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Development stages of soybean varieties against pod sucking pest *Riptortus linearis* F. (Hemiptera: Alydidae) under two different cultivation technologies

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Abstract. Pod sucking pest, *Riptortus linearis*, is one of the important pests on soybeans which cause high yield losses. In order to reduce yield loss, information related to the development stages of resistant varieties and appropriate cultivation technology is needed. This study aimed to determine the relationship between the development stages of soybean varieties and cultivation technology on the population and intensity of pod sucking pests, *R. linearis,* attack and soybean yield. The study was conducted in a split plot design with two factors, namely cultivation technology [recommendation technology (TR) and existing technology (TE)], and soybean varieties: [Detap-1 (V1), Dega-1 (V2), Anjasmoro (V3), Biosoy (V4), and Dena-1 (V5)]. Each treatment combination was replicated three times resulting in 30 experimental plots. The results showed that soybean varieties affected the population and intensity of *R. linearis*. Development stages of soybean varieties that positively correlated with pest populations were plant height with a correlation coefficient value $r = 0.52$, followed by pod trichome density ($r = 0.12$), and the number of pods attacked ($r = 0.49$). While the character that correlated with the intensity of pest attack was the density of trichomes ($r = 0.20$). Recommended cultivation technology can increase soybean productivity between 0.1 – 0.47 ton/ha compared to farmers' existing technology.

Keywords: cultivation, development, soybean, *Riptortus linearis*, varieties

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the strategic food crop commodities after rice and corn, which serves as a source of vegetable protein, raw material for various food processing industries and raw materials for the animal feed industry. In addition, the vegetable protein content in soybean is very important for improving public nutrition, which is safe and relatively cheaper than animal protein [1]. The average soybean need per capita in 2013-2017 was 6.59 kg/capita/year, and continues to increase along with population growth [2]. This causes the demand for soybean to continue to increase far beyond domestic production.

In 2018, the national soybean production was 982,598 tonnes and could not meet the national needs so the government imported 2,585,809 tonnes of soybean. The low domestic soybean production is caused, among others, by the low interest of farmers in soybean cultivation, low productivity at the farmer level, low adoption of soybean cultivation technology, underdeveloped partnerships as well as pest and disease attacks [3], the use of low-quality and inadequate certified varieties, traditional cultivation technology, and unintegrated pest and disease control [4].

The presence of pests is one of the biotic factors that become an obstacle in increasing soybean productivity. There are 15 main pests on soybean plants that have an impact on soybean productivity, one of which is the pod sucking pest *Riptortus linearis* [5]. Pod sucking pests *R. linearis* can cause seed damage up to 79% [6]. Yield loss reaches 80% and can even cause a total loss if not controlled [7]. The area of *R. linearis* pest attack in 2018 on soybean plants in West Nusa Tenggara Province was reported to be 111 ha and in Central Lombok Regency an area of 10.10 ha [8]. The results of the study by Sarjan and Sab'i [9] showed that the morphological characteristics of soybean plants in the form of pod shell thickness had a strong relationship with the intensity of *R. linearis* attack, the higher the soybean pod shell thickness, the lower the attack intensity. Furthermore, it was stated that tight and long trichomes reduce the number of pod-sucking stylet puncture wounds [10]. Therefore, the increase in productivity is achieved through the use of improved varieties obtained by assembling new improved varieties that are high yielding, drought tolerant and resistant to pest attack [11].

In addition, planting soybean varieties that are tolerant of pests will reduce damage to crops and the use of insecticides, thus providing economic, environmental and human health benefits [12]. In addition to soybean varieties, cultivation technology also affects the intensity of attack and yield loss caused by pod sucking pests *R. linearis.* The use of technology such as the use of certified seeds, new improved varieties, spacing, and proper fertilization can increase plant resistance to pests and diseases as well as increase soybean yield and farmers' income [13].

One of the emphases on recommended cultivation technology is setting the spacing and controlling the number of plant populations which are believed to be able to increase soybean yield per unit area. The optimum plant density to produce maximum productivity varies between plants, between genotypes, and between locations [14]. The application of soybean recommendation technology in Bima Regency by applying a spacing of 60 – 30 x 10 cm *jajar legowo* was able to increase the yield of soybeans of the Anjasmoro variety by 2.8 tonnes compared to the farmers existing practices which only reached 1 ton [15]. This study aimed to determine the relationship between the development stages of five soybean varieties and cultivation technology on the population and attack intensity of the pod sucking pest *R. linearis* and soybean yield.

2. Materials and Methods

This research was conducted from September to December 2020 in the rice fields of Setanggor Village, West Praya District, Central Lombok Regency, West Nusa Tenggara (WNT) Province of Indonesia. The experimental design used was a Split Plot Design with two factors. The first factor was cultivation technology: Recommended Technology (TR) and Farmers' Existing Technology (TE). The second factor was soybean varieties: Detap-1 (V1), Dega-1 (V2), Anjasmoro (V3), Biosoy (V4) and Dena-1 (V5) which replicated 3 (three) times to obtain 30 experimental plots. The experimental site was a central location for soybean production and there has been an attack by soybean pod sucking pests. Land preparation was without tillage (no tillage) starting with cleaning weeds and the former base of the rice stalks, drainage channels were made at the edges of the plots, and the area of each treatment plot was made in 4 m x 5 m. Furthermore, planting, weeding, fertilizing and controlling pests were conducted according to the treatment (Table 1).

Development stages of soybean plants observed were: (1) flowering time, (2) plant height, (3) number of branches, (4) total number of pods, (5) number of filled pods, (6) number of infected pods, (7) pod shell thickness, (8) pod trichome density, (9) pod trichome length, and (10) yield. Observations were made at the age of 10, 11 and 12 weeks after sowing (WAS). Observation of parameters of pod shell thickness was observed using a micrometer screw, length and density of trichomes were observed using a Meiji binocular microscope with an area of 100x100 m^2 at a magnification of 10x4. The imago population of pod-sucking pests was carried out by catching imago using Sweep net with two swings on each treatment plot, while the attack intensity was calculated using the attack intensity formula according to Gatut and Muchlis [16].

$I = [a/(a+b)] \times 100\%$
I = attack intensity of the pest (%)
a = number of attacked pod
b = number of un-attacked pod

All collected data were analyzed for variance followed by the honestly significant difference (HSD) for parameters with significant difference at a level of 5%. Regression and correlation analysis were used to examine the influence and how strong the influence between parameters.

Table 1. Differences in treatments between technology recommendations and farmers existing technology.

Activities	Cultivation Technology	
	Recommendation	Farmers Existing Practices
Sowing	Hand sowing at 2-3 cm depth, planting space 40 x 20 cm, 2 seeds/hole	Spread on each varietal plot without spacing, with the same amount of seeds as the recommended technology treatment
Weeding	Weeding at 14 and 50 DAS	No weeding
Fertilizing	NPK Phonska fertilizer (200 kg/ha) applied at 14 DAS by sowing between rows of plants	NPK Phonska fertilizer (100 kg/ha) applied at the sowing time
Pest and Disease control	Intensive control during the vegetative phase	Intensive control during the vegetative phase
Irrigation	Irrigated at the pre-sowing, flowering phase and pod filling phase	Irrigated at the pre-sowing, flowering phase and pod filling phase

3. Results and Discussion

Of the five soybean varieties tested, flowering ages ranged from 4-5 WAS. The earliest flowering age was found in the Dega variety (4 WAS) followed by four other varieties (5 WAS). The difference in the flowering age of soybean varieties is a marker of soybean plants entering the generative growth phase and is influenced by the characteristics of each variety [17]. The treatment of cultivation technology did not significantly affect the age of flowering (Table 2). For the plant height performance of the five varieties, the variety with the highest average plant height was Dena (68.85 cm) followed by Anjasmoro (61.1 cm), Detap (55.98 cm), Dega (48.03 cm) and the lowest was Biosoy (40.4 cm). The treatment of cultivation technology had a significant independent effect on plant height with the recommended technology was higher (58.09 cm) than the existing technology (51.65 cm).

Differences in plant height in cultivation technology are caused by different spacing treatments and fertilizer doses. It was stated that a looser spacing stimulated the formation of leaves, branches, and increased dry weight of plants [18]. The combination of treatments did not show a significant effect on plant height. Similarly, there was no significant difference in the number of branches of the five varieties. Furthermore, the total number of pods was only affected by the soybean varieties but was not affected by cultivation technology, with the highest total number of pods was in Anjasmoro (49.94), followed by Dena-1 (49.5), Detap-1 (47.5), Biosoy-1 (43.06) and the lowest one was in Dega-1 (32.55) (Table 2).

Table 2. Development stages of soybean varieties in two cultivation technologies.

Variety	Flowering Age (WAS)			Plant Height (cm)			Number of Branches			Number of Pod		
	TR	TE	Average	TR	TE	Average	TR	TE	Average	TR	TE	Average
Detap	5,00b	5,00b	5,00 b	57.97	54.00	55,98 b	2.60	2.67	2.63	56,78	38,22	47,50 a
Dega	4,00c	4,00c	4,00 c	54.23	41.83	48,03 c	2.67	2.23	2.45	38,44	26,67	32,55 b
Anjasmoro	5,00b	6,00a	5,00 b	65.00	57.2	61,10 b	2.50	2.93	2.72	51,00	48,89	49,94 a
Biosoy	5,00b	5,67a	5,00 b	42.13	38.67	40,40 c	2.40	2.20	2.30	44,89	41,22	43,06 ab
Dena	5,00b	5,00b	5,00 b	71.13	66.57	68,85 a	3.13	3.07	3.10	53,56	45,44	49,50 a
Average	5,00b	5,00b	5,00 b	58,09 a	51,65 b		2.66	2.62	2.64	48,93	40,09	
HSD 5%		0.54			5,41	5,25		-			-	11,84

3.1 Population and intensity of pod sucking pests of R. linearis on five soybean varieties under two cultivation technologies

There was different population of imago *R. linearis* between soybean varieties, the highest population was in Dena-1 (1.9 imagos/plant), followed by Detap-1 (1.7 imagos/plant), Anjasmoro (1.6 imagos/plant), Dega-1 (1 imago/plant) and Biosoy-1 (0.9 imago/plant). The treatment of cultivation technology did not show a significant effect on *R. linearis* population (Figure 1). The uniform distribution of imago populations in all treatments was due to *R. linearis* having a very strong flight power [18] and it is determined by the availability of food, according to Marwoto [7], if food is available in the plantation, the *R. linearis* pest is able to breed throughout the year. *R. linearis* attack on soybean pods began to be found at the age of 9 WAS or the pod formation phase, but at this phase the attack intensity was still low, this was because the seeds were not fully formed so they were not favoured by sucking pests. This is in accordance with the results of research by Koswanudin and Djuwarso [19] which stated that *R. linearis* did not like soybeans in the pod formation phase (R3-R4). Attacks began to be found at the age of 10 WAS and continued to increase with increasing soybean plant biomass. This is in accordance with Marwoto [7] which stated that the availability of abundant food is one of the factors for the emergence of pest attacks. Meanwhile, it was stated that crop damage will increase in line with the increase in biomass (Figure 1) [7].

The attack intensity of the pod sucking pest *R. linearis* in the pod filling phase up to the seed ripening phase (R5 - R8) was different for each variety, with a range of 7.22% - 29.87% (10 WAS), 19.66% - 39.60% (11 WAS) and 20.98% - 43.53% (12 WAS). At the age of 10 WAS the affected soybean pods become dry and fall off. The fall of the pods was caused by the cessation of the food supply to the pods due to damaged seed tissue [20], then at the age of 11 WAS the affected pods showed symptoms in the form of seeds becoming deflated and then drying, and according to Sunarno [21], this age is the most severe phase favoured by *R. linearis* and causes the highest yield damage and lost. The age of 12 WAS was the ripening phase of the seeds and some of the seeds started to harden so that they were less favoured by pests of *R. linearis*. This condition increases the tolerance of the plant to pests. When the pods have begun to harden, it interferes with the stylet nymph or imago of *R. linearis* to suck liquid from soybean pods [22].

Symptoms of the attack in the form of puncture marks on the brown seeds that damage the quality of the seeds. The results of the analysis showed that there was an influence of varieties and cultivation technology at the age of 10 WAS and 12 WAS. At the age of 10 WAS the attack intensity of *R. linearis* was influenced independently by cultivation technology, at which intensity of attack in the recommended cultivation technology (11.98%) was lower than the farmers' existing technology (22.40%). However, at the age of 12 WAS, it was influenced independently by soybean varieties with the lowest intensity was in the variety Biosoy-1 (26.08% b) followed by Dega-1 (27.98% ab), Detap-1 (36.36% ab), Dena-1 (35.02% ab) and the highest was Anjasmoro (37.56% a). In addition, the combination of treatments had no significant effect on attack intensity at the three ages of observation (Table 3).

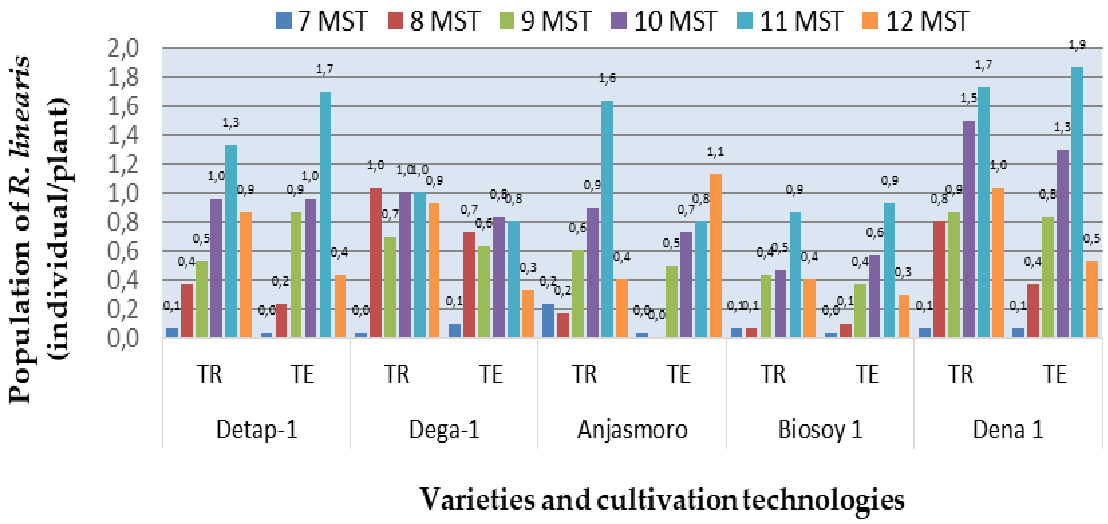

Figure 1. Population trends of *R. linearis* in five soybean varieties with two cultivation technologies

Table 3. Effect of soybean varieties with cultivation technology on the attack intensity of *R. linearis* at 10, 11 and 12 WAS

Observation Time	Variety	Cultivation Technology		Average
		Recommendation	Farmers Existing Practice	
10 WAS	Detap-1	7,22	22,76	14,99
	Dega-1	15,56	29,87	22,71
	Anjasmoro	13,02	18,10	15,56
	Biosoy-1	11,82	21,74	16,78
	Dena-1	12,28	19,56	15,92
Average		11,98 b	22,40 a	
HSD 5%		0.02		- -
11 WAS	Detap-1	25,96	36,19	31,08
	Dega-1	23,25	30,50	26,87
	Anjasmoro	27,33	35,61	31,47
	Biosoy-1	19,66	30,87	25,26
	Dena-1	25,25	39,60	32,43
Average		24,29	34,55	
HSD 5%		- -		- -
12 WAS	Detap-1	29,18	43,53	36,36 ab
	Dega-1	20,98	34,98	27,98 ab
	Anjasmoro	33,38	41,74	37,56 a
	Biosoy-1	22,18	29,98	26,08 b
	Dena-1	35,05	34,99	35,02 ab
Average		28,15	37,04	
HSD 5%		-		0.04

3.2 Relationship of population and attack intensity with flowering age, plant height, trichome length, trichome density and skin thickness of soybean pods

Of the seven agronomic parameters observed, three parameters correlated with the population of *R. linearis*, namely plant height, trichome density and number of infected pods with correlation coefficient (r) respectively r = 0.52, r = 0.12 and r = 0.49, and two parameters that correlated with the intensity of attack of the pod sucking pest *R. linearis*, namely the density of trichomes (r = 0.20) and the number of pods attacked (r = 0.26). While the other three parameters showed a very weak correlation (r < 0.19), namely flowering time, number of branches, trichome length and bark thickness (Table 4).

Table 4. Relationship of development stages of soybean with imago population and attack intensity of *R. linearis* as shown by the correlation coefficient

	Flowering Time	Plant Height	Number of Branches	Trichome Length	Trichome Density	Shell Thickness	Attacked Pod
Imago population	0,02	0,52	0,04	0,06	0,12	0,03	0,49
Attack Intensity (%)	0,02	0,04	0,03	0,05	0,20	0,01	0,26

According to Sugiyono [23], the correlation coefficient interval (r) show the strength of relationship between parameters, with 0.00 – 0.199 is very weak, 0.20 – 0.39 is weak, 0.40 – 0.59 is moderate, 0.60 – 0.79 is strong and 0.80 – 0.100 is very strong. The correlation between the imago population of *R. linearis* and plant height was moderate with coefficient of r = 0.52, where the higher the soybean variety, the higher the population of *R. linearis* (Figure 2). The density of pod trichomes with the imago population of *R. linearis* showed a negative correlation with a very low correlation coefficient value (r = 0.12), while the intensity of *R. linearis* attack had a positive correlation with a weak correlation value (r = 0.20). These data were in accordance with the results of the study by Sarjan and Sab'i [9] which stated that the density of the trichomes had a positive correlation with the attack intensity. Furthermore, the results of the analysis showed that the higher the density of the trichomes, the lower the attack intensity of *R. linearis* (Figure 3), this is in accordance with the results of [10] study which stated that soybean varieties with dense pods of trichomes were less preferred and the attack rate of *R. linearis* was lower compared to soybean varieties which have more tenuous trichomes. According to Marwoto [7], population factors and attack intensity are closely related to the number of pods attacked and loss of production.

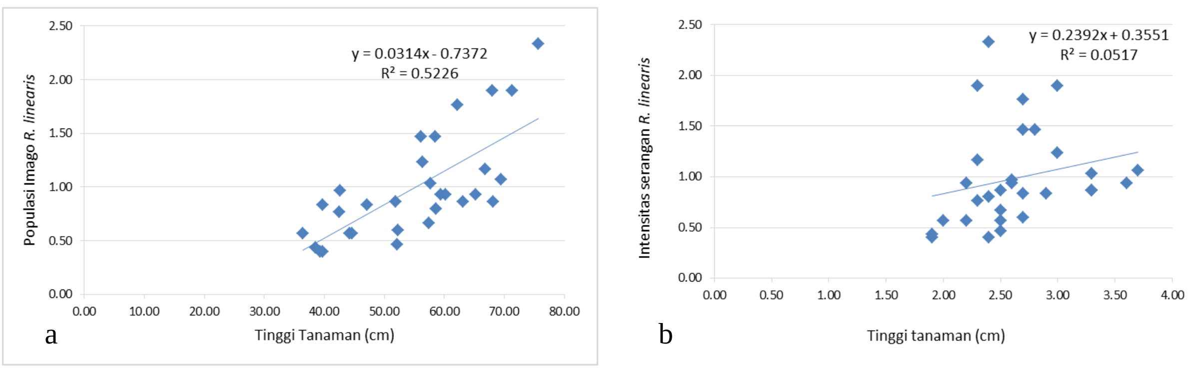

Figure 2. Correlation of plant height with *R. linearis* imago population (a) and attack intensity (b)

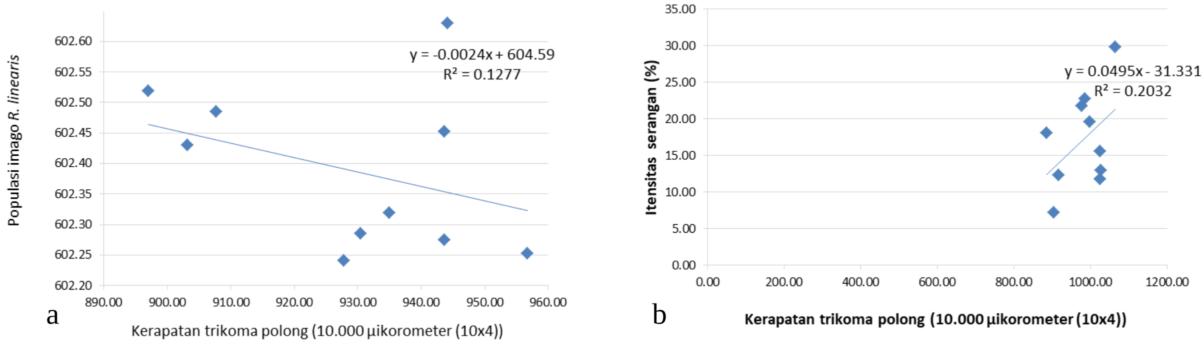

Figure 3. Correlation of trichome density with *R. linearis* imago population (a) and attack intensity (b)

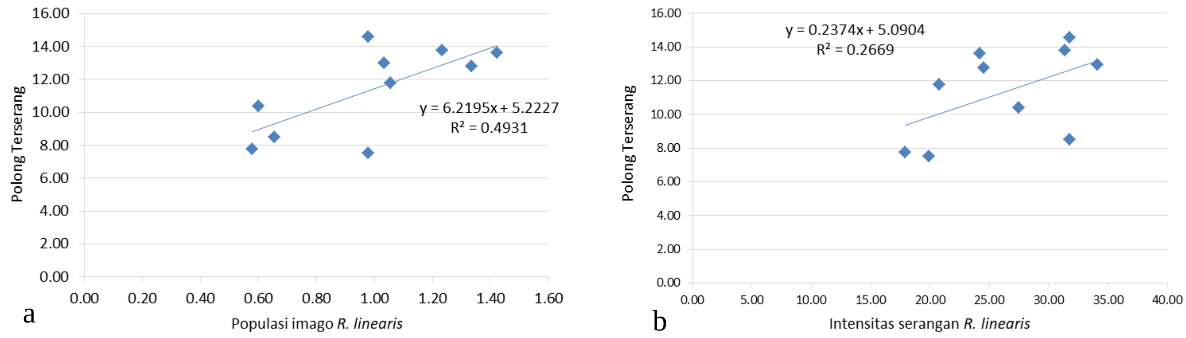

Figure 4. Correlation of infected pods with *R. linearis* imago population (a) and attack intensity (b)

Table 5. Relationship of population and attack intensity of *R. linearis* with soybean productivity

Description	10 WAS	11 WAS	12 WAS
Population of *R. linearis*	0.34	0.05	0.05
Attack Intensity (%)	0.40	0.30	0.19

The results of the analysis also showed that the number of attacked pods was positively correlated with the population of *R. linearis* (r = 0.49) and the attack intensity (r = 0.26). An increase in the population and the attack intensity of *R. linearis* caused the number of attacked pods to increase (Figure. 5). Based on the correlation analysis between population and attack intensity of *R. linearis,* the presence of imago at different plant ages had a correlation with different soybean crop yield, with a correlation coefficient value of r = 0.34, r = 0.05 and r = 0.05 at the age of 10, 11 and 12 WAS. This data means that the presence of *R. linearis* imago on soybean plantations at the age of 10 WAS had the most effect on the intensity of *R. linearis* attack. This is in accordance with the results of research by Sarjan and Sab'i [9] which stated that *R. linearis* attacks at the age of 10 WAS were more sensitive and most preferred because the pods were young and the skin of the pods was still soft, making it easier for the stylet to pierce the soybean pods.

The damage caused by *R. linearis* showed a correlation with soybean yield, but attacks that occurred at the age of 10 WAS had the highest correlation with yield, with a correlation coefficient of r = 0.40 compared to r = 0.30 at the age of 11 WAS and r = 0.19 at 12 WAS *R. linearis* attack during the seed filling phase has the most impact on yield loss at which *R. linearis* attack began to occur when the plant was 44 days old and the attack on the seed pod filling phase had the most impact on yield loss and quality [7]. Therefore, the most effective control efforts have to be carried out in the seed filling phase [24]. Furthermore, it was argued that soybean varieties with a higher level of resistance produced higher weight of seeds [25].

3.3 The relationship between soybean varieties and cultivation technology with yield

The results of the analysis showed soybean varieties and cultivation technology had a significant effect on soybean yield. Of the five varieties, the highest yield was obtained in the treatment of recommended cultivation technology on varieties Dega-1 (0.5 ton/ha) followed by Dena-1 (0.47 ton/ha), Detap-1 (0.36 ton/ha), Anjasmoro (0.19 ton/ha) and the lowest was Biosoy-1 (0.12 ton/ha). The recommended technology can increase soybean yield compared to farmers' existing technology, with a yield increase of Dega-1 was 0.47 ton/ha, Dena-1 was 0.35 ton/ha, Detap-1 was 0.28 ton/ha, Anjasmoro was 0.13 ton/ha and Biosoy-1 of 0.1 ton/ha (Figure 6). Differences in the yield between varieties are caused by different genetic yield potential (productivity) of the variety [26]. According to Hakim [29], agronomic parameters that are closely related to the productivity of each soybean variety are the number of productive nodes, number of pods, seed size, and harvest index, while the recommended technology components that play a role in increasing yield are spacing and fertilizer dosage.

Spacing can increase yield because it is related to the availability of nutrients, sunlight that affects photosynthesis and growing space for plants [27]. Spacing that is too wide results in a large evaporation of water from the soil which disrupts growth and development processes. On the other hand, plant spacing that is too narrow causes a higher plant competition to obtain water, nutrients and sun intensity [26]. Another component that plays a role in increasing soybean yield is the dose of NPK fertilizer. The fertilization dose of recommended technology (200 kg/ha) than the farmers' existing technology (100 kg/ha). The increased dose of NPK fertilizer from 100 kg/ha to 200 kg/ha can increase the yield of some soybean varieties by 21.78% (Anjasmoro variety), 14.23% (Wilis variety) and 12.68% (Grobogan variety).

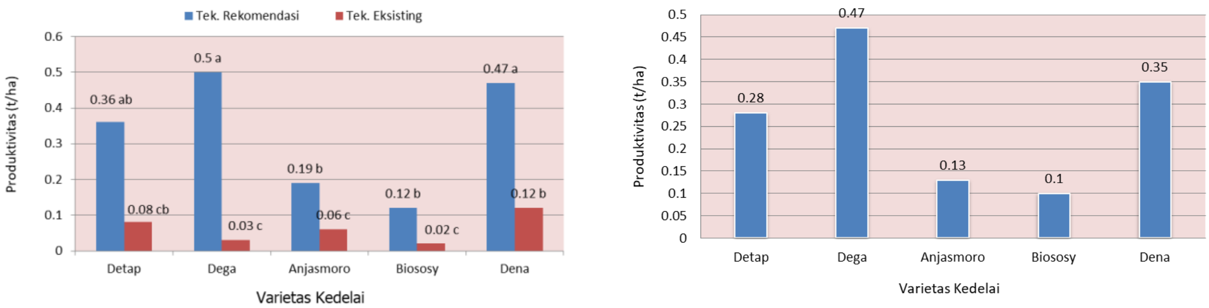

Figure 5. Yield of five soybean varieties in two cultivation technologies (a) soybean yield on recommended cultivation technologies (b)

4. Conclusion

Population and attack intensity of *R. linearis* were only affected by the soybean varieties which are correlated to the development stages of the soybean varieties. Correlations between the development stages of the soybean varieties and intensity of *R. linearis* were weak and moderate. The correlation for plant height with population of *R. linearis* was moderate (r = 0.52), trichome density of pods was weak (r = 0.20), and the number of pods attacked was moderate (r = 0.49), and was weak (r = 0.26). Other development stages have a very low correlation (r = 0.00–0.19). In addition, yield was influenced by cultivation technology with the recommended cultivation technology was able to increase soybean yield by 0.1–0.47 ton/ha compared to existing farmers' technology.

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