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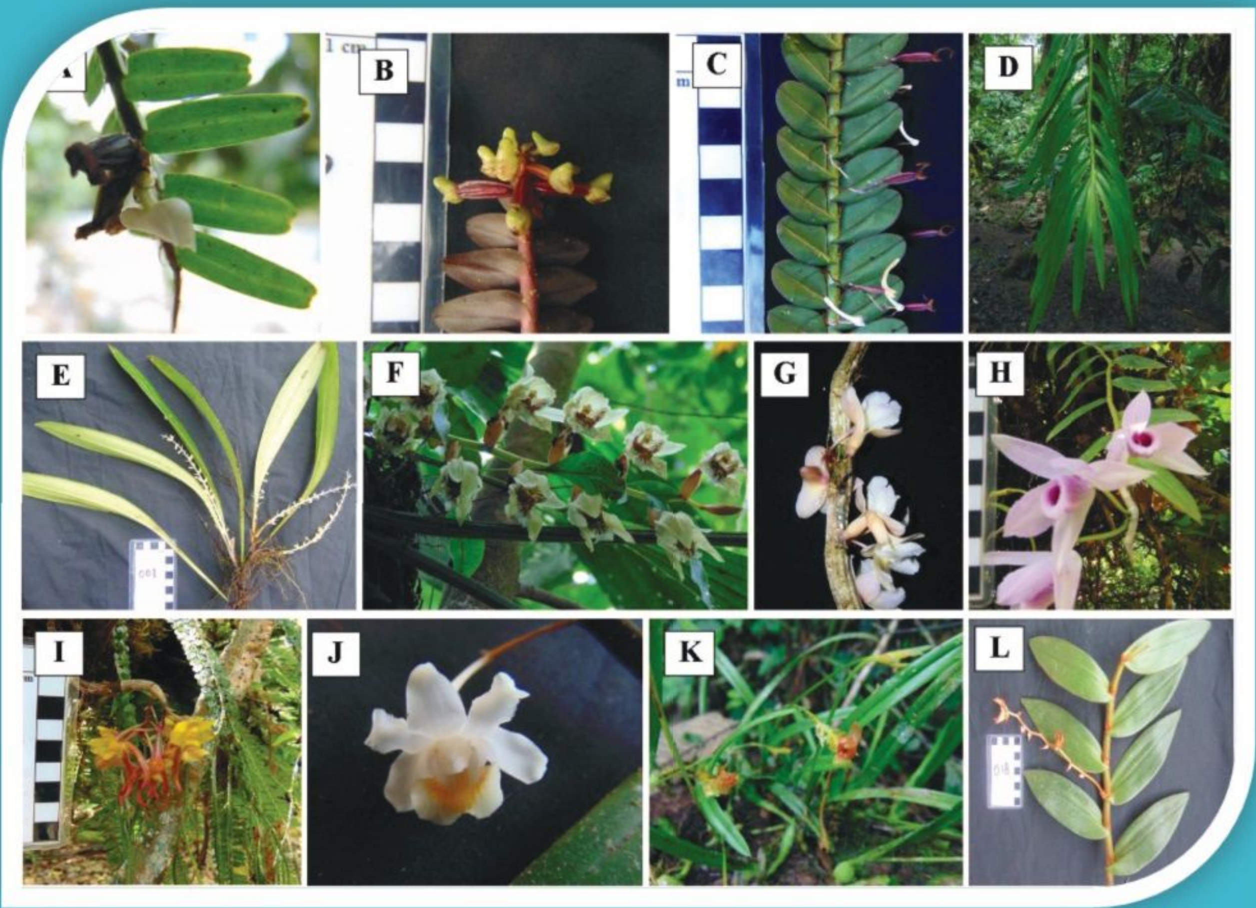

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Keterangan foto cover depan: Jenis anggrek epifit di kaki gunung Liangpran.
(*Notes of cover picture*): (*The epiphytic orchids in the foothill of Mount Liangpran)* sesuai dengan halaman 312 (*as in page 312*).

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AGRONOMIC CHARACTERS OF DROUGHT-TOLERANT SOYBEANS AT THE REPRODUCTIVE STAGE

[Karakteristik Agronomis Genotipe Kedelai Toleran Kekeringan Pada Fase Reproduktif]

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ABSTRAK

Di Indonesia, sebagian besar kedelai dibudidayakan pada musim kemarau sehingga rentan terhadap terjadinya kekeringan pada fase reproduktif. Penelitian ini bertujuan untuk mengkarakterisasi karakter agronomi dari beberapa genotipe kedelai yang toleran terhadap kekeringan pada fase reproduktif. Sebanyak 19 genotipe kedelai diteliti perubahan karakter agronomi dan toleransinya terhadap kekeringan di Probolinggo (Indonesia) selama musim kemarau (Juni-September). Penelitian menggunakan dua lingkungan yaitu lingkungan normal (tanaman diairi secara optimal sepanjang pertumbuhan) dan lingkungan kekeringan (hanya diairi hingga tanaman berumur 40 hst, setelah itu tidak diairi sama sekali). Cekaman kekeringan yang terjadi selama fase reproduktif tidak mempengaruhi karakter tinggi tanaman, jumlah cabang, jumlah buku, dan jumlah polong isi. Karakter jumlah polong hampa, bobot 100 biji, bobot biji/tanaman dan hasil biji secara nyata dipengaruhi oleh cekaman kekeringan yang terjadi selama fase reproduktif. Teridentifikasi genotipe MDT15-6-11 yang berkarakteristik dan hasil tinggi dinilai toleran kekeringan karena mekanisme terhindar. Genotipe MDT15-W-3034 teridentifikasi tahan kekeringan karena memiliki laju kelayuan yang lamban, postur tanaman tinggi, fase vegetatif lamban dan berdaya hasil tinggi. Kedua genotipe tersebut berpotensi dilepas sebagai varietas unggul kedelai toleran kekeringan dan juga berpeluang digunakan sebagai sumber gen perbaikan ketahanan kedelai terhadap kekeringan pada fase reproduktif.

Kata kunci: cekaman kekeringan, *Glycine max*, karakter pertumbuhan, kelayuan tanaman, hasil biji

ABSTRACT

In Indonesia, soybeans are typically cultivated during the dry season, thus making it prone to drought stress in the reproductive stage. The objective of the research was to characterize the agronomic characters of several soybean genotypes which were tolerant to drought at the reproductive stage. A total of 19 soybean genotypes were evaluated for its agronomic characters and tolerance to drought stress in Probolinggo (East Java, Indonesia) during the dry season (June – September). The research was arranged in a randomized block design with four replicates. Soybean cultivars were sown at two separate experiments, normal/optimal (plants were irrigated during the growth period) and stress (plants were irrigated up to 40 days after planting) conditions. Drought stress during the reproductive stage did not affect the characters of plant height, the number of branches per plant, the number of nodes per plant, and the number of pods per plant. Meanwhile, the number of empty pod, seed weight per plant, and seed yield were significantly affected. There were two genotypes which were identified as the tolerant genotypes to drought stress at the reproductive stage, *i.e.* MDT15-6-11 and MDT15-W-3034. The agronomic characters of MDT15-6-11 were showed as having a low percentage of yield reduction, hence it was able to mantain its high yield. The MDT15-W-3034 was identified as drought-tolerant due to the slow wilting, high plant character, a slow vegetative phase, and high yields. The genotypes obtained from this study could be recommended to be released as new soybean drought-tolerant varieties due to its high yield and tolerant to drought stress. Those genotypes could also be used as gene donors for soybean improvement to drought stress at the reproductive stage.

Keywords: drought stress, *Glycine max,* growth character, plant wilting, seed yield.

INTRODUCTION

Drought is a limiting factor in soybean production in the world, especially in the era of climate change that is happening today. The decline in the soybean production due to drought stress will be more significant in Indonesian tropical areas because most of the soybeans are planted in the dry season, making them vulnerable to the occurrence of drought stress, especially in the reproductive phase. Soybean yield losses due to drought ranged from 21% to 70% (Frederick *et al.,* 2001; Suhartina and Arsyad 2005), depending on the variety, duration of stress, and growth stadia.

Strategies for reducing yield losses due to drought can be done through the manipulation of the environment and cultivating soybean varieties which are drought tolerant. Cultivation of soybean varieties that are tolerant to drought requires knowledge of their morpho-physiological characters as a determinant of the tolerance. Various studies have reported the relationship between root architecture and drought tolerance characters of the plant (Huck *et al.,* 1983, Bassani *et al*., 2004; Brady *et al.,* 2007; Fenta *et al.,* 2014; Opitz *et al.,* 2016). It is certainly understandable because seed yield is a function of a number of several processes, such as water loss

**Kontributor Utama*
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through respiration, water use efficiency and harvest index (Turner *et al*., 2001). Water use efficiency is also used as a selection indicator at the early generation selection lines in barley plants (Kovacevic *et al.,* 2015). Those three components are directly related to the architecture of plant roots. Thus, the improvement program of drought tolerance is associated with the efforts to minimize water input, reduce yield losses, and increase plant water use efficiency. Soybean's reproductive phase is considered as the most sensitive phase to drought, especially related to a decrease in the seed yield (Saitoh *et al.,* 1999; Oya *et al.,* 2004). The similar pattern was also reported in other plants (Boonjung and Fukai 2000; Pantuwan *et al.,* 2002; Griffiths and Parry 2002).

Drought disturbs the various yield components and cumulatively reduces the seed yield of soybeans. It is often stated that the soybean tolerance to drought is caused by a complex factor among their morpho-physiology characters. Sloane *et al.* (1990) stated that the drought-tolerant soybeans resulted in a relatively low decrease in the seed yield. The characteristics of the soybean tolerance to drought are determined by a high partitioning of biomass to the roots, thereby increasing the ratio of roots to canopies (Huck *et al.,* 1983), the growth rate of plant height, and the ability to maintain the leaf area during the drought stress (Oya *et al.,* 2004). Suresh *et al.* (2015) reported that drought-tolerant soybeans and other genotypes that are considered drought tolerant are characterized by relatively high shoot length and shoot dry weight.

In Indonesia, Adhiwibawa *et al.* (2015) analyzed leaf chlorophyll to examine the drought-tolerant level of soybeans. The type of soil also determines the characteristics of soybean drought-resistance. The result showed that in clay soil, Plant Introduction (PI) 578477A and 088444 were found to have a higher root number and forks with higher yield under water limitation. Similarly, in sandy soil, PI458020 was found to have a thicker lateral root system and higher yield under water limitation. The genotypes identified in this study can be used to enhance drought tolerance of elite soybean cultivars through improved root traits specified to the target environments (Prince *et al.* 2016). In sunflower crops, Mohammadi *et al.* (2015) reported that a higher plant height, a higher leaf number, a higher capitulum number, a higher seed number per plant and a higher seed weight per plant characterized drought-tolerant cultivars. The ability of plants to maintain the growth rate in conditions of drought stress is probably caused by the ability of the root system to absorb water so as to keep pace with the rate of transpiration, or the ability of the plant to reduce the transpiration rate.

There are genotypic variations in growth, yield, and yield components of soybean genotypes under drought stress condition, especially at the reproductive stage. The objective of this study was to characterize the agronomic characters of several soybean genotypes which were tolerant to drought at the reproductive stage.

MATERIALS AND METHODS

The experiment was conducted on dry land in Probolinggo, Indonesia, during the dry season. The materials consisted of 19 soybean genotypes. The research was performed utilizing a randomized block design with four replications. Soybean cultivars were sown in two different kinds of environment. The normal or optimal environment group (O) was all genotypes irrigated during the growth period. Meanwhile, the stressed environment group (D) was plants irrigated up to 40 days after planting. Each genotype was planted in a 1.2 m × 4.5 m plot size with 40 cm × 15 cm planting distance or two plants/ hill.

Soil tillage was done intensively. Before planting, the land had to be cleared of weeds. The soybeans were planted by using the *tugal* method with 2–3 seeds per hole. Pest and disease control was performed optimally. The drainage was used to maintain optimum soil moisture. The plants were fertilized using 250 kg Phonska and 100 kg SP36 or other compound fertilizers with equivalent doses, which were given evenly before planting. Cultivation included weeding and intensive pest and disease control.

Measurements of soil moisture in the environment O and D were performed at the plant age of 45, 50, 55, 60, 65, 70, and 75 days after planting, respectively. Soil sampling was conducted at five points diagonally. Soil moisture was measured by using the oven method (Abdurrahman *et al.,* 2013). Data were collected for the growth and seed yield characters. The wilting level was measured using wilting scores of 45, 50, 55, 60, 65, 70, and 75 days after planting, respectively. Observation on wilting as the plant response to drought stress was rated visually on 1–5 scale following Del Rosario *et al.,* (1992) scoring method: 1 = all leaves were green and fresh (turgid); 2 = > 50% of the leaves were still fresh, no older leaves were brown; 3 = > 50% of the leaves began to wither and <50% of young leaves were brownish; 4 = > 50% leaves withered, > 50% of the old leaves started browning but there were no dead plants, and 5 = > 50% leaves wilted and > 50% of older leaves began to brown and there were dead plants.

RESULT

Combined analysis of variance

The combined analysis of variance of growth characters and seed yield characters is presented in Table 1. The interaction of genotype × environment was significant in growth characters, *i.e.* the number of pods and number of empty pods. The environment influenced all the characters except the number of pods, whereas genotype effect was significant on all characters except the number of empty pods. The seed characters consisted of seed weight per plant and seed yield per ha. The interaction of genotype × environment was siginificant in 100 seed weight and seed yield per ha. Based on the combined analysis of variance of various characters in both drought stressed condition and optimal environment, the result indicates that the most affected characters by drought were the number of empty pods and seed yield.

Soil moisture

Soil moisture content in the stressed and optimal conditions is presented in Figure 1. The soil moisture on the 55th day after planting (DAP) was similar in the optimal environment and in the stressed one. Differences in soil moisture levels in both environment conditions started at the age of 60 DAP or 20 days after the drought stress treatment, and differences in the soil moisture content in the two environment conditions gradually increased along with the increasing age of the plants.

The soil moisture content on the 60th DAP in the optimal and stressed environment conditions reached 30.69% and 21.71%, respectively; or there was a decline in the soil moisture content by 29.13%. At the age of 65 days after planting or 25 days after the drought treatment, the soil moisture content reached 26.61% in the optimal environment, and 20.58% in

Table 1. The analysis of variance for characters of growth and seed yield *(Sidik ragam karakter pertumbuhan dan karakter hasil biji)*

Character *(Karakter)*	Mean square *(Kuadrat tengah)*				CV (%)
	Environment (E) *(Lingkungan)*	Replication|Environment *(Ulangan|Lingkungan)*	Genotype *(Genotipe)*	G × E	
Growth					
PH	3056.4379 **	57.9577 ns	1134.1667 **	47.5657 ns	11.69
NOB	6.5695 **	0.4452 ns	1.9235 **	0.4436 ns	26.55
NON	2.3750 *	0.5340 ns	8.6809 **	1.0589 ns	8.38
NFP	9.7010 ns	16.6400 ns	262.0058 **	53.0483 **	14.55
NEP	87.0066 **	0.2638 ns	0.4419 ns	0.6660 *	24.41
Seed Yield					
SWP	648.0796 **	4.1955 ns	41.4290 **	12.9184 ns	22.37
YLD	9.9758 **	0.6190 **	1.1925 **	0.3023 **	17.06

Note *(keterangan)*: CV= coefficient of variation *(koefisien keragaman)*; * = significant at 5 % probability level ($p < 0.05$) *(nyata pada taraf probabilitas 5%)*, ** = significant at 1% probability level ($p < 0.01$) *(nyata pada taraf probabilitas 5%)*, ns = not significant (*tidak signifikan*), PH = plant height *(tinggi tanaman)* (cm), NOB = number of branches/plant *(jumlah cabang/tanaman)*, NON = number of nodes/plant *(jumlah buku/tanaman)*, NFP = number of filled pods *(jumlah polong isi)*, NEP = number of empty pods *(jumlah polong hampa)*, SWP = seed weight per plant *(berat biji per tanaman)* (g), YLD = seed yield *(hasil biji)* (t/ha).

the stress condition; or a decline of 22.66% in soil moisture content. The plant ages between 55 and 65 days are the critical period of soybean crops against drought, which means that the occurrence of drought stress during those periods are able to disrupt crop production performance.

Growth characters

The result indicates that the drought-stressed environment increased the plant height, the number of branches, and the number of empty pods; but decreased the number of nodes and number of empty pods. The average of plant height in the stressed environment was 56.23 cm and that in the optimal environment was 47.27 cm; the average number of branches in the drought stressed and optimal environment conditions was 2.29 and 1.88 branches per plants, respectively. Additionally, the average number of empty pods/plant under the drought stress and optimal conditions were 3.32 and 1.81 empty pods, respectively. All three characters had increased by 15.93%, 17.90% and 45.48% in drought-stressed environment, respectively. Meanwhile, three growth characters declined in drought-stressed environment, *i.e.* the number of nodes decreased by 2.58% and the number of pods dropped to 1.43% (Table 2 and 3).

The growth development of soybean plants is divided into generative (reproductive) and vegetative phases. Generative phase starts from the emergence of the flower. The pod formation process of tropical soybeans in Indonesia with days to maturity is about 83 days beginning from the age about 50 days. When connecting the phenology of soybean plants with Figure 1, the impact of drought stress started to appear on the 60th days after planting, when irrigation cessation was conducted on the DAP. This means that the process of pod and node formation and plant height and branch growth have been completed on the 60th DAP.

The difference in characters between drought-stressed environment and more optimal environment are due to differences in genetic factors of tested genotypes. Among the various growth factors, it seems that the number of empty pods becomes the most ideal character used to assess the effects of drought-stressed environment compared to other growth characters.

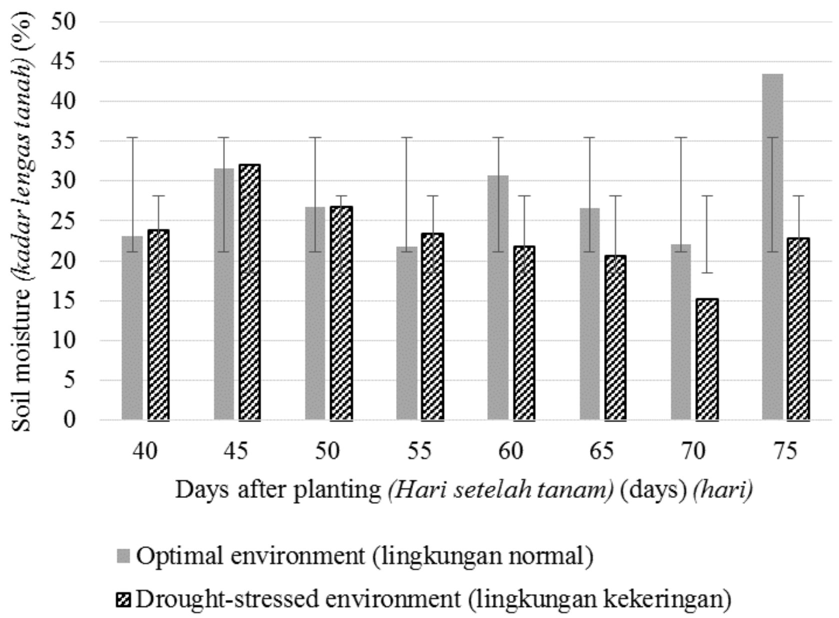

Fig. 1. Soil moisture content in optimal and drought-stressed environments *(Kadar lengas tanah pada lingkungan kekeringan dan normal)*

Table 2. Plant height, number of branches/plant, number of node/plant of 19 soybean genotypes in drought-stressed and optimal environments *(Tinggi tanaman, jumlah cabang per tanaman, dan jumlah buku per tanaman dari 19 genotipe kedelai pada lingkungan kekeringan dan normal)*

No	Genotype *(Genotipe)*	Plant height (*tinggi tanaman)* (cm)			Number of branches/ plant *(Jumlah cabang/ tanaman)*			Number of nodes/plant *(Jumlah buku/tanaman)*		
		D	O	Mean	D	O	Mean	D	O	Mean
1	MDT15-2-13	52.15	52.05	52.10	2.40	1.55	1.98	8.85	9.15	9.00
2	MDT15-1-1	54.85	37.70	46.28	1.80	1.55	1.68	9.10	9.30	9.20
3	MDT15-30-7	66.35	58.05	62.20	2.65	2.30	2.48	9.40	10.10	9.75
4	MDT15-4-4	55.70	41.20	48.45	3.40	2.30	2.85	9.70	9.90	9.80
5	MDT15-16-2	67.10	53.60	60.35	1.50	1.40	1.45	13.30	11.60	12.45
6	MDT15-3-3	29.30	24.65	26.98	2.20	2.05	2.13	7.75	7.90	7.83
7	MDT15-6-13	69.75	62.25	66.00	3.65	2.30	2.98	10.80	10.95	10.88
8	MDT15-1-2	69.25	65.55	67.40	1.25	2.00	1.63	9.05	10.75	9.90
9	MDT15-5-5	54.80	39.75	47.28	1.65	1.30	1.48	9.90	9.70	9.80
10	MDT15-6-11	45.60	35.25	40.43	2.95	2.15	2.55	8.30	9.70	9.00
11	MDT15-8-1	48.40	40.95	44.68	1.90	1.50	1.70	9.05	9.55	9.30
12	MDT15-1-3	45.90	27.00	36.45	2.30	1.75	2.03	9.20	8.60	8.90
13	MDT15-6-12	53.50	44.45	48.98	2.30	1.65	1.98	9.25	8.95	9.10
14	MDT15-6-8	55.90	47.40	51.65	1.75	1.60	1.68	9.00	9.20	9.10
15	MDT15-A-49-4	59.95	54.45	57.20	1.90	1.95	1.93	10.00	10.05	10.03
16	MDT15-G-0	37.30	30.45	33.88	1.60	1.40	1.50	7.60	7.85	7.73
17	MDT15-D1-1-2	69.00	60.60	64.80	2.60	2.35	2.48	9.65	10.20	9.93
18	MDT15-W-3034	68.15	61.95	65.05	2.85	2.60	2.73	9.20	10.25	9.73
19	MDT15-D4-66	65.50	60.75	63.13	2.95	2.00	2.48	10.35	10.50	10.43
	Mean	56.23	47.27	51.75	2.29	1.88	2.09	9.44	9.69	9.57

D = drought-stressed environment *(lingkungan kekeringan)*, O = optimal environment *(lingkungan normal)*

Seed yield characters

Seed characters in this study consisted of seed weight per plant and seed yield per ha. The reduction of seed weight/plant from optimal environment (average 15.26 g/plant) to drought-stressed environment (average 11.13 g/plant) was 27.06% (Table 4). There were three genotypes that showed a very low decrease in the seed weight/ plant, namely MDT15-1-3 (2.90%), MDT15-D4-66 (8.77%) and MDT15-2-13 (9.33%). On the contrary, genotype MDT15-1-2 showed a significant decrease in seed yield/plant, reaching 53.18%. Ranges of seed weight per plant 10.26 – 21.75 g (average 15.26 g) in the optimal environment and 8.46 to 15.18 g (average 11.13 g) in the stressed environment. The MDT15-A-49-4 consistently had the highest yield in the two types of environment. Meanwhile, genotype MDT15-1-3 indicated the most significant decrease in the seed yield/plant (2.90%).

The seed yield per ha in optimal and stressed types of environment ranged from 1.64 to 3.41 t/ha (average 2.43 t/ha) and from 1.16 to 2.45 t/ha (average 1.92 t/ha), respectively. The range of yield declined from the optimal to the stressed environment by 4.83 – 55.21% (an average of 20.99%) (Table 5, Fig. 2). The highest seed yield in the optimal environment was MDT15-D1-1-2 (3.41 t/ha), followed by MDT15-1-2 (3.31 t/ha) and MDT15-A-49-4 (2.76 t/ha); while the three genotypes which were able to produce the highest yield in the stressed environment were MDT15-W-3034 (2.45 t/ha), MDT15-D1-1-2 (2.22 t/ha), and MDT15-6-11 (2.27 t/ha). The smallest decrease in seed yield were observed in MDT15-3-3 (4.83%), MDT15-G-0 (4.87%), and MDT15-1-1 (5.58%).

Table 3. Number of filled pods and number of empty pods of 19 soybean genotypes in drought-stressed and optimal environment *(Jumlah polong isi dan hampa dari 19 genotipe kedelai pada lingkungan kekeringan dan normal)*

No	Genotype *(Genotipe)*	Number of filled pods/plant *(Jumlah polong isi/ tanaman)*			Number of empty pods/plant *(Jumlah polong hampa/ tanaman)*		
		D	O	Mean	D	O	Mean
1	MDT15-2-13	31.85	26.35	29.10	2.55	2.15	2.35
2	MDT15-1-1	37.15	33.05	35.10	2.85	1.55	2.20
3	MDT15-30-7	30.10	35.00	32.55	3.65	1.65	2.65
4	MDT15-4-4	39.55	39.25	39.40	2.95	1.75	2.35
5	MDT15-16-2	46.45	41.30	43.88	3.55	1.45	2.50
6	MDT15-3-3	29.10	26.85	27.98	3.55	1.85	2.70
7	MDT15-6-13	42.35	38.60	40.48	3.25	1.55	2.40
8	MDT15-1-2	32.70	44.90	38.80	2.90	1.75	2.33
9	MDT15-5-5	26.20	26.50	26.35	4.25	1.90	3.08
10	MDT15-6-11	34.75	33.35	34.05	3.25	2.10	2.68
11	MDT15-8-1	30.90	35.50	33.20	4.10	1.80	2.95
12	MDT15-1-3	39.25	33.15	36.20	2.90	2.60	2.75
13	MDT15-6-12	35.85	34.95	35.40	3.65	1.75	2.70
14	MDT15-6-8	32.40	33.85	33.13	3.60	2.05	2.83
15	MDT15-A-49-4	45.45	46.20	45.83	3.40	1.50	2.45
16	MDT15-G-0	23.10	25.70	24.40	3.05	1.85	2.45
17	MDT15-D1-1-2	33.45	41.10	37.28	3.25	1.80	2.53
18	MDT15-W-3034	32.90	41.40	37.15	3.55	1.50	2.53
19	MDT15-D4-66	42.90	39.00	40.95	2.80	1.75	2.28
	Mean	35.07	35.58	35.33	3.32	1.81	2.56

D = drought-stressed environment *(lingkungan kekeringan)*, O = optimal environment *(lingkungan normal)*

Table 4. Seed weight/plant of 19 soybean genotypes in drought-stressed and optimal environment *(Berat biji/tanaman dari 19 genotipe kedelai pada lingkungan kekeringan dan normal)*

No	Genotype *(Genotipe)*	Seed weight/plant *(Berat biji/tanaman)* (g)		
		D	O	Mean
1	MDT15-2-13	11.57	12.76	12.17
2	MDT15-1-1	11.00	14.17	12.58
3	MDT15-30-7	8.92	14.09	11.51
4	MDT15-4-4	11.43	17.39	14.41
5	MDT15-16-2	16.74	19.46	18.10
6	MDT15-3-3	10.92	13.98	12.45
7	MDT15-6-13	13.88	17.82	15.85
8	MDT15-1-2	9.23	19.72	14.47
9	MDT15-5-5	8.46	10.26	9.36
10	MDT15-6-11	11.83	14.87	13.35
11	MDT15-8-1	9.50	14.54	12.02
12	MDT15-1-3	13.23	13.63	13.43
13	MDT15-6-12	9.98	13.42	11.70
14	MDT15-6-8	9.91	14.05	11.98
15	MDT15-A-49-4	15.18	21.75	18.46
16	MDT15-G-0	9.63	12.29	10.96
17	MDT15-D1-1-2	8.91	15.56	12.23
18	MDT15-W-3034	8.49	16.35	12.42
19	MDT15-D4-66	12.65	13.86	13.25
	Mean	11.13	15.26	13.19

D = drought-stressed environment *(lingkungan kekeringan)*, O = optimal environment *(lingkungan normal)*

Table 5. Seed yield of 19 soybean genotypes in drought-stressed and optimal environments *(Hasil biji dari 19 genotipe kedelai pada lingkungan kekeringan dan normal)*

No	Genotype *(Genotipe)*	Seed yield *(Hasil biji)* (t/h)		Mean *(Rata-rata)*	Reduction from O to D *(Penurunan hasil dari O ke D)* (%
		D	N		
1	MDT15-2-13	2.19	2.47	2.33	11.34
2	MDT15-1-1	1.86	1.97	1.92	5.58
3	MDT15-30-7	2.08	2.54	2.31	18.11
4	MDT15-4-4	1.16	2.59	1.88	55.21
5	MDT15-16-2	1.26	1.79	1.53	29.61
6	MDT15-3-3	1.97	2.07	2.02	4.83
7	MDT15-6-13	1.98	2.73	2.36	27.47
8	MDT15-1-2	2.17	3.31	2.74	34.44
9	MDT15-5-5	1.45	1.70	1.58	14.71
10	MDT15-6-11	2.27	2.51	2.39	9.56
11	MDT15-8-1	1.62	1.98	1.80	18.18
12	MDT15-1-3	1.50	1.64	1.57	8.54
13	MDT15-6-12	2.04	2.61	2.33	21.84
14	MDT15-6-8	1.93	2.31	2.12	16.45
15	MDT15-A-49-4	1.84	2.76	2.30	33.33
16	MDT15-G-0	2.15	2.26	2.21	4.87
17	MDT15-D1-1-2	2.33	3.41	2.87	31.67
18	MDT15-W-3034	2.45	2.74	2.60	10.58
19	MDT15-D4-66	2.16	2.73	2.45	20.88
	Mean	1.92	2.43	2.18	20.99

D = drought-stressed environment *(lingkungan kekeringan)*, O = optimal environment *(lingkungan normal)*

The level of plant wilting

The level of plant wilting is one of the benchmarks of soybean tolerance to drought. In the optimal environment until 65 DAP, the whole plant leaves were still green and fresh. Starting from 70 DAP, most of the leaves turned to yellow, a sign of ageing and death of the plant. In contrast, in the drought-stressed environment, all the leaves were green and fresh only until 55 DAP (Table 6).

In addition, starting from 60 DAP, soybean genotypes began to show a diverse response tolerance, and this continued until 75 DAP. On the 60th DAP, nine of 19 tested genotypes began to show withered leaves. At the age of 65 DAP, six genotypes showed withered leaves by as much as more than 50% and the young leaves turned into a brown color. The peak diversity of genotype responses to drought occurred at the age of 70 DAP, and there were two genotypes that had a wilt score of 2 (the leaves were still fresh), eleven genotypes had a score of 3 (over 50% withering leaves appeared) and six genotypes were at a score of 4 (over 50 % leaves wilted and turned to brown). On the 75th DAP, all genotypes showed withering and brown leaves.

Based on the score of wilting, genotypes MDT15-16-2 and MDT15-W-3034 consistently had a score of 2 until 70 DAP, while the other genotypes were at a score between 3 and 4. This indicates that those two genotypes are considered drought-stress tolerant.

DISCUSSION

Drought is a serious problem within soybean cultivation in Indonesian tropical area because most of the soybeans are planted in the dry season.

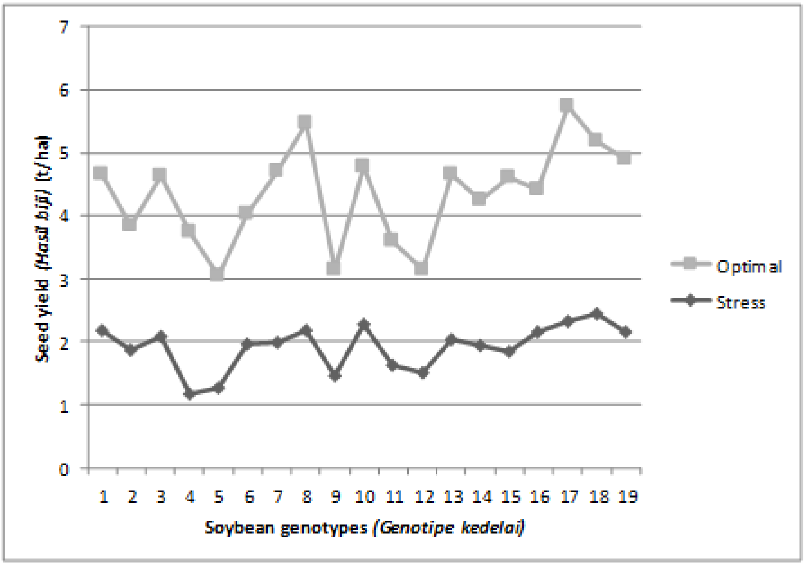

Fig. 2. Seed yield (t/ha) in drought-stressed and optimal environments (*Hasil biji pada lingkungan kekeringan dan normal)*

Table 6. Wilting score of 19 soybean genotypes in drought-stressed and normal environments *(Skor layu dari 19 genotipe kedelai pada lingkungan kekeringan dan normal)*

No	Genotype *(Genotipe)*	Wilting score *(Skor layu)*													
		Drought-stressed environment *(lingkungan kekeringan)*							Optimal environment *(lingkungan normal)*						
		45	50	55	60	65	70	75	45	50	55	60	65	70	75
1	MDT15-2-13	1	1	1	2	3	3	5	1	1	1	1	1	2	3
2	MDT15-1-1	1	1	1	1	2	3	5	1	1	1	1	1	2	3
3	MDT15-30-7	1	1	1	2	3	4	5	1	1	1	1	1	2	3
4	MDT15-4-4	1	1	1	2	2	3	5	1	1	1	1	1	2	3
5	MDT15-16-2	1	1	1	1	2	2	4	1	1	1	1	1	1	2
6	MDT15-3-3	1	1	1	1	3	4	5	1	1	1	1	1	2	4
7	MDT15-6-13	1	1	1	2	2	4	5	1	1	1	1	1	2	4
8	MDT15-1-2	1	1	1	2	2	3	5	1	1	1	1	1	2	3
9	MDT15-5-5	1	1	1	1	2	3	5	1	1	1	1	1	2	3
10	MDT15-6-11	1	1	1	2	3	4	5	1	1	1	1	1	2	5
11	MDT15-8-1	1	1	1	1	2	3	5	1	1	1	1	1	2	3
12	MDT15-1-3	1	1	1	1	2	3	5	1	1	1	1	1	2	3
13	MDT15-6-12	1	1	1	1	2	3	5	1	1	1	1	1	2	3
14	MDT15-6-8	1	1	1	2	3	3	5	1	1	1	1	1	2	3
15	MDT15-A-49-4	1	1	1	1	2	3	5	1	1	1	1	1	2	3
16	MDT15-G-0	1	1	1	2	3	4	5	1	1	1	1	1	2	5
17	MDT15-D1-1-2	1	1	1	2	2	3	5	1	1	1	1	1	2	3
18	MDT15-W-3034	1	1	1	2	2	2	4	1	1	1	1	1	1	2
19	MDT15-D4-66	1	1	1	2	2	4	5	1	1	1	1	1	2	3

Drought stress is also reported in other crops to be responsible for more yield losses than any other abiotic stresses (Boyer 1982). The availability of soybean varieties to tolerate drought is important to mantain the soybean yield per unit area. Seed yield is influenced by the amount of water lost through respiration, water use efficiency and harvest index (Manavalan *et al.,* 2009), and it is also related to various yield components that are interlinked with other yield components. Drought will affect each of yield component and its accumulation will reduce seed yield.

Soybean cultivation in Indonesia are carried out in the dry season, on the rice fields after paddy, and soybean are grown between 5 and 10 days after the rice is harvested immediately without any soil tillage. Seed filling phase is a critical phase of the occurrence of the drought stress. In this study, the drought stress began on the 40th days after planting. Nonetheless, decreased levels of soil moisture began to occur on the 60 DAP or 20 DAP after cessation of irrigation. Thus, the effects of drought in the reproductive phase did not influence various components of growth such as plant height, number of branches, and number of pods. The component that may be affected is the number of empty pods. It was also addressed by Desclaux *et al.* (2000) that the drought during the flowering phase will reduce the number of pods, number of seeds per pod, and seed size. But the drought that occurred in seed development period (R5 - R7) may lowering the soybean yield between 45–88% (Eck *et al.,* 1987).

In this study, seed yield characters which consist of seed weight per plant and seed yield per ha decrease due to the drought stress, and the amount of the decline varied among soybean genotypes. Soybeans tolerant to drought are characterized by a relatively low decrease in the seed yields, a relatively slow level of wiltering leaves (Sloane *et al*., 1990), an increasing partitioning of biomass to root thereby increasing the ratio of root to canopy (Huck *et al.,* 1983), a high rate of plant growth in the drought-stressed environment, and an ability to maintain leaf areas (Oya *et al.,* 2004). Several researchers reported that drought-tolerant cultivars with early flowering and deep root phenotype have longer and deeper roots that contribute to better water uptake (Au *et al.,* 2010; Zhao *et al.,* 2004). It was also reported that in soybeans, several morphological characters, such as diameter of tracheas belonging to the root, stem, and leaf; stomata index; and size and average number of stomata and epidermal cells are important characters which vary among soybean plants under stress conditions (Makbul *et al.,* 2011). It is also emphasized that drought stress at any time from R4 to shortly after R6 (beginning to seed) will reduce yields more than the same stress in any other periods of development. The period from the late pod formation to shortly before full seed is especially critical, because flowering ceases and can no longer compensate for the lost pods. The younger pods and stems are also more susceptible to aborting under stress than older pods and seeds (Hall and Twidwell 2002).

Disruption various morphological characters will accumulate to the decrease of the seed yields. Soybean genotypes which able to maintain or have smallest decrease in the yields are considered as resistant or tolerant to drought. In this study, the highest yield genotypes in the optimum environment are MDT15-D1-1-2, MDT15-1-2, and MDT15-W-3034. The highest yields in the drought -stressed environment are MDT15-W-3034, MDT15-D1-1-2, and MDT15-6-11. From this fact, it can be identified that soybean genotypes which are able to produce high yields in the optimal environment are also likely to be able to produce high yields in the drought-stressed environmental, as seen on MDT15-W-3034 and MDT15-D1-1-2. There are five soybean genotypes that have the lowest rate of yield loss, *i.e*. MDT15-3-3, MDT15-G-0, MDT15-1-1, MDT15-1-3, and MDT15-6-11. Based on the result, due to the characters such as the smallest yield loss in the optimal environment to drought-stressed environment, the performance of seed yield per ha in the drought-stressed environment, the genotype MDT15-6-11 is considered as drought tolerant. If the mapping of soybeans tolerant to drought is based on the level of wiltering leaves in the drought environments, then two drought-tolerant genotypes are gained, namely the MDT15-16-2 and MDT15-W-3034. Those genotypes show green and fresh (turgid) leaves after 70 DAP or 30 days after the drought-stress treatment.

From this study, soybean genotypes with high yields (2.27 t/ha) in the drought-stressed environment are obtained. These genotypes are recommended to be introduced as a drought-tolerant variety in Indonesia, or can be used as a gene source for improvement of soybean resistance to drought through the escape mechanism. A study conducted by Song *et al.* (2016) showed that soybeans can survive drought stress if there is a robust and deep root system at the early vegetative growth stage. The MDT15-W-3034 is considered tolerant to drought because it has a slow rate of wilting, a high posture of plant, and a long duration of the vegetative phase

CONCLUSION

The development of a soybean variety which is tolerant to drought at the reproductive phase in the tropical Indonesian area has the potential to use the yield reduction and a score of wilting plants as the selection indicators. Drought tolerant genotypes can be evaluated from the slow withering time and a high yield. There are two genotypes which are identified as the drought-tolerant plants at the reproductive stage, *i.e.* MDT15-6-11 and MDT15-W-3034. The agronomic characters of MDT15-6-11 include having high yields and low percentage of yield reduction. The MDT15-W-3034 is identified as drought-tolerant due to the slow wilting, high plants, a slow vegetative phase, and high yields.

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Pedoman Penulisan Naskah Berita Biologi

Berita Biologi adalah jurnal yang menerbitkan artikel kemajuan penelitian di bidang biologi dan ilmu-ilmu terkait di Indonesia. Berita Biologi memuat karya tulis ilmiah asli berupa makalah hasil penelitian, komunikasi pendek dan tinjauan kembali yang belum pernah diterbitkan atau tidak sedang dikirim ke media lain. Masalah yang diliput harus menampilkan aspek atau informasi baru.

Tipe naskah

1. **Makalah lengkap hasil penelitian (*original paper*)**
   Naskah merupakan hasil penelitian sendiri yang mengangkat topik yang *up to date*. Tidak lebih dari 15 halaman termasuk tabel dan gambar. Pencantuman lampiran seperlunya, namun redaksi berhak mengurangi atau meniadakan lampiran.
2. **Komunikasi pendek (*short communication*)**
   Komuniasi pendek merupakan makalah hasil penelitian yang ingin dipublikasikan secara cepat karena hasil termuan yang menarik, spesifik dan atau baru, agar dapat segera diketahui oleh umum. Hasil dan pembahasan dapat digabung.
3. **Tinjauan kembali (*review*)**
   Tinjauan kembali merupakan rangkuman tinjauan ilmiah yang sistematis-kritis secara ringkas namun mendalam terhadap topik penelitian tertentu. Hal yang ditinjau meliputi segala sesuatu yang relevan terhadap topik tinjauan yang memberikan gambaran '*state of the art*', meliputi temuan awal, kemajuan hingga issue terkini, termasuk perdebatan dan kesenjangan yang ada dalam topik yang dibahas. Tinjauan ulang ini harus merangkum minimal 30 artikel.

Struktur naskah

1. **Bahasa**
   Bahasa yang digunakan adalah Bahasa Indonesia atau Inggris yang baik dan benar.
2. **Judul**
   Judul diberikan dalam bahasa Indonesia dan inggris. Judul ditulis dalam huruf tegak kecuali untuk nama ilmiah yang menggunakan bahasa latin, Judul harus singkat, jelas dan mencerminkan isi naskah dengan diikuti oleh nama serta alamat surat menyurat penulis dan alamat email. Nama penulis untuk korespondensi diberi tanda amplop cetak atas (*superscript*). Jika penulis lebih dari satu orang bagi pejabat fungsional penelitian, pengembangan agar menentukan status sebagai kontributor utama melalui penandaan simbol dan keterangan sebagai kontributor utama dicatatan kaki di halaman pertama artikel.
3. **Abstrak**
   Abstrak dibuat dalam dua bahasa, bahasa Indonesia dan Inggris. Abstrak memuat secara singkat tentang latar belakang, tujuan, metode, hasil yang signifikan, kesimpulan dan implikasi hasil penelitian. Abstrak berisi maksimum 200 kata, spasi tunggal. Di bawah abstrak dicantumkan kata kunci yang terdiri atas maksimum enam kata, dimana kata pertama adalah yang terpenting. Abstrak dalam Bahasa Inggris merupakan terjemahan dari Bahasa Indonesia. Editor berhak untuk mengedit abstrak demi alasan kejelasan isi abstrak.
4. **Pendahuluan**
   Pendahuluan berisi latar belakang, permasalahan dan tujuan penelitian. Perlu disebutkan juga studi terdahulu yang pernah dilakukan terkait dengan penelitian yang dilakukan.
5. **Bahan dan cara kerja**
   Bahan dan cara kerja berisi informasi mengenai metode yang digunakan dalam penelitian. Pada bagian ini boleh dibuat sub-judul yang sesuai dengan tahapan penelitian. Metoda harus dipaparkan dengan jelas sesuai dengan standar topik penelitian dan dapat diulang oleh peneliti lain. Apabila metoda yang digunakan adalah metoda yang sudah baku cukup ditulis sitasinya dan apabila ada modifikasi maka harus dituliskan dengan jelas bagian mana dan hal apa yang dimodifikasi.
6. **Hasil**
   Hasil memuat data ataupun informasi utama yang diperoleh berdasarkan metoda yang digunakan. Apabila ingin mengacu pada suatu tabel/ grafik/diagram atau gambar, maka hasil yang terdapat pada bagian tersebut dapat diuraikan dengan jelas dengan tidak menggunakan kalimat 'Lihat Tabel 1'. Apabila menggunakan nilai rata- rata maka harus menyertakan pula standar deviasinya.
7. **Pembahasan**
   Pembahasan bukan merupakan pengulangan dari hasil. Pembahasan mengungkap alasan didapatkannya hasil dan arti atau makna dari hasil yang didapat tersebut. Bila memungkinkan, hasil penelitian ini dapat dibandingkan dengan studi terdahulu.
8. **Kesimpulan**
   Kesimpulan berisi infomasi yang menyimpulkan hasil penelitian, sesuai dengan tujuan penelitian, implikasi dari hasil penelitian dan penelitian berikutnya yang bisa dilakukan.
9. **Ucapan terima kasih**
   Bagian ini berisi ucapan terima kasih kepada suatu instansi jika penelitian ini didanai atau didukungan oleh instansi tersebut, ataupun kepada pihak yang membantu langsung penelitian atau penulisan artikel ini.
10. **Daftar pustaka**
    Tidak diperkenankan untuk mensitasi artikel yang tidak melalui proses *peer review*. Apabila harus menyitir dari "laporan" atau "komunikasi personal" dituliskan '*unpublished*' dan tidak perlu ditampilkan di daftar pustaka. Daftar pustaka harus berisi informasi yang *up to date* yang sebagian besar berasal dari *original papers* dan penulisan terbitan berkala ilmiah (nama jurnal) tidak disingkat.

Format naskah

1. Naskah diketik dengan menggunakan program Microsoft Word, huruf New Times Roman ukuran 12, spasi ganda kecuali Abstrak spasi tunggal. Batas kiri-kanan atas-bawah masing-masing 2,5 cm. Maksimum isi naskah 15 halaman termasuk ilustrasi dan tabel.
2. Penulisan bilangan pecahan dengan koma mengikuti bahasa yang ditulis menggunakan dua angka desimal di belakang koma. Apabila menggunakan Bahasa Indonesia, angka desimal ditulis dengan menggunakan koma (,) dan ditulis dengan menggunakan titik (.) bila menggunakan bahasa Inggris. Contoh: Panjang buku adalah 2,5 cm. Lenght of the book is 2.5 cm. Penulisan angka 1-9 ditulis dalam kata kecuali bila bilangan satuan ukur, sedangkan angka 10 dan seterusnya ditulis dengan angka. Contoh lima orang siswa, panjang buku 5 cm.
3. Penulisan satuan mengikuti aturan *international system of units*.
4. Nama takson dan kategori taksonomi ditulis dengan merujuk kepada aturan standar yang diakui. Untuk tumbuhan menggunakan *International Code of Botanical Nomenclature* (ICBN), untuk hewan menggunakan International *Code of Zoological Nomenclature* (ICZN), untuk jamur *International Code of Nomenclature for Algae*, *Fungi and Plant* (ICFAFP), *International Code of Nomenclature of Bacteria* (ICNB), dan untuk organisme yang lain merujuk pada kesepakatan Internasional. Penulisan nama takson lengkap dengan nama author hanya dilakukan pada bagian deskripsi takson, misalnya pada naskah taksonomi. Penulisan nama takson untuk bidang lainnya tidak perlu menggunakan nama author.
5. Tata nama di bidang genetika dan kimia merujuk kepada aturan baku terbaru yang berlaku.
6. Untuk range angka menggunakan en dash (–), contohnya pp.1565–1569, jumlah anakan berkisar 7–8 ekor. Untuk penggabungan kata menggunakan hyphen (-), contohnya: masing-masing.
7. Ilustrasi dapat berupa foto (hitam putih atau berwarna) atau gambar tangan (*line drawing*).
8. Tabel
   Tabel diberi judul yang singkat dan jelas, spasi tunggal dalam bahasa Indonesia dan Inggris, sehingga Tabel dapat berdiri sendiri. Tabel diberi nomor urut sesuai dengan keterangan dalam teks. Keterangan Tabel diletakkan di bawah Tabel. Tabel tidak dibuat tertutup dengan garis vertikal, hanya menggunakan garis horisontal yang memisahkan judul dan batas bawah.

8. Gambar
   Gambar bisa berupa foto, grafik, diagram dan peta. Judul gambar ditulis secara singkat dan jelas, spasi tunggal. Keterangan yang menyertai gambar harus dapat berdiri sendiri, ditulis dalam bahasa Indonesia dan Inggris. Gambar dikirim dalam bentuk .jpeg dengan resolusi minimal 300 dpi, untuk *line drawing* minimal 600dpi.
9. Daftar Pustaka
   Sitasi dalam naskah adalah nama penulis dan tahun. Bila penulis lebih dari satu menggunakan kata 'dan' atau *et al*. Contoh: (Kramer, 1983), (Hamzah dan Yusuf, 1995), (Premachandra *et al*., 1992). Bila naskah ditulis dalam bahasa Inggris yang menggunakan sitasi 2 orang penulis maka digunakan kata 'and'. Contoh: (Hamzah and Yusuf, 1995). Jika sitasi beruntun maka dimulai dari tahun yang paling tua, jika tahun sama maka dari nama penulis sesuai urutan abjad. Contoh: (Anderson, 2000; Agusta *et al*., 2005; Danar, 2005). Penulisan daftar pustaka, sebagai berikut:

   a. **Jurnal**
      Nama jurnal ditulis lengkap.
      Agusta, A., Maehara, S., Ohashi, K., Simanjuntak, P. and Shibuya, H., 2005. Stereoselective oxidation at C-4 of flavans by the endophytic fungus *Diaporthe* sp. isolated from a tea plant. *Chemical and Pharmaceutical Bulletin*, *53*(12), pp.1565–1569.
   b. **Buku**
      Anderson, R.C. 2000. *Nematode Parasites of Vertebrates, Their Development and Tramsmission*. 2nd ed. CABI Publishing. New York. pp. 650.
   c. **Prosiding atau hasil Simposium/Seminar/Lokakarya.**
      Kurata, H., El-Samad, H., Yi, T.M., Khammash, M. and Doyle, J., 2001. Feedback Regulation of the Heat Shock Response in *Eschericia coli*. *Proceedings of the 40th IEEE Conference on Decision and Control*. Orlando, USA. pp. 837–842.
   d. **Makalah sebagai bagian dari buku**
      Sausan, D., 2014. Keanekaragaman Jamur di Hutan Kabungolor, Tau Lumbis Kabupaten Nunukan, Kalimanan Utara. Dalam: Irham, M. & Dewi, K. eds. *Keanekaraman Hayati di Beranda Negeri*. pp. 47–58. PT. Eaststar Adhi Citra. Jakarta.
   e. **Thesis, skripsi dan disertasi**
      Sundari, S., 2012. Soil Respiration and Dissolved Organic Carbon Efflux in Tropical Peatlands. *Dissertation*. Graduate School of Agriculture. Hokkaido University. Sapporo. Japan.
   f. **Artikel online.**
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      Himman, L.M., 2002. A Moral Change: Business Ethics After Enron. San Diego University Publication. *http:ethics.sandiego.edu/LMH/oped/Enron/index.asp*. (accessed 27 Januari 2008) bila naskah ditulis dalam bahasa inggris atau (diakses 27 Januari 2008) bila naskah ditulis dalam bahasa indonesia

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