EVALUATION OF COCOA PRODUCTIVITY IN RESPONSE TO SHADE AND FERTILISER TREATMENTS IN SUMATRA UTARA, INDONESIA

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ABSTRACT

Cocoa is the second important cash crops, after oil palm, in Indonesia. The plant origin is tropical Amazon forest and it requires shade tree for commercial plantings. In the plantations, fertiliser application is utmost important to achieve high production and profit. The cocoa response to fertiliser is related to shade requirement. Therefore, trial was established in cocoa plantations of PT PP London Sumatra Indonesia in Sumatra Utara province. The objectives were to determine the optimum fertiliser requirement in three shade levels and evaluate the long term yield in response to shade. The trial arranged in two replicates of split split plot design with shade intensity as main plots and 3 x 2² NPR factorial fertiliser treatments as sub-plots. The plot size was 150 cocoa trees and inner of 63 trees were recorded. Results showed that application of nitrogen fertiliser at low rate significantly increased number of pods per tree which consequently increased dry bean yield. The yield was not affected by high phosphorus fertiliser and residual phosphorus from the previous planting. There was no interaction of shade and fertiliser treatments in this experiment which indicated that the same fertiliser recommendation can be used for any shade levels. The shade treatment showed that zero shade significantly gave the highest yield compared with high shade, however the zero and medium shade treatments gave the same level of yield accumulation for 15 years period. In addition, dieback of cocoa trees observed in all shade levels and the highest intensity was in the zero shade. This dieback may had declined cocoa productivity by reducing the tree canopy. Consequently, medium shade is preferable as standard commercial plantings because it maintains the cocoa tree health. Therefore, it was concluded that the optimum fertiliser requirement in the trial site for any shade level was applying N fertiliser at 200 gram/tree and P fertiliser is required if available P below than 10 ppm. Medium shade level is preferable to maintain high yield of cocoa plantation.

Key words: cocoa productivity, fertiliser application, shade requirements

Introduction

Global cocoa bean production in 2013-2014 was approximately 4.3 million tonnes, with Cote d'Ivory supplying more than 1.7 million tonnes, followed by Ghana and Indonesia with 900 and 400 thousand tonnes of dry beans respectively. The exported cocoa from Indonesia generated income of US$ 1.2 billion in 2013 which positioned cocoa as top third foreign exchange commodities after oil palm and rubber (Kementrian Pertanian Direktorat Jenderal Perkebunan, 2014). In addition to this, 440 thousand tonnes were supplied to the local market from an estimated total production of 840,000 tonnes of beans harvested from 1.7 million hectares of plantations (Ministry of Agriculture, 2013) . The cocoa plantations are mostly owned by smallholder farmers, who account for 94% of the area, with plantation companies holding 4% of the area (Statistics Indonesia, 2014). Cocoa (Theobromae cacao) is an important cash crops in the country.

In Indonesia, a large proportion of cocoa is planted in acidic and highly weathered soil which often low in nutrient availability. Nitrogen, phosphorus, potassium, magnesium and other essential nutrients are relatively low in this soil type (Baligar & Fageria, 2005). Therefore, fertiliser application is essential to achieve and sustain high productivity in Indonesia. Fertiliser application rates are influenced by many factors, for instance yield response, fertiliser price, application cost, and profit. In addition, the yield response of cocoa to fertiliser cannot be separated from the shade level. Towards the high yield and fertiliser application, a trial was investigated at the commercial cocoa plantation in Sumatra Utara, Indonesia. The objectives were to determine the optimum fertiliser requirement in three shade levels. This paper reported the yield response short (3 years) and long terms (16 years) of data collection. The long term effect of three shade levels were evaluated in this study.

Methodology

The study was carried out in a commercial cocoa plantation of Bah Lias Estate, PT London Sumatra Indonesia in Perdagangan, Simalungun, Sumatra Utara, Indonesia. It is located north of the equator between latitude 3°9'0'-3°13'30' and longitude 99°16'30'-99°21'0 E. The annual rainfall and rainy days averaged at 1700 mm and 103 days, respectively which distributed evenly through out the year. Fertiliser and shade trial was started in 1992 and ended in 2011. The cocoa was planted in red-yellow podsolic soil in flat topography and good drainage. The área was previously cultivated with rubber and coconut at 160 palms/hectare. The experimental design was Split Split plot design with shade level as the main plot and 3 x 2^2 NPR factorial fertiliser treatments as sub-plots. R is a residual phosphorus fertiliser application in the previous coconut plantings. There were 7 clones (GC29, Pa191, UF11, Pa310, BL412, BLC 4 and Pa 4) of cocoa as the sub-sub plot. The population per hectare were 952 trees. Detail treatments of main and sub-plots are in the Table 1. N and P fertiliser were applied in the form of urea and TSP, respectively. The fertiliser treatment was started in March 1995, repeated every year and the last application was in March 2010.

Table 1. Details treatment of main and sub-plots

Split Plot Treatments	Main Plot Treatments

Level	Urea (g/tree/yr)	TSP (g/tree/yr)	Residual TSP (kg/ha)	Shade (coconut palm/ha)		
				Level	Started	Sep'95
0	0	-	0	High	86	53
1	200	175	1556	Medium	53	27
2	400	350		Zero	27	0

Residual= Previous fertiliser applied to the coconuts

The plot size was 150 cocoa trees and inner of 63 trees were measured. The pods were harvested from these trees and number of pods produced per tree was counted. This number was subjected for calculation of dry cocoa bean per hectare which is estimated from number of pod to produce 1 kg dry bean. It was measured that 1 kg of dry bean resulted from 30 pods.

The cocoa plant started to show death of young leaves flush and branches in 2006. This symptom was described as dieback which resulted in loss of the tree canopy and dying of susceptible trees. A scoring system was used to measure tree canopy and as an indication of plant health. The scores were: 0 = no dieback, 1 = >10 % dieback and canopy loss, 2 = 11-20% dieback and canopy loss, 3 = 21-30% dieback and canopy loss, 4 = 31-40% dieback and canopy loss, 5 = 41-50% dieback and canopy loss, 6 = 51-60% dieback and canopy loss, 7 = 61-70% dieback and canopy loss, 8= 71-80% dieback and canopy loss, 9 = 81-90% dieback and canopy loss,10 = <90% dieback and canopy loss.

Results And Discussions

Yield response to shade treatment

Main effects of treatments on yield is shown in Table 2. The effects of shade was not significant to the yield (number of pods per tree and dry bean per hectare) of cocoa in 2008 and averaged 2008-2010. In both year periods, the medium shade level (27 coconut/ha) produced the highest dry bean per ha, followed by high and zero shade levels. This yield response in the last 3 years of data collection was slightly different from the first 12 years. From 1995 up to 2007 (Figure 1), the zero shade treatment significantly increased the yield compared with the high shade treatment, but it was not significantly different with the medium shade treatment. Since 2008 the zero shade treatment no longer gave the highest yield. On the other hand, the medium shade was still significantly higher compared with the high shade treatment. This results indicated that zero or low shade levels tended to increase annual cocoa productivity but it would not remain high in a longer term. The cumulative yield in each shade treatment during 15 years data collection for high shade, medium shade, and nil shade were 27, 31, and 31 t/ha.

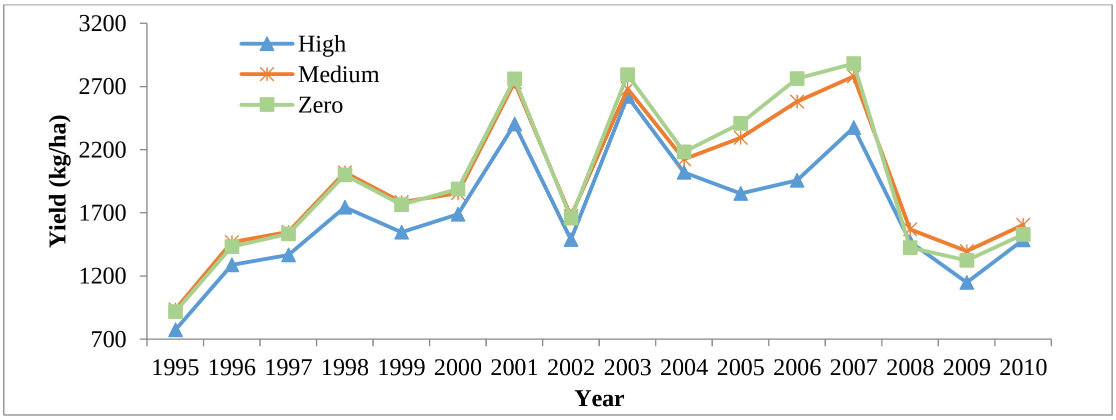
Table 2. Effects of shade, fertiliser, and clone treatments to the yield of cocoa in 2010 and averaged over 2008-2010

Treatment		**No of pods per tree**		**Dry bean(kg/ha)**	
		2010	**2008-2010**	**2010**	**2008-2010**
Shade	High	72.94a	60.05a	1486a	1369a
	Medium	79.65a	68.28a	1605a	1524a
	Zero	80.11a	68.70a	1528a	1425a
N	0	74.34a	**59.61b**	**1438b**	**1263b**
	1	81.13a	**69.82a**	**1621a**	**1535a**
	2	77.23a	**67.60a**	**1560a**	**1520a**
P	1	77.57a	65.68a	1540a	1439a
	2	77.57a	65.68a	1540a	1439a
Res	0	79.76a	67.79a	1493a	1412a
	1	75.37a	63.56a	1586a	1466a
Clone	BL 412	**23.00e**	**20.20d**	**395e**	**364e**
	BLC 4	**64.30c**	**51.50c**	**1644b**	**1421c**
	GC 29	**32.50d**	**27.60d**	**845d**	**793d**
	Pa 191	**94.50b**	**88.00b**	**1782b**	**1908b**

Pa 310	**99.40b**	**84.20b**	**1402c**	**1435c**
Pa 4	**174.10a**	**142.40a**	**3367a**	**2888a**
UF 11	**55.10c**	**45.90c**	**1345c**	**1266c**

Note: numbers followed by the different letter in one column is statistically significant at LSD 5%, numbers followed by the same letter in one column is not statistically different.

Figure 1. The effect of shade treatment on dry bean yield of cocoa

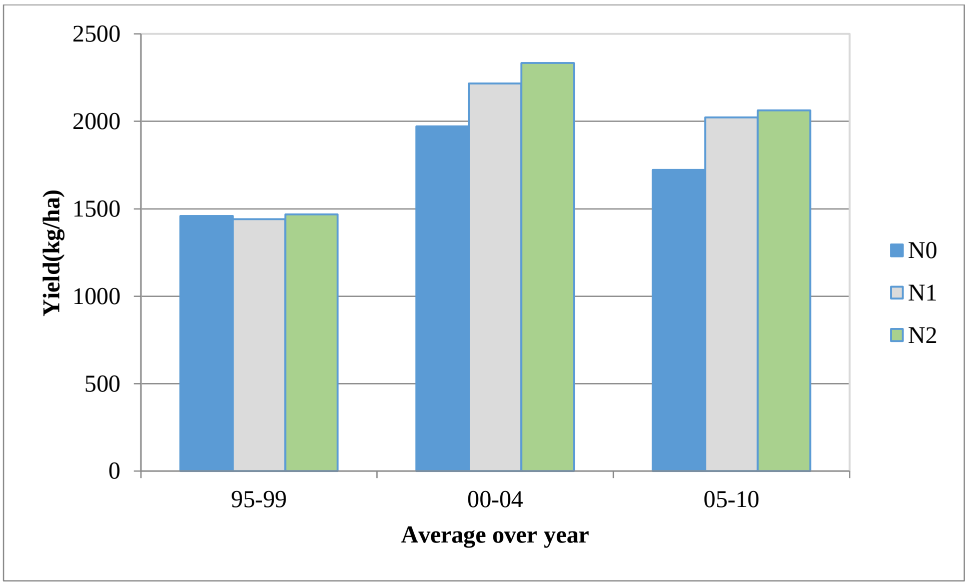


Yield response to fertiliser treatments

Main effect of fertiliser treatments (Table 2) indicates that nitrogen fertiliser significantly increased number of pods averaged 2008-2010 and dry cocoa bean both in 2008 and averaged 2008-2010. Yield of cocoa was statistically higher with application of urea at 200 gr/tree (low level) compared to the nil fertiliser treatment. Another increases of N fertiliser failed to produce higher yield. This low N fertiliser rate had consistently increased the dry bean per hectare and number of pods produces (data not shown) for 15 years of data collection.

During the 15 years of observation, the yield response to application of N fertiliser can be divided into 3 periods as in Fig. 2. In 1995-1999 there was no significant response to application of N fertiliser, but from 2000 up to 2004, there was a significant yield increase with application of N fertiliser at level 1 and 2 relative to the unfertilized treatment, and the yield increase with N fertiliser at level 2 tended to be higher although not significant if compared with level 1. The last period 2005-2010 shows that application of N fertiliser at level 1 significantly increased the yield, but there was no further response to level 2.

Figure 2. The effect of N fertiliser to the dry bean yield of cocoa



The yield response to phosphorus fertiliser in 2008 and averaged 2008-2010 is shown in Table 2. High level of P fertiliser was not significantly increased number of pods and dry bean per hectare in both period. This fertiliser had been applied annually since 1995, but none of the annual yield or 15 years cumulative yield data demonstrated positive response to higher rate of P at 350 gram/tree of TSP (data not shown). This indicated that application of 175 gram/tree of TSP was sufficient to maintain the soil P and support the growth of cocoa in this experimental site. The results confirmed the previous fertiliser trials in two other locations of PT PP London Sumatra in Sumatra Utara, Indonesia which concluded that application of 200 gram/tree of TSP was required to increase the cocoa yield. It was noted that available P in unfertilized soil adjacent to experiment site is 3-10 ppm. In addition to P response, there was no effect of residual P from previous coconut plantings to the yield of cocoa in this study.

Yield response to clone variation

The effect of cocoa clone to the yield is shown in Table 2, indicating that number of pod and dry bean yield in 2008 and 2008-2010 was affected by clone. The Pa 4 clone was the best which consistently produced dry bean per hectare higher than 2 ton. The other two Pa clones (191 and 310) were in the second and third position for yield performance and then followed by BLC 4, UF 11, GC 29 and lastly BL 412 with the lowest yield. GC 29 and BL 412 produced yield which were lower than 1 ton/ha, this level may not be prospective commercial use in the future.

Effect of treatments on dieback score

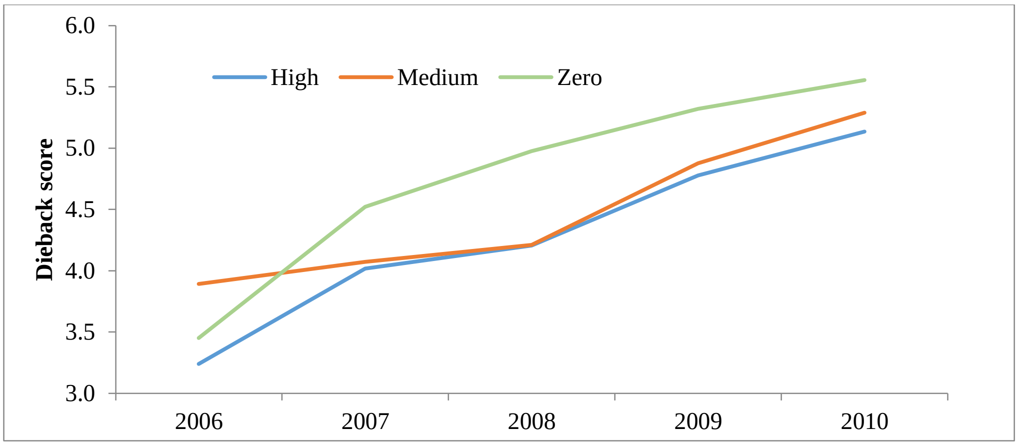
Dieback incidence was started to be seen in 2006 and then a scoring system was introduced to measure the degree of canopy reduction. The measurement was done every 2 months and Table 3 shows the effect of treatments to dieback score in 2010. It shows that shade and fertiliser treatments did not significantly affected the cocoa tree canopy. All treatments were in the same level of dieback score. However, dieback score tended to be higher in the zero shade treatment (Figure 4). It indicates that since 2007 the dieback in the zero shade was always higher than the shaded treatments. Moreover, the canopy reduction in 2010 was the worst in the nil shade cocoa. On the contrary, dieback incidence in medium and high shade levels were at very similar range. This indicates that zero shade cocoa will not survive for long term commercial cultivation.

Table 3. Effects of shade, fertiliser and clone treatments on dieback score of cocoa

Treatment		**Dieback score data**					
		Feb-10	**Apr-10**	**Jun-10**	**Aug-10**	**Oct-10**	**Dec-10**
Shade	High	4.94a	4.95a	4.84a	4.95a	5.40a	5.73a
	Medium	5.48a	5.52a	4.94a	5.14a	5.29a	5.35a
	Nil	5.77a	5.81a	5.15a	5.37a	5.57a	5.65a
N	0	5.30a	5.32a	4.97a	5.12a	5.42a	5.57a
	1	5.38a	5.37a	4.98a	5.18a	5.47a	5.63a
	2	5.52a	5.59a	4.99a	5.17a	5.37a	5.54a
P	1	5.40a	5.43a	4.98a	5.16a	5.42a	5.58a
	2	5.40a	5.43aa	4.98a	5.16a	5.42a	5.58a
Res	0	**5.55a**	5.55a	5.07a	5.23a	5.47a	5.67a
	1	**5.25a**	5.30a	4.89a	5.08a	5.38a	5.49a
Clone	BL 412	**7.34a**	**7.38a**	**7.08a**	**7.39a**	**7.36a**	**7.44a**
	BLC 4	**5.57b**	**5.56b**	**5.10b**	**5.20b**	**5.49b**	**5.53b**
	GC 29	**5.46b**	**5.50b**	**4.92b**	**5.11b**	**5.32b**	**5.48b**
	Pa 191	**4.68d**	**4.61d**	**4.24d**	**4.39d**	**4.76d**	**4.97c**
	Pa 310	**5.03c**	**5.10c**	**4.68c**	**4.83c**	**5.12c**	**5.31b**
	Pa 4	**4.52d**	**4.50d**	**3.97e**	**4.12e**	**4.59d**	**4.88c**
	UF 11	**5.20c**	**5.33b**	**4.86b**	**5.04b**	**5.31bc**	**5.44b**

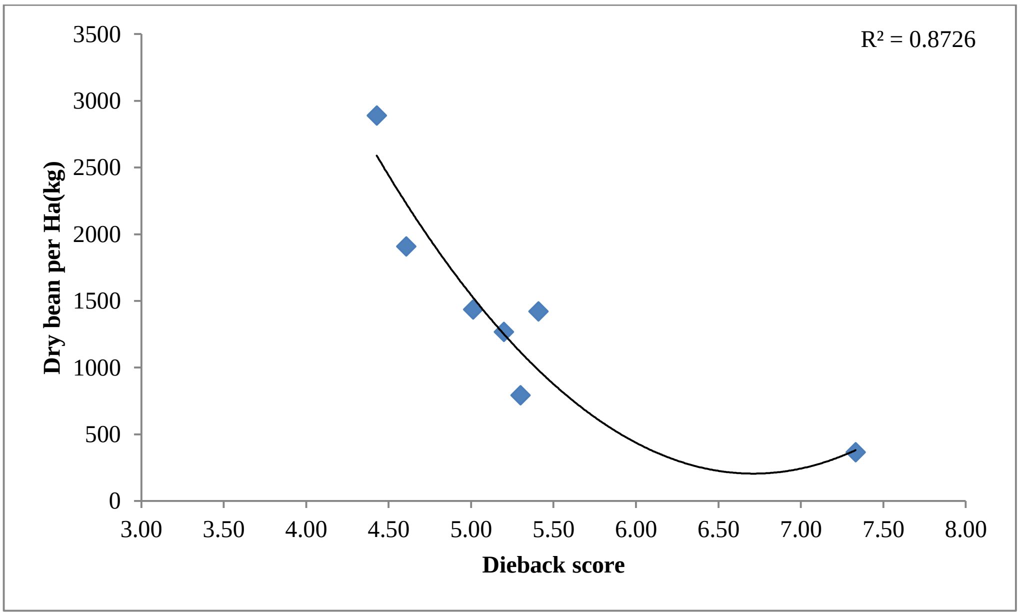
Note: numbers followed by the different letter in one column is statistically significant at LSD 5%, numbers followed by the same letter in one column is not statistically different.

Figure 3. The trend of dieback score in cocoa with 3 shade levels between 2006-2010



The effect of clones on dieback score was significant (Table 3). Among all clones, BL 412 had the worst dieback indicating that this clone is susceptible to dieback, while the Pa 4 clones had the least dieback indicating that they are relatively tolerant. Table 1 shows that Pa 4 gave the highest yield while BL 412 gave the lowest yield compared with all clones, which is related to the dieback. Relationship between dry bean yield and dieback score in 7 clones is illustrated in Figure 4. The higher the dieback score, the lower dry bean yield produced by cocoa trees. This is because dieback leads to death of the young branches and resulted in a significant reduction of vegetative part. The susceptible tree indicated severe dieback and lead to plant death, as noted in this trial that BL 412 clone showed the most number of death tree amongst all clones. In contrast, the Pa clones had the lower number of death tree (data not shown).

Figure 4. Relationship between dieback score and yield of 7 cocoa clones



Previous studies showed that the yield response of cocoa to fertiliser treatments were related to the shade requirement (Ling, 1980, 1984; Wessel, 1985). It was reported that cocoa trees exposed to high fertiliser rate and minimum shade level produced the highest yield. However, a significant interaction of yield response to fertiliser and shade treatments was not observed in our study. The yield response to fertiliser or shade treatments were independent. This probably due the difference of planting material in this study which used cocoa from clonal propagation, while previous studies used cocoa from seed propagation.

Ling (1990) reported that although the yield of cocoa is higher in nil shade and high fertiliser application, this is uneconomical for commercial plantation because it lead to severe damage to the trees and yield decline in a longer term. This was best demonstrated in our study, that the zero shade treatment indicated a higher dieback score than medium and high shade levels. This zero shade also demonstrated yield decline in 2010 as the dieback was the worst. In addition, estimated of cumulative yield for 15 years of planting were only 27 ton/hectare compared to 31 ton/hectare in medium or high shade. The results of this study confirms the importance of shade management for long term commercial cocoa plantings.

This study demonstrated that yield response to nitrogen was not observed in an early mature (3-7 years old) of cocoa tree and for fully mature cocoa (>7 years), the requirement for N fertiliser increased significantly. At least low level of N fertiliser (Urea at 200 gr/tree) is required to sustain high yield of cocoa. A higher rate of this fertiliser may not be required because of insignificant yield increased and higher fertiliser cost. The low N requirement in this study probably due to good fertile soil and decomposition of plant litter from the leaves, prune branches, and pod husks. Ling (1984) reported that a lower fertiliser response was observed in Malaysia for fully mature cocoa due to slower growth rate and nutrient recycling from plant litter.

A numerous fertiliser trials had been reported in other countries, such as Ghana, Nigeria, Trinidad, Brazil, and Malaysia (Ling, 1980, 1984; Wessel, 1985). Their studies indicated a marked yield increased for phosphorus application if the soil available P is lower than 10 ppm. Annual application of phosphorus fertiliser is required to sustain high yield. Our study showed a low level of phosphorus fertiliser was sufficient to support growth and maintain high yield in this experimental site.

Conclusion

On a red yellow podsolic soil of Sumatra Utara, Indonesia, an adequate of fertiliser application is essential to support plant growth and sustain high yield of cocoa. Nitrogen and phosphorus fertilisers are required in this trial site, with optimum combination of 200 gram/tree Urea and 175 gram/tree TSP. In particular for phosphorus, it is essential if the soil P below than 10 ppm. Fertiliser yield response was not interacted with shade requirement. It was found that zero shade is uneconomical for long term of cocoa cultivation and a medium shade level is recommended for commercial planting to minimize dieback and achieve high yield.

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