated crop management = PTT and farmer pattern) as subplots, and varieties (JH 37, Nasa 29 and Bisi 18 = farmer's existing hybrid maize) as sub-plots. Each treatment was repeated 3 times so that there were 18 treatment combinations. The sub-plot plots are 350 m2 in size and the distance between the sub-plots is 1.0 m.

Planting using a system without tillage (TOT) with a spacing of 75 cm x 40 cm (2 seeds/hole). After planting, the planting hole is covered with drum fertilizer. The seeds used had a germination rate of >95%. Planting was carried out one week before planting time for farmers around the research area. Plant maintenance includes: 1) weed control with herbicides and concomitant planting; 2) pest prevention and control; 3) periodic monitoring of pest and disease attacks; and 4) irrigation according to the needs and environmental conditions of the plantation. Hybrid maize cultivation techniques with PTT and farmer patterns are shown in detail in Table 1.

Table 1. Hybrid maize cultivation techniques with PTT and farmer patterns

No	Component	Cultivation Technique	
		PTT	Farmer Pattern
1	Varieties	JH 37, Nasa 29	Bisi 18
2	Seed quality	Certified	Certified
3	Seed treatment	Metalaksil (Ridomil)	-
4	Planting distance	75 cm x 40 cm	75 cm x 40 cm
5	Number of seeds per hole	2 seeds	2 seeds
6	Land cultivation	Without tillage	Without tillage
7	Chemical fertilizer	Urea 200 kg/ha and NPK 350 kg/ha	300 kg/ha and NPK 500 kg/ha
8	Chemical fertilizer application	Twice: 7-10 days after planting = DAP (1/3 Urea) and 30 DAP (2/3 Urea); pit 5-7 cm from plant	Dua kali 7-10 DAP and 30-35 DAP; pit 5-7 cm from plant
9	Organic fertilizer	Compost Petroganik	Cow dung
10	Irrigation	Watering at the beginning of growth, the vegetative phase, the flowering phase, and the cob formation phase	No irrigation schedule setting
11	Weeding	Herbicides before planting and mechanically together with soiling	Herbicides before planting and mechanically together with soiling
12	Pest control	Observation of pests on a regular basis, especially the control of pests in the vegetative phase	Pesticide

Parameters observed were the percentage of growing plants, plant height at harvest, cob height, length of the cob, circumference of the cob, weight of the cob, number of rows/cob, number of rows of seeds/cob, weight of wet shells, weight of dry shells, and weight of wet stover. Wet shelled weight and dry shelled weight were measured from 10 sample cobs from each sub-plot. The weight of wet stover was measured from 10 sample plants and the total weight of tiled plants (number of plants in an area of 2.5 m x 2.5 m). The data were analyzed using analysis of variance and if the F-count showed a significant difference, then proceed with the Duncen multiple range test (DMRT) at the 5% level [13].

3 Results and discussion

3.1 Growth performance and yield components

The results of statistical analysis of growth data and yield components showed that shade and variety treatments had a significant effect on several growth parameters and yield components, while fertilizer treatment significantly affected one yield component, namely dry shell weight. The interaction between shade treatment and fertilizer resulted in a significant difference in the number of rows of seeds/cobs, the interaction between shade treatment and varieties resulted in a significant difference in wet shell weight, the interaction between fertilizer and variety treatments resulted in a significant difference in plant height and cob circumference, and the interaction between treatments shade, fertilizer and variety resulted in significant differences in cob circumference and wet stover weight (Table 2).

Table 2. Results of analysis of variance of treatment effects and interactions between treatments on growth performance and yield components of hybrid maize.

Parameter	Shade (N)	Fertilizer (P)	Variety (V)	N x P	N x V	P x V	N x P x V
Percentage of growing plants (%)	tn	tn	**	tn	tn	tn	tn
Plant height (cm)	tn	tn	**	tn	tn	**	tn
Cob height (cm)	**	tn	tn	tn	tn	tn	tn
Circumference of the cob (cm)	tn	tn	tn	tn	tn	**	**
Length of the cob (cm)	**	tn	**	tn	tn	tn	tn
number of rows/cob	**	tn	tn	**	tn	tn	tn
Weight of wet shells (kg)	**	tn	**	tn	**	tn	tn
Weight of dry shells (kg)	**	tn	**	tn	tn	tn	tn
Weight of dry shells (t/ha)	**	**	**	tn	tn	tn	tn
Weight of wet stover (kg)	**	tn	tn	tn	tn	tn	**
Weight of wet stover tiles (kg)	**	tn	**	tn	tn	tn	tn

Description: tn = not significantly different; ** = significantly different at level = 0.05

Shade is related to the amount of light intensity. The degree of variation in light intensity is highly dependent on the surrounding canopy structure, especially within the dense canopy structure typical of mature plant stands [14]. Light directly affects plant growth and yield potential [15]. Light is directly related to the process of photosynthesis. Light distribution is an important factor affecting maize photosynthesis [16]. The results of rescobch by [17], showed that light intensity had an effect on plant height, number of leaves, leaf width-length ratio, plant dry weight and root-tooth ratio of maize plants. Several maize varieties grown under the shade of oil palm aged 12 ycobs showed significant differences in plant height, amount of chlorophyll a and b, number of leaves, leaf length, leaf area, segment length, weight of cob without skin, dry cob weight, and seed weight. dry per hectare [18]. Coconut tree shade also significantly affected plant height, number of rows per cob, weight of 1000 seeds, and production per hectare of composite and hybrid maize [19].

The results of the study by [20] showed that variety had a significant effect on plant height, leaf area, root fresh weight, cob weight, cob weight, but had no effect on cob diameter and shoot fresh weight. The best interaction between varieties and biological fertilizers is shown in the yield component of cob weight without maize husks [21]. Plant height, number of cobs, and length of maize cobs were significantly affected by N fertilizer treatment and plant population density [22]. Rescobch by [23] also showed that the interaction between varieties and N fertilizer significantly affected the number of seeds per cob, weight of 1000 seeds and weight of seeds per ha.

3.2 The effect of shade on the weight of the maize stove

The results showed that the interaction between shade and variety had a significant effect on the fresh weight of maize plants. Table 3 shows that there is consistency in the weight of each variety. The higher the percentage of shade, the lower the weight of the pods for both the PTT pattern and the farmers. The difference is seen in the highest achievement of wet weight in each shade level. The highest weight of wet pods in open land was obtained on the Nasa 29 variety with farmer-pattern fertilization. In the 20% shade treatment, the highest weight of wet pods was obtained in Bisi 18 variety with farmer pattern fertilization. In the 40% shade treatment, the highest weight of wet pods was obtained in the Nasa 29 variety with PTT fertilization. Meanwhile, the lowest bean weight was consistently obtained in the JH 37 variety with PTT fertilization.

Table 3. The average tile weight of three varieties of hybrid maize in three shade treatments and two fertilizations.

Shade	Fertilizer	Variety		
		JH 37	Nasa 29	Bisi 18
0%	PTT	7.5bcde	8.9abcd	11.4ba
	Farmer Pattern	7.7bcde	12.8a	10.2abc
20%	PTT	5.1cde	7.0bcd	5.4cde
	Farmer Pattern	5.5cde	6.4cde	8.1abcde
40%	PTT	3.2^{e}	5.4cde	4.1ed
	Farmer Pattern	4.0ed	3.3e	3.9ed

Note: The numbers followed by different letters mean that they are significantly different at the DMRT test level of 0.05

The difference in the wet weight gain that varies between varieties is thought to be due to differences in the genetic expression of each variety under different shade stresses and different nutrient availability conditions. The yield of wet bean pods is influenced by the interaction of the growing environment, application of fertilizers and varieties. Space weight is used to determine the assimilation of photosynthate produced by a plant. [24] stated that the height and weight of fresh bean curd is determined by the rate of photosynthesis which is the accumulation of photosynthate during growth.

3.3 The effect of shade on the weight of dry pillars and weights

Table 4 shows that the higher the shade density, both with PTT fertilization and farmer patterns, the lower the yield. Based on the results obtained, it can be seen that there is a consistency in the highest and lowest yields of each variety in the treatment of farmer patterns, namely Bisi 18 and JH 37. While in the PTT fertilization treatment, the highest yields were in 0% shade (open land) and 20% shade (medium). obtained in the Bisi 18 variety and the lowest was in the JH 37 variety, while in the shade 40% (weight) the highest yield was obtained in the Nasa 29 variety and the lowest was in the JH 37 variety. Based on the average yield, that in the 40% shade there was a decrease in yield ranging from 38, 5-63.5% (3.7-6.1 t/ha dry shelled seeds).

Table 4. The average weight of dry shelled seeds of three hybrid maize varieties in three shade treatments and cultivation techniques.

Shade	Fertilizer	Variety		
		JH 37	Nasa 29	Bisi 18
0%	PTT	6.5bc	8.7ba	9.6a
	Farmer Pattern	6.3bc	8.5ba	8.6ba
20%	PTT	5.2cde	5.3cde	5.9de
	Farmer Pattern	3.4^{e}	5.8de	5.3cde
40%	PTT	3.1^{e}	3.9de	3.5de
	Farmer Pattern	2.9^{e}	3.2e	3.4^{e}

Note: The numbers followed by different letters mean that they are significantly different at the 0.05 DMRT test level

The dry shell yield of Bisi 18 variety in open land with a dose of PTT fertilizer was 9.6 t/ha, exceeding the average yield in the variety description, which was 9.1 t/ha. Meanwhile, the dry shell yield of the Nasa 29 and JH 37 varieties was still below the average yield in the variety description, which were 11.9 t/ha and 10.7 t/ha, respectively. The dry shell yield of the three varieties was seen to be lower on land with denser shade. In the Nasa 29 variety there was a decrease in dry shelled yield of 39-55.1% (3.4-4.8 t/ha), and in the JH 37 variety there was a decrease in yield of 20-52.3% (1.3-3.4 t/ha). However, the yield of the three varieties was still higher than the results of [25] study, that maize planted under coconut stands with 55.8% light intensity produced 1.7 t/ha and maize planted in the open produced 2 ,8 t/ha. The yield of dry shelled C3 hybrid maize planted under deep coconut with 35.1% irradiation for three consecutive ycobs was 1.2 t/ha in the first ycob, 0.8 t/ha in the second ycob, and in the third ycob of 2.6 t/ha [26].

Observations showed that the yield on open land was higher than that obtained from shaded land. Sengon plants that are more than 2 ycobs old already have a canopy that has begun to close and reduces the light that reaches the land surface by about 40-50%. Maize plants grown under 50% shade will experience a yield reduction of up to 60% [27; 28]. When compared between dry shelled yields on open land and 20% shaded land with PTT fertilization, the highest yield difference was obtained by Bisi 18 variety of 4.3 t/ha with a potential yield of 44.8%, followed by Nasa 29 variety of 3.4 t/ha with a yield potential of 39.1% and the JH 37 variety 3.1 t/ha with a yield potential of 47.7%. This difference indicates an increase in yield with the interaction between shade level and variety. Utilization of intercropped land under sengon stands should only be carried out until sengon plants are 2-2.5 ycobs old with a plant population of 60% from monoculture systems [29].

4 Conclusion

The shading had a very significant effect on most of the yield components, namely cob length, number of seed rows per cob, wet and dry shell weight per 10 cobs, wet stubble weight per 10 plants, wet stubble weight, and dry shell weight. However, there is no significant effect on the growth components of growth power, cob circumference and cob position. The growth and yield adaptation of maize was better at 20% shade density compared to 40% shade density. On land with a shade density of 20%, the highest productivity was achieved by the Bisi 18 variety with a yield potential of 5.9 t/ha with a potential yield of 62.7%, followed by Nasa 29 with a potential yield of 5.8 t/ha. 58.41%, and JH 37 as much as 5.2 t/ha dry shelled with a potential yield opportunity of 25%.

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