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EVALUATION ON FOXTAIL MILLET (*Setaria italica* L.) RESPONSES TO DIFFERENT LIGHT INTENSITIES AND FERTILIZATIONS

[*Evaluasi Respon Jewawut (Setaria italica L.) Terhadap Perbedaan Intensitas Cahaya dan Pemupukan]*

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ABSTRACT

Foxtail millet is a high nutritional minor crop that has high potency cereal potentially for food diversification. The cultivation expected can be expanded to other marginal areas, such as shading areas in the garden or yard. The research aimed to study the response of foxtail millet growth and production at various shading intensities and fertilization. The experimental design was an RCBD with two factors. The first factor was shading intensity (0. 25, 50, and 75%), while the second was NPK fertilization (0, 2, and 4 g/pot). The variable observed were vegetative phased, generative, chlorophyll content (CC), and leaf area ratio (LAR). The results showed that shading intensity significantly affected all variables observed. The highest plant growth and production achieved at 0% shading intensity (total panicle dry weight 12.31g/plant). The highest both of CC (3.25 SPAD) and LAR were on 75% shading (263.17). Fertilization has no significant effect on growth and production. There was an interaction between shading treatment and fertilization on chlorophyll b content, and the highest was on the combination of 50% shading and 2g/pot (1.04 mg/g) fertilization. The optimum growth and production were achieved at 0% shade. The total panicle dry weight decreased with increasing shade, but at 25% shade, the percentage decreased < 50% (44.27%). It is expected that foxtail millet can be cultivated in areas up to 25% shading intensity.

Key words: respons, foxtail millet, shading, fertilization

ABSTRAK

Jewawut adalah serealia minor lokal bergizi tinggi yang potensial untuk diversifikasi pangan. Budidayanya diharapkan dapat diperluas ke daerah marginal lainnya misalnya area yang kurang cahaya di kebun atau pekarangan. Penelitian dilakukan untuk mempelajari respon pertumbuhan dan produksi jewawut pada berbagai intensitas naungan dan pemupukan. Rancangan yang digunakan adalah Rancangan Acak Kelompok dengan dua faktor. Faktor pertama adalah naungan (0, 25, 50 dan 75%), sedangkan faktor ke dua adalah pemupukan NPK (16-16-16) yakni 0, 2 dan 4 g/pot. Peubah yang diamati meliputi pertumbuhan vegetatif, generatif, kandungan klorofil, dan ratio luas daun. Hasil penelitian menunjukkan bahwa naungan berpengaruh nyata terhadap semua peubah yang diamati. Pertumbuhan dan produksi tanaman tertinggi dicapai pada naungan 0% (berat kering malai total 12,31g/tanaman). Kandungan klorofil total tertinggi (3,25 SPAD) dan rasio luas daun dicapai pada naungan 75% (263,17). Pemupukan tidak berpengaruh nyata terhadap pertumbuhan dan produksi jewawut. Terdapat interaksi antara perlakuan naungan dan pemupukan terhadap kandungan klorofil b, nilai tertinggi pada kombinasi perlakuan naungan 50% dan pemupukan 2g/pot (1.04 mg/g). Pertumbuhan dan produksi optimum jewawut tercapai pada naungan 0%. Bobot kering malai total menurun dengan meningkatnya naungan, akan tetapi pada naungan 25% persentase penurunan < 50% (44,27%). Dengan demikian jewawut dapat dibudidayakan pada area hingga intensitas naungan 25%.

Kata kunci: respon, jewawut, naungan, pemupukan

INTRODUCTION

Foxtail millet (*Setaria italica* (L.) P. Beauv.) is one of Indonesian biodiversity potentially to be developed for food diversification. Some Indonesian vernacular names of foxtail millet are juwawut (Central Java), kunyit (Tasik, West Java), tarreang (Polewali Mandar, West Sulawesi), hotong (Buru, Maluku), pokem (Numfor, Papua), witi (Bima), ba'tang (Enrekang, South Sulawesi) and sekoi (Bengkulu). Nowadays, foxtail millet is generally used for bird feeding. Foxtail millet content high nutritional value. Millet is one of the most digestive and non-allergenic grains (Kamatar *et al.,* 2015). Like other grains (millet), Foxtail millet contains high nutrients compared to wheat, corn, and rice, high protein and antioxidant content, and a low glycemic index value suitable for people with diabetes (Himanshu *et al.,* 2018). In rural India, foxtail millet is consumed as a nutritional source for pregnant and lactating mothers and sick people, and children (Hariprasana, 2016). In Indonesia, local people consume foxtail millet grain as porridge and many traditional cakes. (Juhaeti, 2020) showed that foxtail millet flour could be used for modern culinary bread, cookies, and cakes. The utilization of millet as an ingredient in creating many cookies is expected can be reduced dependency on wheat flour. Affordable prices must accompany the increase in foxtail consumption. So, foxtail millet cultivation should be expanded. The cultivation is suggested to occupy marginal areas, such as shading on young plantations. The potential

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of shading area under young plantations on private/ state plantations is quite enormous, reaching 12.1 million ha. Every year around 3–4% of the plantation area is a new plant (replanting) that can develop intercropped plants until the plantation is 3 years old (Sopandie and Trikoesoemaningtyas, 2011). Generally, plant growth and production decrease when cultivated in a low light intensity environment. In the intercropping cultivation of maize on young rubber plantations, corn production decreased as rubber stands aged. The canopy of older rubber stands became close to each other, decreasing light intensity below the rubber stand, reaching 60% (Sahuri, 2017). Both light quantity (incident radiation) and light quality (light spectrum) are important determinants of plant yield (Sankalpi *et al.,* 2014). Foxtail millet is a C4 plant as well sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), proso millet (*Panicum miliaceum*), finger millet (*Eluasine coracana*), and amaranth (Rowan *et al.,* 2011). The leaf characteristics of C4 crops usually have higher radiation, water, and nitrogen use efficiencies than the C3 species (Zehong *et al.,* 2015). (Nerea *et al.,* 2013) showed that species C4 (*Zea mays*, *Miscanthus x giganteus*, and *Flaveria bidentis* can optimize photosynthesis over a range of PARs, including low light. The information about cultivating foxtail millet plants as intercrops planted between stands is rare. This research was carried out by the ex-situ method. Foxtail millet planted under artificial shade by a plastic shading net with various light intensity levels. The 25% shading net is equivalent to the light intensity under the 2-year-old rubber stand, while the 50% shading net is equivalent to the light intensity under the 3-year-old rubber stand, and for the 4-year-old rubber, the stand has exceeded 75% shading intensity (Chozin *et al.,* 2000). Intercropping cultivation also caused nutrient competition. Fertilization applications must be made optimally to achieve better plant growth and production. In India, generally, fertilizer recommendations to produce a good foxtail millet production are 40 kg nitrogen, 20 kg P2O5, and 20 kg K2O per hectare (Chapke *et al.,* 2018). Few studies have considered the effect of shading on plant responses to soil fertilization, although a few studies have described how soil fertilization affected plant competition for light. The results suggest that shade reduced the benefit of N to the plants (Harbur, 2003). Other research showed that the N sensitivity of field horsetail (*Equisetum arvense* L.) was less in shaded plants than unshaded plants (Andersen and Lundegardh, 1999). Our research aimed to study the growth and production of foxtail millet cultivated under different light intensities and fertilizations.

MATERIALS AND METHODS

Field experiment

The research was carried out in Research Center for Biology, Indonesian Institutes of Sciences, Cibinong, West Java. The foxtail millet seeds were collected from Gambirmanis Central Java. The foxtail millet seeds were germinated on planting media on the mixture of sand : soil: compost = 1: 1: 1 v/v. Four weeks after germination, the seedlings are then planted to a plastic pot with 40 cm height, 30 cm width containing planting media consisting of soil: compost: manure = 2: 1: 1 v/v. The seedlings were acclimatized for one week to reach constant growth. The uniform seedlings were used for the experiment (Table 2). Each pot for every experiment unit contains one seedling. Fertilization treatment was applied twice. First fertilization (1/2 doses) was applied five weeks after germination, and the second fertilization was applied one month later. The treatments were arranged in Randomized Complete Block Design (RCBD) with two factors and three replications, each replication consisting of 3 plants observed. The first factor was shading intensities (Sh) with the level of Sh 0%, Sh 25%, Sh 50%, and Sh 75%; and the second factor was fertilization treatment by applying NPK (16-16-16) fertilizer (Fr) with the level of Fr 0g, Fr 2g and Fr 4g per pot. The doses of 2g NPK/pot were equal to 125 kg NPK/ha, and 4 g/pot was equal to 250kg NPK/ha.

The artificial shading of 25%, 50%, and 75% light intensity was adjusted using a shading net in the form of net-house with 5 m x 5m x 3m. Microclimate conditions inside the net-house were recorded during the crop growth cycle. The microclimate data showed that the increase of shading intensity causes a decrease in temperature and light intensity (Table 1).

Table 1. Microclimate condition at the study site during the foxtail millet growing period (*Kondisi lingkungan mikro saat pertumbuhan jewawut*).

Shading intensity (*Intensitas naungan*) (%)	**Temperature (*Suhu*) (^{0}C)**	**Air Humidity (*Kelembaban udara*) (%)**	**Light intensity (*Intensitas cahaya)* (Lux)**
0	34.5	49.5	602.0
25	34.5	50.0	374.5
50	33.5	52.0	303.0
75	32.5	53.0	189.5

Table 2. Uniformity of seedlings before treatments (*Keseragaman bibit sebelum perlakuan*).

NPK Fertilizer Treatments (*Perlakuan pemupukan NPK*) (g/pot)	**Plant height (cm) (*Tinngi tanaman) (cm)***			
	0% Shading (*Naungan 0%)*	**25% Shading (*Naungan 25%*)**	**50% Shading (*Naungan 50%*)**	**75% Shading (*Naungan 75%*)**
0	27.33	28.00	28.00	28.33
2	28.67	28.00	28.00	28,33
4	29.00	27.67	29.33	28.66

Note: The ANOVA test showed uniformity of seedlings.
(Keterangan: Hasil test ANOVA menunjukkan keseragaman bibit).

Data collection and analysis

The parameters observed were vegetative growth (plant height, stem diameter, the length of longest leaf, the length of flag leaf, root and shoot fresh and dry weight), generative phase (fresh and dry weight of panicle, peduncle and panicle length, and 100 seed dry weight), chlorophyll content (Arnon, 1949), and leaf area ratio. The grain harvesting was done when 90% of panicles were maturely indicated by panicle becoming dry and brownish ten weeks after planting (WAP). The Thermo-hygrometer measured the temperature and humidity, while Lux-meter measured light intensity. Observation of temperature, humidity, and light intensity was conducted three times a day between 09.00, 12.00, and 15.00 am. Measurement of Specific Leaf Areas was done using a Scanner to obtain leaf image softcopy then analyzed using Image J software. Leaf samples were dried using an oven and weighed for dry weight. Specific leaf area is calculated using a formula (Ningrum, 2011). Specific Leaf Area = Leaf area (cm)/leaf dry weight (g). The data obtained from the experiments were analyzed using SPSS 16 software with a two-way analysis of variance (ANOVA) with a 5 % confidence level. If there is a significant effect between treatments, further testing is done using the DMRT test at the level of 5 %.

Results

Interaction effect of treatments

Statistical analysis of the effects of shading and fertilization treatments on plant growth and production showed no interaction between shading and fertilization treatment on almost all the parameters observed, except on chlorophyll b content (Table 3). Shading intensity treatments as a single factor were significantly affected all of the parameters. Meanwhile, fertilization dosages as a single factor did not significantly affect plant growth and production except on stem diameter, most extended leaf size, and the fresh weight of the main panicle.

Table 3. An Analysis of Variance (ANOVA) results on foxtail millet plant growth and production (*Hasil analisis ragam pertumbuhan dan produksi jewawut*).

No. (*No*)	**Parameter (*Peubah*)**	**Unit (*Satuan*)**	**Weeks after planting (WAP) (*Minggu setelah tanam*) (*MST*)**	**Effect of shading (*Pengaruh naungan*)**	**Effect of fertilization (*Pemgaruh pemupukan*)**	**Interaction effect (*Pengaruh interaksi*)**
1.	Plant height (*Tinggi tanaman)*	cm	5	4.45**	2.65ns	0.73ns
2.	Stem diameter (*Diameter batang*)	cm	5	17.37**	3.30*	1.40ns
3.	Longest leaf size (*Ukuran daun terpanjang*)	cm	5	13.81**	3.21*	0.66ns
4.	Length of flag leaf (*Panjang daun bendera*)	cm	7	7.06**	0.96ns	0.80ns
5.	Chlorophyll a content (*Kandungan klorofil a*)	mg/g	4	14.77**	1.18ns	1.04ns
6.	Chlorophyll b content (*Kandungan klorofil b*)	mg/g	4	5.55**	3.60ns	3.85**
7.	Total Chlorophyll (*Total klorofil*)	mg/g	4	12.62**	1.15ns	0.76ns
8.	Spesific leaf area (*Luas area specific*)	cm^2/g	5	17.54**	0.81ns	0.88ns
9.	Root fresh weight (*Bobot basah akar*)	g	10	12.11**	1.06ns	0.94ns
10.	Shoot fresh weight (*Bobot basah tajuk*)	g	10	38.81**	3.08ns	0.85ns
11.	Root dry weight (*bobot kering akar*)	g	10	30.19**	0.02ns	0.52ns
12.	Shoot dry weight (*Bobot kering tajuk*)	g	10	51.02**	1.98ns	0.45ns
13.	Main panicle fresh weight (*Bobot basah malai utama*)	g	10	56.84**	3.25*	0.55ns
14.	Total panicle fresh weight (*Bobot basah total malai*)	g	10	52.52**	3.03ns	0.55ns
15.	Main panicle dry weight (*Bobot kering malai utama*)	g	10	22.97**	1.26ns	0.57ns
16.	Total panicle dry weight (*Bobot kering total malai*)	g	10	29.28**	1.84ns	0.55ns
17.	100 seeds weight (*bobot 100 butir biji*)	g	10	2.77**	2.04ns	1.91ns
18.	The length of main peduncle (*Panjang tangkai malai utama*)	cm	10	3.31**	0.99ns	0.94ns
19.	The length of the main panicle (*Panjang malai utama*)	cm	10	11.93**	2.14ns	0.54ns

Noted: * = significant, **= very significant, ns= non significant. (*Ket.: * = beda nyata, **= beda sangat nyata, ns= tidak berbeda nyata*).

The interaction between shade and fertilization has only occurred on chlorophyll b content. The highest value of chlorophyll b content (1.04 mg /g) was obtained at 50% shade combined with 2 g fertilizer dose (Sh50Fr2), and it is not significantly different with Sh75Fr0, Sh75Fr2, Sh75Fr4, Sh25Fr2, and Sh50Fr4 (Table 4).

Table 4. The Duncan Multiple Range Test (DMRT) on chlorophyll b content (*Hasil analisa Duncan terhadap kandungan klorofil b*).

Shading intensity (*Intensitas naungan*) (%)	**NPK Fertilization (*Pemupukan NPK*) (g /pot)**		
	0	**2**	**4**
0	0.46 abc	0.16 a	1.01 c
25	0.27 ab	0.75 bcde	0.49 abcd
50	0.42 ab	1.04 e	0.71 bcde
75	0.94 cde	0.96 de	0.96 de

Note : The value followed by the same letter is not significantly different on the 5% DMRT test.
(*Ket.: Angka yang diikuti huruf yang sama menunjukkan tidak berbeda nyata pada uji Duncan 5%*).

Effect of shading intensity

The present research showed that shading intensity significantly affected all vegetative growth parameters of foxtail millet. The highest value for plant height, stem diameter, longest leaf, and flag leaf length was achieved on 0% shading intensity, significantly different from others. There were no significant differences between 25, 50, and 75% treatment on plant height. On the leaf size parameter, the result showed that the longest leaf was achieved on 0% shading, that not significantly different with 25 and 50% shading. On the other hand, stem diameter was significantly decreased up to 28 % under low light intensity (Table 5).

This study also observed that foxtail millet responded to lack of light intensity conditions by increasing specific leaf area. Specific leaf area measurements were carried out five weeks after planting (WAP). The result showed that light intensity significantly affected the specific leaf area value. The highest specific leaf area value was obtained on 75% shade treatment. The growth of foxtail millet at shade conditions showed a higher specific leaf area value than those on the full sun (Table 5).

Table 5. The effect of shading treatments on foxtail millet growth and production (*Pengaruh naungan terhadap pertumbuhan dan produksi jewawut*).

No. (*No.*)	**Parameter (*Peubah*)**	**Unit (*Satuan*)**	**Weeks After Planting (WAP) (*Minggu setelah tanam*)(*MST*)**	**Shading intensity (*Intensitas cahaya*) (%)**			
				0	**25**	**50**	**75**
			Vegetative Growth *(Pertumbuhan vegetatif)*				
1	Plant height (*Tinggi tanaman*)	cm	5	121.54b	105.71a	114.24a	105.14a
2	Stem diameter (*Diameter batang*)	cm	5	0.64c	0.53b	0.55b	0.46a
3	The longest leaf size (*Ukuran daun terpanjang*)	cm	5	45.03c	41.37ab	42.82b	40.43a
4	The length of flag leaf (P*anjang daun bendera*)	cm	7	37.12b	34.31b	36.89b	30.06a

Continued Table 5…………

No. **(*No.*)**	**Parameter** **(*Peubah*)**	**Unit** **(*Satuan*)**	**Weeks After Planting (WAP) (*Minggu setelah tanam*)(*MST*)**	**Shading intensity (*Intensitas cahaya*) (%)**			
				0	**25**	**50**	**75**
	Vegetative Growth						
5	Chlorophyll a content (*Kandungan klorofil a*)	mg/g	4	0.67a	1.18a	1.87b	2.29b
6	Chlorophyll b content (*Kandungan klorofil b)*	mg/g	4	0.54a	0.50a	0.72a	0.95b
7	Chlorophyll total content (*Kandungan klorofil total*)	mg/g	4	1.21a	1.75a	2.55b	3.25b
8	Spesific leaf area (*Luas area daun spesifik*)	cm^2/g	5	149.77a	224.51b	194.64b	263.17c
	Biomass at Harvesting time (*Biomasa saat panen*)						
9	Root fresh weight (*Bobot basah akar*)	g	10	5.90c	1.57b	2.83b	0.88a
10	Shoot fresh weight (*Bobot basah tajuk)*	g	10	22.54c	11.58b	9.62ab	5.36a
11	Root dry weight (*Bobot kering akar*)	g	10	2.87b	0.92a	0.75a	0.59a
12	Shoot dry weight (*Bobot kering tajuk*)	g	10	12.75c	5.64b	4.21b	2.29a
	Plant Production (*Produksi tanaman*)						
13	Main panicle fresh weight (*Bobot basah malai utama*)	g	10	14.40c	8.38b (41.81)	7.21b (49.93)	4.36a (69.72)
14	Total panicle fresh weight (*Bobot basah malai total)*	g	10	18.40c	10.26b (44.24)	8.84b (51.96)	4.63a (74.84)
15	Main panicle dry weight (*bobot kering malai utama*)	g	10	9.37c	5.43b (42.05)	4.75b (49.31)	2.64a (71.82)
16	Total panicle dry weight (*bobot kering malai total*)	g	10	12.31c	6.86b (44.27)	5.81b (52.80)	2.79a (77.35)
17	Length of main peduncle (*Panjang tangkai malai utama*)	cm	10	16.24b	13.98ab (13.92)	15.17b (6.58)	11.33a (30.23)
18	Length of main panicle (*Panjang malai utama*)	cm	10	22.22c	18.54b (16.56)	16.33ab (26.50)	13.50a (71.36)

Note: The same alphabet on the same line indicated no significant difference on 5% DMRT Test. The parentheses showed a comparison value to 0% shading intensity treatment.

(*Keterangan*: *Huruf yang sama pada baris yang sama menunjukkan tidak beda nyata pada uji Duncan 5%. Angka dalam kurung menunjukkan nilai relatif terhadap perlakuan intensitas naungan 0%).*

Effect of fertilization

In the present study, fertilization treatment with the doses of 0g, 2g and 4g per pot, which are equivalent to 125 kg NPK/ha and 4 g/pot was equal to 250kg NPK/ha, did not seem to significantly affect plant growth and production, except for stem diameter parameters, the longest leaf size and main panicle fresh weight (Table 3, Table 6). The 2 g/pot fertilizer dosage treatment produced the highest value for the biggest stem diameter and leaf size parameter.

Table 6. The effect of fertilization on foxtail millet growth and production (*Pengaruh pemupukan terhadap pertumbuhan dan produksi jewawut*).

No. (*No*)	**Parameter (*Peubah*)**	**Unit (*Satuan*)**	**Weeks After Planting (WAP) (*Minggu setelah tanam*) (*MST*)**	**Fertilization (*Pemupukan*) (g/pot)**		
				0	**2**	**4**
1.	Plant height (*Tinggi tanaman*)	cm	5	106.9	156.3	110.8
2.	Stem diameter (*Diameter batang*)	cm	5	0.52a	0.57b	0.54ab
3.	The longest leaf size (*Ukuran daun terpanjang*)	cm	5	41.94a	43.38b	41.92a
4.	The length of flag leaf (*Panjang* d*aun bendera*)	cm	7	35.4	37.1	35.7
5.	Chlorophyll a content (*Kandungan klorofil a*)	mg/g	4	1.56	1.3	1.64
6.	Chlorophyll b content (*Kandungan klorofil b*)	mg/g	4	0.52	0.72	0.79
7.	Chlorophyll total content (*Kandungan klorofil total*)	mg/g	4	2.16	1.97	2.43
8.	Spesific leaf area(*Luas area daun spesifik*)	cm^2/g	5	208.84	198.98	216.48
9.	Root fresh weight (*Bobot basah akar*)	g	10	2.29	3.41	2.67
10.	Shoot fresh weight (*Bobot basah tajuk*)	g	10	10.22	13.4	13.15
11.	Root dry weight (*Bobot kering akar*)	g	10	1.29	1.25	1.30
12.	Shoot dry weight (*Bobot kering tajuk*)	g	10	5.33	6.82	6.61
13.	Main panicle fresh weight (*Bobot basah malai utama*)	g	10	**9.16a**	9.02a	7.58b
14.	Main panicle dry weight (*Bobot kering malai utama*)	g	10	5.62	**6.07**	4.94
15.	Total panicle dry weight (Bobot kering malai total)	g	10	6.74	**7.85**	6.13
16.	100 seeds weight (*Bobot 100 butir biji*)	g	10	0.12	**0.13**	0.13
17.	Length of main peduncle (*Panjang tangkai malai utama*)	cm	10	13.07	**15.01**	14.45
18.	Length of main panicle (*Panjang malai utama*)	cm	10	16.64	**19.18**	17.12

Note: The same alphabet on the same line indicated non-difference on 5% Duncan Test.
(Keterangan: Huruf yang sama pada baris yang sama menunjukkan tidak beda nyata pada uji Duncan 5%).

There was an indication of increasing values in most millet growth variables observed on the highest level of fertilizer applied (4g), compared to control (Table 6); however, the differences were not significant except on the value of stem diameter and the longest leaf size.

DISCUSSION

It seems that fertilization up to 2g NPK/pot resulted in a positive increase of chlorophyll b content on foxtail millet which is planted under low light intensity. The chlorophyll b content in the treatment of low light intensity (shading 25%, 50%, and 75%) combined with no fertilization treatment showed a lower value of chlorophyll b content (Table 4). This is consistent with (Ridwan *et al.,* 2018) that reported that foxtail millet planted on low light intensity showed increasing chlorophyll b content. The increased chlorophyll b content will positively affect photosynthesis since it is known that chlorophyll b is a light-capturing pigment (Ridwan *et al.,* 2018). Based on the results of this study, it is suggested to continue the research with other aspects of fertilization such as improved fertilization dosages, the time of application, and the variety of fertilizers such as urea, TSP, KCl, or ZA to optimize millet growth and production under low light intensity. The research showed that shading intensity significantly affected foxtail millet growth and production. Light in terms of solar radiation is an essential requirement for the photosynthesis process; meanwhile, shading reduces the light intensity, which leads to changes in morphology, physiology, biomass, grain yield, and quality of crops. Shading stress could also delay flowering and decreases biomass and grain yield. Reduced light is known to limit carbon accumulation and nitrogen content (Parande *et al.,* 2019). The result also showed that light intensity was significantly affected chlorophyll content. The content of chlorophyll a, chlorophyll b, and total chlorophyll were increasing, and the increasing of shade intensity (Table 5). The phenomena of increasing chlorophyll b content were an adaptation mechanism of foxtail millet to maximize light absorption under low light intensity conditions. The plant leaves will use more energy to produce light-harvesting pigments when light intensity is limited (Salisbury and Ross, 1995). The results of this study are similar to (Pradnyawan *et al.,* 2004), which showed that the chlorophyll content was most significant when the conditions of light intensity were 30%; meanwhile, the lowest content was under conditions of normal light intensity (100%). Similarly, soybean plants cultivated at 50% light intensity produced higher leaf chlorophyll than those planted under full light intensity (Muhuria et al., 2006). The shading condition resulted in a significant effect on leaf chlorophyll content in terms of an increase in chlorophyll a and b (Muhidin *et al.,* 2019).

Chen *et al*. (2004) stated that in response to light exposure, plants utilize several photoreceptors to modulate growth and development, including ultraviolet B (UV-B), blue/ultraviolet A (B/UV-A), and red/far-red (F/FR) receptors; meanwhile, plant growth in vegetative shading, photoreceptors regulate shade-induced changes in growth and development as reported that the leaf chlorophyll contents of velvetleaf (*Abutilon theophrasti* Medik.) and common cocklebur *(Xanthium strumarium L.)* increased with shading (Regnier *et al*., 1988). Shading also increased the leaf area ratios and heights of common lambsquarters (*Chenopodium album* L.) and velvetleaf (Stoller and Myers, 1989). Low light penetration on the canopy reduced photosynthesis and plant yield (Nandini and Sridhara, 2019). The plant biomass weight in the shade condition was lower due to decreasing photosynthesis rates (Table 5). The high energy cost and low plasticity of C4 photosynthesis compared with C3 photosynthesis may limit the productivity and distribution of C4 plants in low light (LL) environments (Balasaheb *et al.,* 2018). The shading tolerant plant will respond to the condition of low light intensity by increasing the specific leaf area (Lambers *et al.,* 2008). Biomass accumulation is dependent on the radiation use efficiency and light interception (Sankalpi *et al.,* 2014). The research showed that the effect of fertilization treatments was not significantly different to improve foxtail millet growth and production under shading conditions. The growth and production of foxtail millet decreased in shading conditions. The optimum vegetative and generative performances were achieved on 0% shading condition. However, foxtail millet is still tolerant of cultivating up to 25% shading due to the total panicle dry weight decreasing less than 50% (44.27%) on 25% shading intensity to 50% light intensity. The plant promoted an adaptation mechanism to shading conditions by increasing the chlorophyll b content and specific leaf area. NPK application dosages in this research could not support plant growth and production on low light intensity treatment. The low light intensity as an effect of shading intensity was dominant in decreasing plant growth and production.

The increase in shading levels from 0% to 75% resulted in a decrease in plant growth, and it appears on the decreasing of the fresh and dry weight of shoot and root (Table 5). The shading causes a reduction of the light intensity required for photosynthesis, resulting in a decrease in assimilation products (Lambers and Poorter, 1992) and finally decreasing plant biomass dry weight (Ginting *et al.,* 2015). The shade on upland rice varieties decreases the number of tillers, number of panicles, number of productive grains, grain production per hill of upland rice plants, and total sugar content of upland rice plants (Ginting *et al.,* 2015). The shading condition also significantly affected all crop production variables due to decreasing assimilation rates. Under normal conditions, plants will allocate energy and nutrient for plant growth and production. However, under shading stress conditions, the plant will use much more energy and nutrients to survive (Ginting *et al.,* 2015). (Yuan *et al.,* 2016) showed that on foxtail millet, the fresh grain mass per panicle, yield, photosynthetic pigment contents, net photosynthetic rate, stomatal conductance, effective quantum yield of PSII photochemistry, and electron transport rate decreased with the increase of shading intensity, whereas the intercellular CO_2 concentration increased. Futhermore (Yuan *et al.,* 2016) also stated that shading changed a double-peak diurnal variation of photosynthesis to a one-peak curve; so the lower yield of foxtail millet was caused mainly by a reduction of grain mass assimilated, a decline in chlorophyll content, and the low photosynthetic rate due to low light during the grain-filling stage. Reduced light energy absorption and conversion, restricted electron transfer, and reduced stomatal conductance might cause a decrease in photosynthesis. In general, metabolism on foxtail millet was significantly affected by shading conditions.

The plant growth and production were decreased. The optimum vegetative and generative performances were on 0% shading condition. Meanwhile, the panicle dry weight decreased less than 50% (44.27%) on 25% shading intensity (Table 5). It is expected that cultivation of foxtail millet can be done until 25% shading intensity. It seems that foxtail millet does not require large amounts of fertilizer for its growth (Prasch and Sonnewald, 2015). The longest leaf and the biggest stem diameter were treated with 2 g NPK fertilizer/ pot. Fertilization with a dose of 4g/pot decreases plant growth and production; presumably, it is an excessive dose. Excessive fertilization can disturb an osmosis process, disrupting plant physiological processes resulting in non-optimal plant growth (Satria *et al.,* 2015). Meanwhile, other research showed that urea fertilization tends to better affect the growth and production of foxtail millet and adlay (*Coix lacryma-jobi* L.) compared to ZA fertilizer (Juhaeti, 2017). (Parande *et al.,* 2019) showed that nitrogen had a significant effect on days to panicle emergence, days to maturity, grain filling period, and grain yield; the application of 150 kg nitrogen per hectare improved phenological traits and grain yield of millet. (Parande *et al.,* 2019) also stated that the grain yield of foxtail millet reduced by 61 percent with increasing shading intensity contrasting with no shading. This reduction was due to the negative effects of shading on the number of grains per panicle and 1000-grain weight.

Harvest index also decreased with increasing shading levels. The reduction in harvest index was due to a greater grain yield contrasting dry matter production at shading treatments. In terms of morphological responses, the results of this study agree that leaves growing under low light intensity are generally thin and wide as a mechanism of a plant; as a response to maximizing light absorption, the leaves become wider and thinner. (Onwueme and Johnston, 2008) stated that on tannia (*Xanthosoma sagittifolium*), sweet potato (*Ipomoea batatas*), yam (*Dioscorea esculenta*), cassava (*Manihot esculenta*), and taro (*Colocasia esculenta*), shading generally resulted in the production of larger (in terms of surface area) but thinner leaves, with a decreased dry matter concentration.

CONCLUSION

It can be concluded that the effect of fertilization treatments was not significantly different to improve foxtail millet growth and production under shading conditions. The growth and production of foxtail millet decreased in shading conditions. The optimum vegetative and generative performances were achieved on 0% shading condition. However, foxtail millet is still tolerant of cultivating up to 25% shading intensity, due to the total panicle dry weight decreasing less than 50% (44.27%) on 25% shading intensity to 50% light intensity. The plant promoted an adaptation mechanism to shading conditions by increasing the chlorophyll b content and specific leaf area. The low light intensity as an effect of shading intensity was dominant in decreasing plant growth and production.

CONTRIBUTORSHIP

All of the authors of this manuscript are the main contributors.

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