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Effects of Perennial Intercrops on Oil Palm Agronomic and Yield Traits

Thanet Khomphet, Theera Eksomtramage, Jakarat Anothai, Pilalak Popet

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ABSTRACT

Background: Intercropping is wildly practiced in oil palm plantation in Thailand for a long time. However, there are few studies connected to oil palm intercropping. This study evaluated the effects of perennial intercrops on the agronomic and yield traits of oil palm.

Methods: The observation used a completely randomized design with eight treatments including oil palm monocropping, oil palm intercropped with *Intsia palembanica*, *Hopea odorata*, *Swietenia macrophylla*, *Ternstroemia wallichiana*, *Azardirachta excelsa*, *Magnolia champaca* and *Mesua ferrea*. The height and stem perimeter of intercrops were recorded as were the plant height and diameter, number of male and female inflorescences and sex ratio of the oil palms. Those parameters were observed in October 2019, February and June 2020.

Result: Oil palm intercropped with *A. excelsa* produced the highest number of female inflorescences and oil palm intercropped with *M. champaca* produced the highest sex ratio in October 2019 and February 2020, however, the differences of those parameters were not found in June 2020. There were no significant differences in the diameter, height, the number of male inflorescences throughout the observation. Among the 7 intercrops, *M. champaca* and *A. excelsa* produced the highest growth rate of plant height and stem perimeter, respectively. In conclusion, oil palm can be intercropped with perennial plants. However, more research is needed to determine the long-term effects of intercropping in oil palm.

Key words: Agronomic traits, Oil palm, Perennial intercrop, Yield traits.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a potentially economic oil crop in Thailand (Soonsuwon *et al*., 2020). In 2019, Thailand had 0.94 million hectares under cultivation with oil palm, of which 86.23 per cent was in the south of Thailand (Office of Agricultural Economics, 2019). In general, oil palms are planted at a triangular distance of 9 x 9 x 9 m with 143 palm trees per hectare (Dariah *et al*., 2014). In plantations in southern Thailand, the first harvestable bunches appear less than 3 years after planting, but during the period when the palm trees are young, they are intercropped with a number of different short-lived plants such as pineapple, banana, chili, cucumber, cocoyam, soybean, maize and groundnut. Several previous studies have reported that the intercropping of plants has no effect on oil palm. Moreover, some studies have found that intercropping oil palm improves the properties of the soil and aids the development the trees as compared to monocropped oil palm (Erhabor and Filson, 1999; Okyere *et al*., 2014; Putra *et al*., 2012; Salako *et al*., 1995; Dissanayake and Palihakkara, 2019). However, once the trees become mature, 3 years after planting, few plants can be intercropped with oil palm because of lack of sufficient light under the oil palms and restriction on the availability of minerals and water in the soil due to high use by the oil palms (Goh *et al*., 2011; Dhandapani *et al*., 2020). Nevertheless, some farmers in southern Thailand have planted perennial plants among mature oil palms and it appears that those plants have not been affected by the growth and cropping of oil palm and have been successfully intercropped with oil palm. However, there have been a few empirical studies reported in this connection. The findings reported will be helpful and informative to farmers and may form a baseline for researchers to further study this subject.

Agricultural Innovation and Management Division, Faculty of Natural Resources, Prince of Songkla University, Hat Yai, 90110, Thailand.

Corresponding Author: Jakatat Anothai, Agricultural Innovation and Management Division, Faculty of Natural Resources, Prince of Songkla University, Hat Yai, 90110, Thailand.
Email: jakarat.a@psu.ac.th

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MATERIALS AND METHODS

Study site

The plantation studied is located at Lam Sin Tambon, Srinagarindra District, Phatthalung Province, southern Thailand (7°30′02.4"N 99°53′58.7"E). This site has a tropical climate with an average rainfall of 2,156.9 mm per year, with the highest rainfall occurring between October and

December. The lowest monthly average temperature in December is 26.7°C and April is the hottest month with an average temperature of 29.3°C. The relative humidity ranges between 75 and 83 percent. The area of the plantation studied is around 6 hectares, to which chemical fertilizers are applied every 3 months. The quantity and quality of the fertilizers applied are monitored based on soil analysis and the nutrient demands of the oil palms. In addition, manure is applied twice a year to improve the physical and biological properties of the soil. Harvestable bunches are harvested twice a month and the fronds of the oil palms are cut during the harvesting of the oil palm fruit bunches. The fronds are maintained at 24-32 fronds per plant. The soil properties in the 0-30 cm soil depth are: pH = 6.0, organic carbon = 1.5%, cation exchange capacity = 12 $molkg^{-1}$, total nitrogen = 0.15 gkg^{-1}, available phosphorus = 20.00 $mgkg^{-1}$ and available potassium = 30.09 $mgkg^{-1}$.

Oil palms, Intercrops and parameters measurements

This study employed a completely randomized design of 8 treatments as follows: oil palm monocropping (Palm), oil palm intercropped with *Intsia palembanica* (Palm-A), *Hopea odorata* (Palm-B), *Swietenia macrophylla* (Palm-C), *Ternstroemia wallichiana* (Palm-D), *Azardirachta excelsa* (Palm-E), *Magnolia champaca* (Palm-F) and *Mesua ferrea* (Palm-G). Each treatment consisted of 10 replications. In each replication, a ten-year-old intercropped plant was planted with a twelve-year-old oil palm (*tenera* variety) as the same row. Their agronomic and yield traits were recorded. For the oil palms, their diameter and height were measured, the number of male and female inflorescences were counted and the sex ratio was calculated as the number of female inflorescences relative to the total number of inflorescences (Rival, 2017). The growth rates (GR) of the stem perimeter and plant height in the observed months were calculated as:

$$GR = (H_2\text{-}H_1)/(t_2\text{-}t_1),$$

where

H_2 and H_1 are the plant height (or stem perimeter) at t_2 and t_1, respectively. For the perennial intercrops, their perimeter and height were measured. The observations were carried out in October 2019, February and June 2020. General information regarding the oil palms and perennial intercrops is shown in Table 1.

Statistical analysis

The variance in the parameters was calculated using ANOVA. The means were compared using Duncan's multiple range test and differences were reported as significant at or above $p < 0.05$ (Harter, 1960). All statistical analyses were conducted using the R software program (version 3.6.1) with the Agricolae package (de Mendiburu, 2019).

RESULTS AND DISCUSSION

The agronomic traits and inflorescence yield of oil palm

The plant diameter and height, the number of male and female inflorescences and sex ratio of oil palms planted with different intercrops are presented in Table 2. Plate 1 illustrates twelve-year-old oil palms intercropped with some perennial plants. The diameter, height and the number of male inflorescences in all observed months, the number of female inflorescences in June 2020 and sex ratio in October 2019 and June 2020, were not significantly different among the various treatments. The only significant differences were found in the number of female inflorescences in October 2019 and February 2020 and sex ratios in February 2020. Oil palm intercropped with *A. excelsa* (6.00±0.00) and *M. champaca* (5.71±1.70) produced the greatest number of female inflorescences in October 2020, but they were statistically at par with monocropped oil palm (3.25±0.38; $p < 0.05$), oil palm intercropped with *I. palembanica* (4.20±2.17; $p < 0.05$), *H. odorata* (3.55±2.62; $p < 0.05$), *S. macrophylla* (3.43±1.40; $p < 0.05$) and *T. wallichiana* (4.50±1.91; $p < 0.05$). Monocropped oil palm (5.13±2.75), oil palm intercropped with *I. palembanica* (5.40±3.13), *H. odorata* (5.25±2.65), *S. macrophylla* (5.57±3.74), *T. wallichiana* (5.25±2.87), *A. excelsa* (6.00±1.41) and *M. champaca* (4.43±2.64) produced a greater number of female inflorescences than oil palm intercropped with *M. ferrea* (0.50±0.07; $p < 0.05$) in February 2020. Oil palm intercropped with *T. wallichiana* (0.93±0.14), *A. excelsa* (0.92±0.12) and *M. champaca* (1.00±0.00) produced the greatest sex ratio in February 2020, but they were statistically at par with monocropped oil palm (0.86±0.35; $p < 0.05$), oil palm intercropped with *I. palembanica* (0.76±0.43; $p < 0.05$), *H. odorata* (0.87±0.25; $p < 0.05$) and *S. macrophylla* (0.76±0.27; $p < 0.05$).

The agronomic traits of perennial intercrops and their growth rates

The plant height and stem perimeter of the intercrops are presented in Table 3. *M. champaca* produced the greatest

Table 1: General information relating to oil palm and perennial intercrops.

Plants	Codes	Scientific names	Plant ages
Oil palm	Palm	*Elaeis guineensis* Jacq.	12 years
Borneo Teak, Merbau	A	*Intsia palembanica* Miq.	10 years
Iron Wood	B	*Hopea odorata* Roxb.	10 years
Broad Leaf Mahogany	C	*Swietenia macrophylla* King.	10 years
Ternstroemia	D	*Ternstroemia wallichiana* (Griff.) Engl.	10 years
Indian walnut	E	*Azardirachta excelsa* (Jack) Jacobs	10 years
Champak	F	*Magnolia champaca* L.	10 years
Ceylon ironwood	G	*Mesua ferrea* L.	10 years

Table 2: Plant diameter, plant height, number of male and female inflorescences and sex ratio of oil palms intercropped with different plants.

Treatments	Plant diameter (cm)	Plant height (m)				Number of male inflorescences			
		Oct 2019	Feb 2020	Jun 2020	Average	Oct 2019	Feb 2020	Jun 2020	Average
Palm	75.63±5.63	5.81±0.37	6.38±0.23	7.13±0.35	6.44±0.29	1.13±0.46	0.13±0.05	0.38±0.06	0.54±0.59
Palm-A	72.00±4.47	5.86±0.35	6.40±0.42	7.20±0.27	6.49±0.33	1.40±0.67	0.40±0.09	0.40±0.09	0.73±0.60
Palm-B	76.69±6.39	5.73±0.47	6.26±0.46	7.02±0.56	6.33±0.47	1.77±0.88	0.48±0.09	0.72±0.05	0.99±0.81
Palm-C	72.14±8.59	6.04±0.31	6.64±0.24	7.57±0.19	6.75±0.19	2.00±0.29	1.14±0.21	0.86±0.21	1.33±1.00
Palm-D	73.75±11.09	5.75±0.65	6.25±0.65	7.13±0.63	6.38±0.63	1.25±0.89	0.50±0.00	0.00±0.00	0.58±0.69
Palm-E	70.00±7.07	5.00±0.00	6.00±0.71	6.75±0.35	5.92±0.35	2.50±0.12	0.50±0.07	0.50±0.01	1.17±0.71
Palm-F	73.57±6.90	5.91±0.27	6.21±0.27	7.00±0.29	6.38±0.24	0.71±0.25	0.00±0.00	0.14±0.08	0.29±0.49
Palm-G	65.00±7.07	5.75±0.35	6.50±0.71	7.25±1.06	6.50±0.71	0.50±0.71	0.00±0.00	0.00±0.00	0.17±0.24
F-test	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**
CV	**8.87**	**7.69**	**6.96**	**7.23**	**6.88**	**109.66**	**174.37**	**166.94**	**87.22**

Treatments	Number of female inflorescences				Sex ratio			
	Oct 2019	Feb 2020	Jun 2020	Average	Oct 2019	Feb 2020	Jun 2020	Average
Palm	3.25^{ab}±0.38	5.13^{a}±2.75	7.00±2.83	5.13±0.64	0.67±0.38	0.86^{ab}±0.35	0.97±0.09	0.83±0.19
Palm-A	4.20^{ab}±2.17	5.40^{a}±3.13	6.00±1.41	5.20±1.43	0.83±0.18	0.76^{ab}±0.43	0.94±0.13	0.84±0.11
Palm-B	3.55^{ab}±2.62	5.25^{a}±2.65	6.46±2.73	5.09±1.57	0.64±0.35	0.87^{ab}±0.25	0.87±0.22	0.79±0.17
Palm-C	3.43^{ab}±1.40	5.57^{a}±3.74	6.00±2.16	5.00±1.22	0.63±0.17	0.76^{ab}±0.27	0.88±0.16	0.76±0.16
Palm-D	4.50^{ab}±1.91	5.25^{a}±2.87	8.00±2.94	5.92±1.26	0.78±0.31	0.93^{a}±0.14	1.00±0.00	0.90±0.11
Palm-E	6.00^{a}±0.00	6.00^{a}±1.41	6.00±0.00	6.00±0.47	0.73±0.18	0.92^{a}±0.12	0.93±0.10	0.86±0.05
Palm-F	5.71^{a}±1.70	4.43^{a}±2.64	6.71±3.86	5.62±1.01	0.89±0.19	1.00^{a}±0.00	0.99±0.04	0.96±0.07
Palm-G	1.50^{b}±0.71	0.50^{b}±0.07	6.00±2.83	2.67±0.94	0.83±0.24	0.50^{b}±0.07	1.00±0.00	0.78±0.31
F-test	*	*	**ns**	**ns**	**ns**	*	**ns**	**ns**
CV	**64.42**	**53.57**	**42.17**	**27.94**	**47.57**	**31.08**	**21.24**	**20.21**

The values are mean ± standard error. ns: Not significantly different, * Significantly different at $p < 0.05$: values with the same alphabetical superscript within the same column are not significantly different based on Duncan's multiple range test. CV is coefficient of variation.

plant height (15.83±4.62, 18.83±2.99 and 19.83±3.20 m) in all observed months, but they were statistically at par with *S. macrophylla* (13.67±3.61, 13.87±1.94 and 13.92±1.72 m; $p < 0.01$), *A. excelsa* (13.00±3.45, 14.00±1.55 and 15.00±3.25 m; $p < 0.01$) and *M. ferrea* (9.50±2.12, 11.00±1.41 and 12.00±1.41 m; $p < 0.01$). *A. excelsa* produced the greatest stem perimeter (84.90±4.90, 90.00±3.00 and 93.20±3.20 cm) in all observed months, however, these were statistically at par with *M. champaca* (74.90±14.27, 80.83±16.23 and 83.30±15.16 cm; $p < 0.01$) and *S. macrophylla* (54.55±8.11, 58.92±9.82 and 60.70±10.54 cm; $p < 0.01$). Growth rates of plant height and stem perimeter of intercrops are presented in Table 4. From October 2019 to February 2020, *M. champaca* produced the highest growth rate of plant height (55.00±8.74 cm month^{-1}), but was at par with *S. macrophylla*, *A. excelsa* and *M. ferrea* (29.17±9.21, 25.00±3.56 and 37.50±7.68 cm month^{-1}). *A. excelsa* produced the highest growth rate of stem perimeter (2.03±0.15 cm month^{-1}), but they were statistically at par with *S. macrophylla* and *M. champaca* (1.09±0.85 and 1.48±0.85 cm month^{-1}). From February to June 2020, *M. champaca* produced the highest growth rate of plant height (35.00±7.91 cm month^{-1}), but they were statistically at par with *S. macrophylla*, *A. excelsa* and *M. ferrea* (18.75±6.85, 25.00±4.25 and 29.00±5.00 cm month^{-1}). *A. excelsa* produced the highest growth rate of stem perimeter (1.05±0.11 cm month^{-1}) and were also statistically at par with *S. macrophylla*, *T. wallichiana* and *M. champaca* (0.45±0.30, 0.38±0.19 and 0.92±0.42 cm month^{-1}).

The results are similar to those found in previous studies relating to oil palm, where it has been reported that oil palm can be intercropped with different plants at different growth stages. Salako *et al*. (1995) studied the effect of intercropping oil palm with cocoyam (*Xanthosoma sagittifolium*) and the results show that such intercropping did not affect the growth or yield of oil palm. They recommended that owners of oil palm plantations maximize their land use and profit by intercropping oil palm with cocoyam during the first five years after planting oil palm. Erhabor and Filson (1999) investigated the nutrient dynamics in relation to soil fertility management for oil palm intercropped with soybean (*Glycine max*), maize (*Zea mays*) and cocoyam during the first three years after planting. The results showed that, there was no significant change in soil pH after three years of using these cropping systems. Moreover, oil palm intercropped with soybean showed a 71 per cent increase in the level of phosphorus in the soil. Putra *et al*. (2012) determined the effect of soybean and groundnut on oil palm, with neither producing high yields. However, the presence of soybean and groundnut between the rows

Table 3: Plant height and stem perimeter of intercrops.

Intercrops	Plant height (m)			Stem perimeter (cm)		
	Oct 2019	Feb 2020	Jun 2020	Oct 2019	Feb2020	Jun 2020
I. palembanica	7.83^{b}±2.84	8.67^{b}±3.06	9.33^{b}±3.01	20.60^{b}±9.20	21.17^{b}±9.17	21.87^{b}±8.81
H. odorata	5.81^{b}±4.33	6.54^{b}±4.80	7.16^{b}±5.02	22.19^{b}±22.15	22.54^{b}±18.41	23.03^{b}±18.88
S. macrophylla	13.67^{ab}±3.61	13.87^{ab}±1.94	13.92^{ab}±1.72	54.55^{ab}±8.11	58.92^{ab}±9.82	60.70^{ab}±10.54
T. wallichiana	5.83^{b}±1.61	6.33^{b}±1.61	6.93^{b}±1.29	23.10^{bc}±11.03	24.50^{b}±11.82	26.00^{bc}±11.09
A. excelsa	13.00^{ab}±3.45	14.00^{ab}±1.55	15.00^{ab}±3.25	84.90^{a}±4.90	90.00^{a}±3.00	93.20^{a}±3.20
M. champaca	15.83^{a}±4.62	18.83^{a}±2.99	19.83^{a}±3.20	74.90^{a}±14.27	80.83^{a}±16.23	83.30^{a}±15.16
M. ferrea	9.50^{ab}±2.12	11.00^{ab}±1.41	12.00^{ab}±1.41	21.40^{b}±9.33	22.50^{b}±10.61	23.10^{b}±11.17
F-test	**	**	**	**	**	**
CV	**57.76**	**55.07**	**53.03**	**59.15**	**61.83**	**58.11**

The values are mean ± standard error. ** Significantly different at $p < 0.01$: values with the same alphabetical superscript within the same column are not significantly different based on Duncan's multiple range test. CV is coefficient of variation.

Table 4: Growth rates of plant height and stem perimeter of intercrops.

Intercrops	Growth rate of plant height (cm month^{-1})		Growth rate of stem perimeter (cm month^{-1})	
	Oct 2019-Feb 2020	Feb-Jun 2020	Oct 2019-Feb 2020	Feb-Jun 2020
I. palembanica	20.83^{b}±7.22	16.67^{b}±7.22	0.14^{c}±0.03	0.18^{b}±0.09
H. odorata	18.14^{b}±7.57	15.57^{b}±9.86	0.42^{bc}±0.48	0.25^{b}±0.23
S. macrophylla	29.17^{ab}±9.21	18.75^{ab}±6.85	1.09^{abc}±0.85	0.45^{ab}±0.30
T. wallichiana	12.50^{b}±2.00	15.00^{b}±9.01	0.35^{bc}±0.22	0.38^{ab}±0.19
A. excelsa	25.00^{ab}±3.56	25.00^{ab}±4.25	2.03^{a}±0.15	1.05^{a}±0.11
M. champaca	55.00^{a}±8.74	35.00^{a}±7.91	1.48^{ab}±0.85	0.92^{a}±0.42
M. ferrea	37.50^{ab}±7.68	29.00^{a}±5.00	0.28^{bc}±0.32	0.15^{b}±0.14
F-test	**	**	**	*
CV	**127.02**	**56.28**	**97.04**	**86.35**

The values are mean ± standard error. **Significantly different at $p < 0.01$: Values with the same alphabetical superscript within the same column are not significantly different based on Duncan's multiple range test. CV is coefficient of variation.

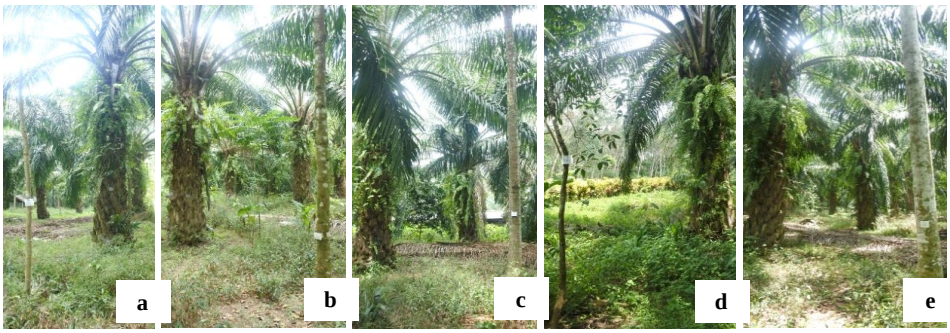

Plate 1: Twelve-year-old oil palms intercropped with *I. Palembanica* (a), *H. odorata* (b), *S. macrophylla* (c), *T. wallichiana* (d) and *M. champaca* (e).

of oil palms was found not to inhibit the growth rate and development of the oil palms. Okyere *et al*. (2014) investigated the effects of intercropping four-year-old oil palm with maize, cassava and plantain, finding that there were no significant differences between the vegetative growth and yield of oil palm intercropped with those plants and those of sole cropped oil palm. Moreover, intercropping oil palm with maize, plantain and / or cassava had no adverse effect on the growth, development and yield of the oil palm. Amoah *et al*. (1995) studied the feasibility of cocoa intercropping with eighteen-year-oil palm which had achieved maximum canopy formation. The results found that, there were no significant differences in oil palm yield between oil palms intercropped with cocoas and monocropped oil palms. Oil palms have a four-level root system, consisting of primary, secondary, tertiary and quaternary roots. The root system of oil palm spreads in both the vertical and horizontal directions and extends to a maximum depth of over 6 meters (Jourdan and Rey, 1997). The number and strength of the roots of oil palms affects their potential to absorb water and minerals from the soil. In addition, intercropping oil palm with other plants could provide a habitat for and increase the activities of soil microorganisms, resulting in the release of fixed minerals, leading to an increase in available plant nutrients in the soil (Belel *et al*., 2014; Buragohain, 2015; Rahim *et al*., 2016).

CONCLUSION

Oil palm can be intercropped with many perennial plants which can be grown under light competition conditions under oil palm shading. Based on the findings of this study, *A. excelsa* and *M. champaca* can be grown as intercrops with oil palm. However, more research is needed to determine the long-term effects of intercropping in oil palm.

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