Effect of crop intensity of soybean-cassava intercropping on storage capacity of soybean (*Glycine max* [L.] Merrill) seeds

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Abstract. Providing of high qualified soybean seeds with minimum germination capacity of 80% to increase soybean production, apart from being largely determined by quantity of seed produced, it is also determined by its storage capacity. The aim of this research was to determine the effect of crop intensity of soybean-cassava intercropping on the storage capacity of soybean seeds, both in non-air-conditioned storage room with temperature of ±26 ºC and air-conditioned storage room with temperature of ±18 ºC. Six levels of crop intensity of soybean-cassava intercropping, namely 100%, 134%, 145%, 147%, 156%, and 164% were implemented in a completely randomized block design (CRBD) with 5 blocks. The sixth soybean seed lots that harvested from the different experimental plots were packed in plastic bags and stored for 10 months in that storage room. Vigor of storage capacity was measured every two months for up to 10 months. The result showed that soybean seed lots obtained from the soybean-cassava inter cropping with crop intensity of 100-164% had a similar storage capacity in air-conditioned storage room, but there was different storage capacity among the seed lots in the non-air-conditioned storage room. Storing the seed lots under temperature of ±26 ºC, the storage capacity of soybean seed lot of the intercropping with crop intensity of 164% was not different from those of monocropping.

1 Introduction

Efforts to increase domestic production of soybeans (*Glycine max* [L.] Merrill) require land, seeds, fertilizer, pesticides and assistance. Land and soybean seeds are important production components. The Indonesian people's need for soybeans, which reach 2.61 million tons in 2023, was met by domestic production of 0.34 million tons [1] and imports of 2.27 million tons worth IDR 23.55 trillion [2] (Figure 1). With a productivity of 1.6 tons/ha, 1.0-1.5 ton/ha [3], or 1.54 ton/ha [4], 2.61 million tons of soybeans require a harvest area of 1,631,250 hectares with 65,250,000 kg of soybean seeds. If land productivity reaches 1,600 kg/ha of soybean seeds, then 40,781.25 hectares of land are needed to prepare that amount of seed.

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Apart from seeds, the availability of land to produce soybeans with monoculture planting is getting smaller, so it is necessary to produce soybean intercrops with other crops.

Soybean varieties Argomulyo, Dena-1, and Dega-1 are reported to be capable of high production to be intercropped with corn, which can achieve an average yield of 63.65% from monoculture planting [5]. Intercropping with sugar cane, the average soybean yield reached 1.56 tons/ha and with values of land use efficiency 1,41-2,21 [6]. The yield of Indonesian superior soybean varieties more than 2,0 ton/ha [7]. Regulating plant intensity of intercropping was very important so that the percentage reduction in soybean yield was not large 76.7%-88.5% [8].

Intercropping with cassava, the yield of soybean seeds Dega-1 reached 11.14 g/plant and was no different from that harvested from monoculture plantings at 10.95 g/plant, and the yield per area reached 70% of the monoculture crop yields. The initial vigor of soybean seeds harvested from intercropping with cassava showed germination capacity (93.7%) was no different from those harvested from monoculture (94.0%). Intercropping with sorghum, the soybean seeds yield of Grobogan was 835.67 kg/ha a bit lower than those of monocropping 906.52 kg/ha, and Argomulyo was 868.84 kg/ha a bit higher than those of its monocropping 854.67 kg/ha.

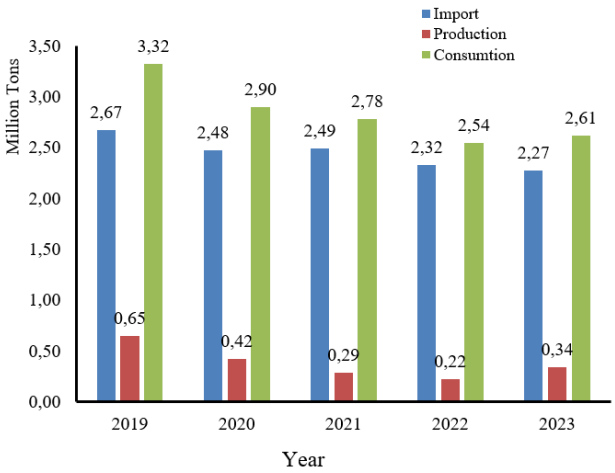

Fig. 1. Imports of Indonesian soybeans for the 2019-2023 period [2], domestic consumption, domestic production [1].

Indonesia's soybean harvest area in 2023 was still very small (218,740 hectares) with production of 0.34 million tons [1]. Soybean planting intercropped with cassava planting in Lampung Province can reach an area of 207,000 ha and throughout Indonesia it can reach 550,225 ha [9], In 2023, the cassava harvest area reached 618,270 ha, and corn 2,480,000 ha [1]. The potency for increasing soybean production through intercropping with cassava and corn is enough high. The success of multiple crops, apart from being able to harvest two kinds of results, it can save time for production and reduce crop failures, save land, improve soil fertility [10], reduce erosion [11] and increasing the efficiency of using environmental factors [12], suppressing pest attacks pests [13], improving the nutritional quality of animal feed [14], and increasing of water use efficiency [15]. It is necessary to regulate plant intensity in intercropping to minimize the occurrence of shading which can reduce production and starch content, amount of leaf chlorophyll, stomatous conductivity, and nitrate reductase activity, thereby reducing plant growth and production. Lack of light reduced nitrate reductase activity and was also influenced by genotype.

Since the issuance of the Decree of the Minister of Agriculture of the Republic of Indonesia [16], certified seed production can be carried out using a monoculture planting system or an inter-cropping system. Because the available seeds are not always planted immediately, but must be stored until the planting season arrives, apart from having a high initial vigor (IV), the seeds must also have a high vigor of storage capacity (VSC) and storage capacity (SA). Although information showed that different seed growth environments (induced factors) did not cause differences in initial vigor, the effect of intercropping on storage capacity and/or seed storage capacity is not yet known. On the other hand, the process of seed deterioration during storage varies even between individual seeds in one seed lot [17]. Thus, the storage capacity of soybean seeds harvested from intercropping with cassava may not be the same as those harvested from monoculture plantings. This research aimed to determine the effect of crops intensity of the soybean-cassava intercropping on storage capacity of soybean seeds, both in room temperature (±26 ^{o}C) and air-conditioned (±18 ^{o}C) rooms.

2 Materials And Methods

2.1 Place and time

This research was carried out on the agricultural land of the Horticulture Main Seed Center in Sekincau District, West Lampung Regency from 11 June 2022 to 11 September 2022 for an experiment in producing soybean seeds intercropping with cassava. The Seed storage research was carried out at the Seed and Plant Breeding Laboratory, Faculty of Agriculture, University of Lampung on 1 October 2022 – 15 August 2023.

2.2 Materials and equipments

Soybean seeds of the Dega-1 variety, a white-labeled foundation seed class obtained from the Legume and Tubers Research Institute in Malang, East Java, and local waxy cassava clones were used in the research. Soybeans were planted intercropping with cassava with different soybean and cassava crop intensities. Equipment used in this experimen includes a) land processing equipment such as plows and harrows, b) materials and equipment for controlling soybean plant pests such as pesticide and sprayer, c) equipment for harvesting and seed handling equipment such as sacks, sickles, winnowing baskets, and seed blower, d) equipment for seed storaging such as plastic bags and bracket, and e) equipment for testing seed storage capacity included CD (opaque) paper, plastic sheets, germinator, electric conductivity meter brand Kedida, and drying oven brand Memmert.

2.3 Experimental design and data analysis

This experiment used a single factor treatment which was implemented in a completely randomized block design (CRBD) with 5 blocks as 5 replications. The single factor treatment was crop intensity (T) in intercropping of soybeans (S) and cassava (C) which consisted of six levels, namely t_1 = 100% crop intensity (100%S + 0%C), t_2 = 134% crop intensity (67%S + 67%C) t_3 = 145% crop intensity (67%S+78%C), t_4 = 147% crop intensity (50%S + 97%C), t_5 = 156% crop intensity (67%S + 89%C), and t_6 = crop intensity 164% (67%S + 97%C) (Table 1).

Data analysis for testing the hypothesis included 1) testing the assumption of homogeneity of variance between treatments using the Bartlett Test, 2) testing the assumption of addition of observational data using the Tukey Test, 3) analysis of variance test, 4)

regression analysis to obtain the equation of line of vigor of storage capacity (VSC) of seeds lots harvested from the soybean-cassava inter-cropping with different crop intensity stored for 0-10 months with 2 month of observation, 5) Student's t-test to compare the VSC of soybean seeds stored in a room with a temperature of ±26 ºC and in a room with a temperature of 18 ºC, and BNJ Tukey to compare the VSC and SC among seed lots harvested from the soybean-cassava intercropping with different crop intensities. Each test used a significance level of 5%.

Table 1. Treatment levels of plant intensity in soybean-cassava intercropping (PISCIC), planting distance (PD), number of planting holes per 20 m² (NPH), and intercropping pattern (ICP)

Treatment levels		Cassava			Soybean			ICP[c)]
PISCIC		PD	NPH	%[a)]	PD	NPH	%[b)]	
t_1	100%		0	0	40x15	300	100	-
t_2	134%	120x60	24	67	40x15	200	67	1-2
t_3	145%	120x50	28	78	40x15	200	67	1-2
t_4	147%	120x50-60x50	35	97	40x15	150	50	2-2
t_5	156%	120x45	32	89	40x15	200	67	1-2
t_6	164%	110x50	35	97	30X15	200	67	1-2

Note: [a)] the percentage was calculated as cassava NPH/36; [b)] percentage was calculated as soybean NPH/300, and [c)] first number was rows of cassava and second number was rows of soybean.

2.4 Execution of the experiment

The land was cultivated using a plow and harrow. The experimental plot was made measuring 5 m x 4 m. Soybean seeds of 2-3 grains were planted 3-5 cm deep in alternating rows with cassava plants planted on the same day. The spacing of soybeans and cassava, the arrangement of rows of plants in the intercropping pattern, the percentage of plant types in the intercropping, and the intensity of the plants are presented in Table 1. Cassava cuttings of 25 cm were stuck at the base into the soil to a depth of 5 cm in an upright position. The direction of the row of plants was East-West. The appearance of the experimental soybean-cassava intercropping is presented in Figure 2.

The soybean and cassava plants were given their own dose of fertilizer. Fertilizer doses for cassava were 200 kg/ha Urea, 100 kg/ha SP-36, and 100 kg/ha KCl. The first fertilization was given to 1 month old cassava plants with 2/5 of the urea dose (80 kg/ha) and all the doses of SP-36 and KCl and the second fertilization was given to 3 month old cassava plants with 3/5 of the remaining urea dose. Fertilizing cassava uses the tugal method (1.5 m long stick with a pointed tip), the fertilizer hole was made as depth of 5 cm using the tugal and fertilizer were inserted into the hole and backfilled with soil. Soybeans were given 75 kg/ha of Urea, 100 kg/ha of SP-36, and 50 kg/ha of KCl which were applied twice in a furrow manner. The first fertilizer was applied to 2 weeks old soybean plants with one third of the dose of urea (25 kg/ha), the entire dose of SP-36, and the entire dose of KCl. The second fertilizer was given to 4 weeks old soybean plants with 2/3 of the remaining urea dose.

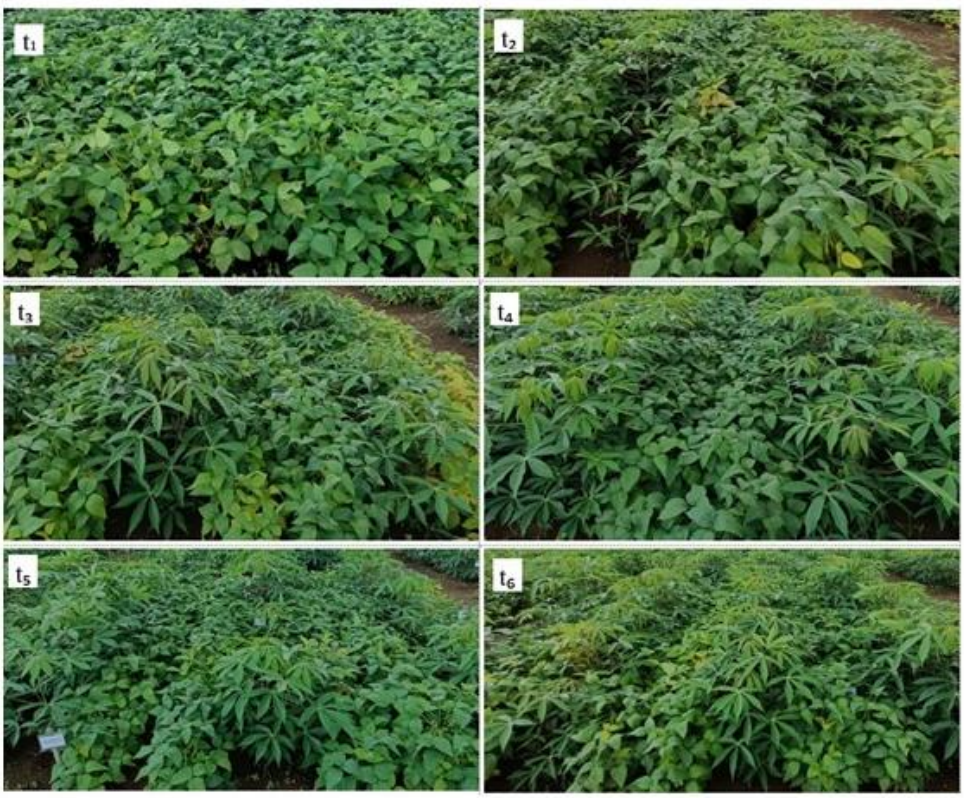

Fig. 2. The appearance of the experimental soybean-cassava intercropping; t_1-t_6 are levels of treatment as presented in Table 1

Soybean seeds were harvested 92 days after planting. Soybean pods were dried in the sun until the pods were dry and easy to break to remove out the seeds. The seeds were then continued sun-dried until the seeds reached a moisture content of 9-10%. Then, the seeds were collected, weighted, and prepared for storage to measure the vigor of storage capacity of seeds and the storage capacity of seeds. The clean and dry soybean seeds were packaged in plastic bags with clips and one lot of seeds were stored in a room temperature of ±26 ºC and the other lot was stored in an air-conditioned room with a temperature of ±18 ºC for 10 months. Vigor of storage capacity (VSC) of seeds was measured at 0, 2, ..., and 10 months by measuring germination capacity (GC) and germination speed (DS). The VSC supporting variables measured were seed moisture content (MC) and electrical conductivity (EC).

2.5 Observation and measurement

Vigor of storage capacity (VSC) was the vigor of seeds during storage [18]. The VSC value was calculated as the average of seed vigor from observations at 0, 2,..., 10 months of storage from the variables germination capacity (GC), germination speed (GS), seed moisture content (MC), and electrical conductivity (EC)**.** Thus, there were four VSC variables measured, namely a) VSC-GC = ⅙ x $\sum GC_i$; b) VSC-GS = ⅙ x $\sum GS_i$; c) VSC-MC = ⅙ x $\sum MC_i$; and d) VSC-EC = $\sum ECi$ {I=0, 2,…, 10}.

Storage capacity (SC) was calculated from the VSC of germination capacity (VSC-GC) line equation, $\tilde{y}=f(x)$. Storage capacity was the value of x from the $\tilde{y}=of(x)$ where f(x) =80.

The function ỹ=f(x) was a line obtained from the regression between germination capacity as y and storage period as x. The VSC line of ỹ=f(x) were a sigmoidal line form [19], or a linear line form.

Germinating of seeds was carried out using the rolled paper test (RPT) method using CD paper (opaque) layered with a sheet of plastic [20] and placed in a seed germinator Type of IPB 75-1. Normal sprout (NS) counting was carried out starting from the second day after germination (DAG) successively until 5 DAG. Germination capacity was calculated using formula GC = ∑ PNSi. Germination speed was calculated using a formula, GS= ∑ PNSi /Ti where *i*={2, 3,…, 5} was the DAG of when the normal sprouts calculated, and PNS = percent of normal sprouts, was the number of normal sprouts divided by 30 of seeds. Electrical conductivity (EC) was measured in the soaking water of 5 soybean seeds for 24 hours using a Kedida EC meter. The EC measurement results were expressed in units of µS/cm/g/50 mL. Seed moisture content was measured using a direct method by weighing three seeds before and after drying in a Memmert oven for 72 hours of 80 C. Water content was expressed in percent based on wet weight.

3 Results and discussion

3.1 Assumption testing and analysis of variance

The results of the assumption test and analysis of variance of the data of variables measured were summarized in Table 2. It was evident that the data in each variable showed a homogenous variance among treatments (P > 0.05) and an additive model (P > 0.05). The intensity of soybean-cassava intercropping did not affect the storage capacity (SC) and vigor of storage capacity (VSC) of soybean seeds during storage in an air-conditioned room at a temperature of ±18 ºC, but it affected them in a storage room at a room temperature of ±26 ºC.

Table 2. P-values of Bartlett's test for homogeneity of variance (HOV), non-additivity test of observed data (NA), and F-test for effect of the treatment (FET)

No	Variables	HOV	NA	FET
Soybean stored in the air-conditioned room at ±18 ºC				
1	Seeds Storage capacity (SC) (month)	0,86	0,83	0,44
2	Vigor of storage capacity of germination capacity (VSC-GC) (in %)	0,33	0,09	0,65
3	Vigor of storage capacity of germination speed (in %/day)	0,33	0,11	0,61
4	Moisture content of seeds (MCS) (in %)	0,64	0,44	0,67
5	Electric conductivity (EC) (µS/cm/g/50mL	0,67	0,39	0,06
Soybean stored in the room temperature ±26 ºC				
1	Seeds Storage capacity (SC) (month)	0,22	0,71	0,00
2	Vigor of storage capacity of germination capacity (VSC-GC) (in %)	0,74	0,17	0,04
3	Vigor of storage capacity of germination speed (in %/day)	0,67	0,33	0,04
4	Moisture content of seeds (MCS) (in %)	0,73	0,78	0,96
5	Electric conductivity (EC) (µS/cm/g/50mL	0,23	0,76	0,36

Note: When P-values > 0.05 the test was non-significant, and when P<0.05 the test was significant

3.2 Vigor of storage capacity (VSC) of soybean seeds

In an air-conditioned storage room (temperature ±18 ºC), VSC of soybean seeds, both VSC-GC and VSC-GS during 10 months of storage did not differ between lots of seeds harvested from inter-cropping with cassava with various crop intensities. The storage capacity of soybean seeds harvested from monoculture planting (plant intensity 100% (100S+0C)) is not different from that harvested from inter cropping. Soybean seeds harvested from monoculture plantings (plant intensity 100S+0C) and those harvested from soybean-cassava inter cropping all intensities had no different VSC-GC or VSC-GS (Figure 3).

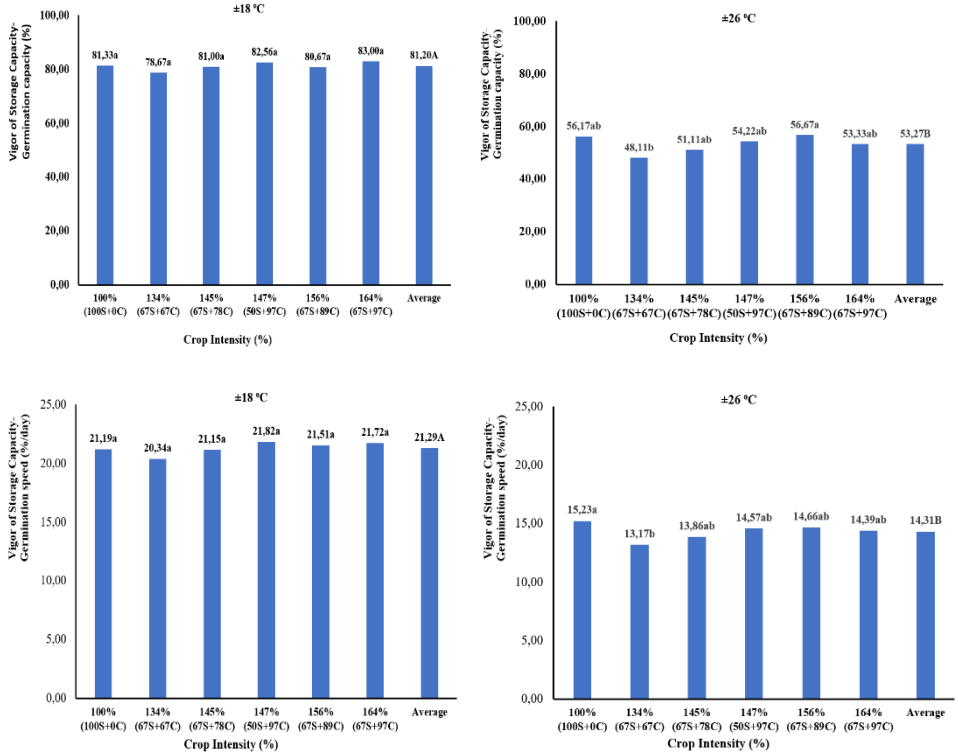

Fig. 3. Effect crop intencities in the soybean-cassava intercropping on vigor of storage capacity of germination capacity (VS-GC), and vigor of storage capacity of germination speed (VSC-GS) during storage under air-conditioned room with temperature of ±18 ºC (left) and room temperature of ±26 ºC (right). The Numbers of two bars followed by a same small letter in the same chart is not different significantly according to Tukey's HSD test 5%. Numbers of two bars followed by a different capital letter of the differ charts and of the same variable is different significantly according to T-test of 5%.

In a non-AC room at room temperature (±18 ºC), the VSC of both VSC-GC and VSC-GS showed a slight difference (Figure 3). Harvested seeds from soybean-cassava intercropping with a crop intensity of 134% (67S+67C) had a lower VSC than those from monoculture or from intercropping with a crop intensity of 156% (67%S+89C). The crop intensity of 134% was consisted of soybean 67% and cassava 67%, and it was the lowest of crop intensity.

The low VSC was thought to be related to the fertilizer application applied to the inter-cropping, which was 67% of the fertilizer dose of soybeans and 67% of the fertilizer dose of

cassava. This amount was lower than those applied on the inter cropping with crop intensity of 156%. In this experiment, each type of plant in the inter cropping was given fertilizer with an independent dose. The amount of fertilizer applied and the interaction between types in the soybean-cassava intercropping were seen in the VSC in the non-AC storage room, but it did not appear in the air-conditioned storage room. The effect of the amount of fertilizer poured in the intercropping and the effect of interaction between plant types were seen in the VSC germination capacity and in the VSC germination speed (Figure 3). The dose of P_2O_5 fertilizer of 226 kg/ha applied to monocropping soybean plants provided seeds with maximum germination capacity and vigor of soybean seeds in monocropping soybean plants.

3.3 Storage Capacity (SC) of Soybean Seeds

In an air-conditioned room with a temperature of ±18 ºC, the storage capacity of soybean seeds harvested from soybean-cassava intercropping with different crop intensities showed no difference and was on average 6.90 months (Figure 4). In a room without air conditioning with a temperature of ±26 ºC, the storage capacity of soybean seed harvest of soybean-cassava intercropping with a planting intensity of 134-156% were lower (2,95-3,98 months) than those seeds from monocropping (planting intensity of 100%) (5.44 months), but did not differ to those seeds from the intercropping with crop intensity of 164% (4,17 months). Meanwhile, the storage capacity of soybean seeds that harvest from soybean-cassava intercropping with crop intensity of 164% (4,17 months) was not differ to those harvests of monocropping (5,44 months). Thus, intercropping of soybean-cassava with crop intensity of 164% was better than other crops intensities. The average storage capacity in non-AC storage room was 3.98 months (Figure 4).

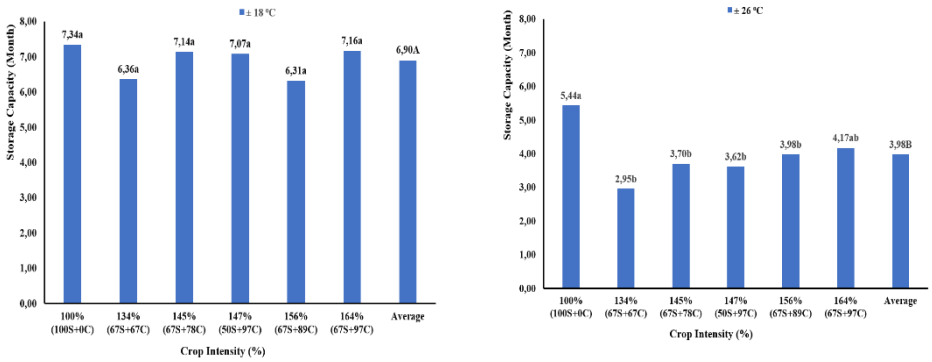

Fig. 4. Effect crop intensity in the soybean-cassava intercropping on storage capacity (SC) of seeds during storage under air-conditioned room with temperature of ±18 ºC (left) and room temperature of ±26 ºC (right). The Numbers of two bars followed by a same small letter in the same chart is not different significantly according to Tukey's HSD test 5%. Numbers of two bars followed by a different capital letter of the differ charts and of the same variable is different significantly according to T-test of 5%.

Storage capacity was related to vigor of storage capacity (VSC) and VSC was closely related to seed deterioration. The line of vigor of storage capacity of germination capacity during storage period of 0-10 months in an air-conditioned room with a temperature of ±18 ºC showed an average decline rate of ±3%/month, lower than the decline rate in a room without air conditioning, an average of ±9%/month. (Figure 5).

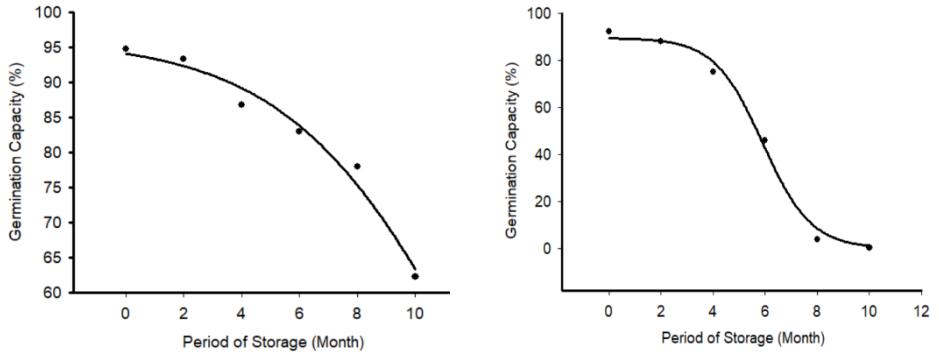

Fig. 5. The relationship between period of storage and germination capacity under airconditioned room with temperature of ±18 ºC (*left*) and non airconditioned room with temperature of ±26 ºC (*right*).

3.4 Seeds moisture content (MC) and electrical conductivity (EC)

Plant intensity soybean-cassava intercropping did not cause differences in average moisture content of seeds during the 0-10 months, both in air-conditioned and non-air-conditioned rooms (Table 2). In an air-conditioned room, the average seed moisture content was 12.30%, while in a room without air-conditioning it was 13.66% (Figure 6). With a higher

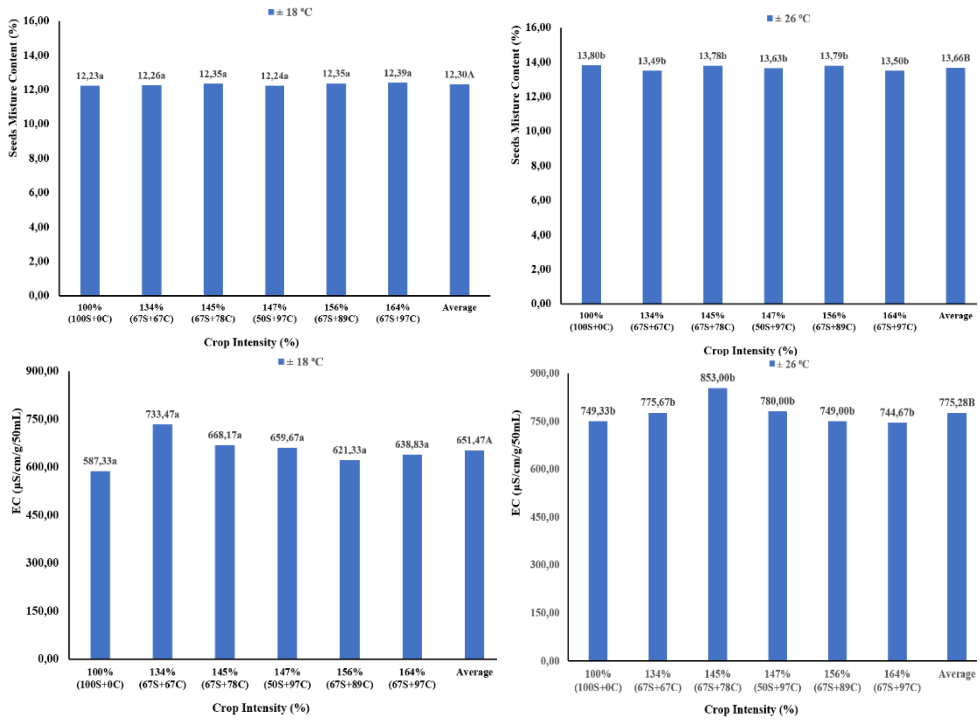

Fig. 6. Effect crop intensity in the soybean-cassava intercropping on seeds moisture content (SMC) and electric conductivity (EC) during storage under room temperature of ±18 ºC (left) and ±26 ºC (right). The Numbers of two bars followed by a same small letter in the same chart is not different significantly according to Tukey's HSD test 5%. Numbers of two bars followed by a different capital letter of the differ charts and of the same variable is different significantly according to T-test of 5%.

water content (13.66%), during 0-10 months of storage in a non-AC room, soybean seeds experienced higher cellular membrane damage than those stored in an air-conditioned room. This was indicated by the electrical conductivity value of 775.28 µS/cm/g/50 mL, which was greater than the EC of seeds stored in an air-conditioned room of 651.47 µS/cm/g/50 mL.

The rate of increase in water content during 0-10 months of storage in an air-conditioned room (9.96-17.25%) was around ±0.67%/month (noticeably higher than seeds stored in an air-conditioned room ±0.64 %/month (Figure 7), (9.96-16.48%). In line with the increase in seed MC, the damage to the cellular membrane in the seed also increases as shown by the electrical conductivity meter (EC) of the seed, which in a room without air-conditioning at a rate of 36.54 µS/cm/g/50 mL per month (from 579-940) was higher than that of the seed. Store in an air-conditioned room (from 579-762), 16.87 µS/cm/g/50 mL per month.

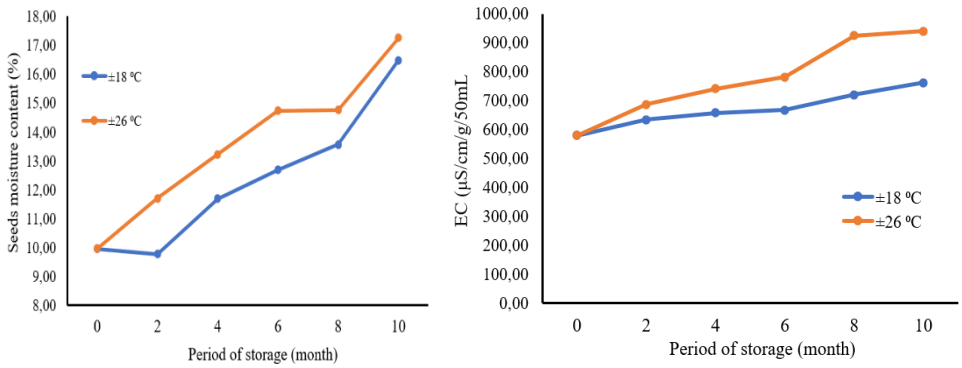

Fig. 7. Effect of period of storage on seeds moisture content (*left*) and electric conductivity (EC) (*right*) of seed lot under room temperature (±26 ºC) and air-conditioned room temperature (±18 ºC).

The increase in MC of soybean seeds, which are still in airtight plastic bags, during storage is strongly suspected to be caused by the rapid seed respiration process. Respiration always produces CO_2 and H_2O. The longer the storage period was, the H_2O released into the environment of seeds was reabsorbed by seeds and it increased the moister content of seeds. It was clear that the water content of soybean seeds at the beginning of storage, 9-10%, was a driver of seed deterioration in storage, Both in non-AC and air-conditioned rooms (Figure 5). A paper informed that soybean seeds with a water content of 7% stored in a non-AC room with a temperature of 27 ºC or in a refrigerator with a temperature of 6 ºC still have KA 7.05% and 6.95% with germination capacity still high at 95.00% and 96.25% after 2 months of storage [21]. It shows that at a low water content of ±7%, soybean seed respiration is thought to still be slow, so that the water vapor from respiration in the container that is reabsorbed is also very small. One more piece of evidence was shown that soybean seeds with an initial water content of ±7% stored in an airtight container for 4 months in a room without air conditioning, they kept their water content of 6.92% and germination capacity of 98.40%. The initial water content of soybean seeds of ±7% greatly supported the slowing down of deterioration during storage, while the seeds initial water content of 9-10% still caused high respiration, so that during storage of 0 to 10 months in room temperature of ±26 ºC and even in air-conditioned rooms of ±18 ºC, it still increased the water content of the seeds, increase seed deterioration, reduced germination capacity, and reduced seed storage capacity.

4 Conclusions and recommendations

Crop intensity of 100-164% in soybean-cassava intercropping did not affect storage capacity of soybean seeds in air-conditioned storage room with temperature ±18 ºC, namely at an average of 6.90 months, but it affected significantly to storage capacity in the non-air-conditioned storage room with temperature ±26 ºC, namely at an average of 3.98 months. Soybean seeds harvested from the soybean-cassava intercropping with crop intensity of 164% had a similar storage capacity to those harvested from monocropping in the storage room with temperature of ±26 ºC.

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6 Authors contribution

All authors played a role in carrying out this research and writing the paper. Muhammad Syamsoel Hadi helped carry out field research and data analysis. Kukuh Setiawan assisted in completing the writing of the manuscript and slides for presentation. Muhammad Kamal helped carry out measurements in the laboratory. This research was designed and carried out by Eko Pramono.

7 Conflict of interest

All authors have read and approved of the final manuscript. The authors declare that they hold no competing interests.

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