Effect of Nitrogen, Phosphorus, and Potassium Fertilizer on cocoa in Indonesia

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METHODS

F1 hybrid cocoa was planted at 1010 trees ha^{-1} on brown sandy podzolic soil in Indonesia with a tropical climate characterized by distinct wet and dry seasons. Coconut trees planted at 37 trees ha^{-1} were used as permanent shade. Treatments were NPK fertilizer applications (see table below), arranged in a factorial randomized block design with 3 replicates.

Level	N (kg/ha)	P (kg/ha)	K (kg/ha)
0	0	0	0
1	93	80	61
2	186	160	None

Ripe pods were harvested every week and the number of pods per tree was calculated in each plot. The amount (kg) of dry cocoa beans per ha was estimated from the number of pods produced per tree in a year divided by 30 (total pods required to produce 1 kg dry beans) and multiplied by 1010 (tree density). Soil and leaf samples were collected for nutrient analysis at 18 YAP.

RESULTS

Effect of N, P, and K fertilizer on yield and leaf nutrient concentration

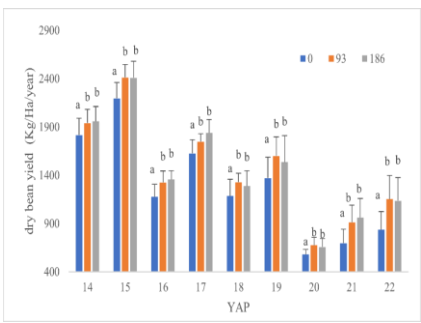

Fig. 1 - N fertilizer effects on cocoa dry bean yield

- Compared with the control, N fertilizers applied at 93 and 186 kg ha^{-1} significantly increased dry bean yield from 14-22 years after planting (YAP) (Figure 1).
- Both low and high N applications increased yield by 30% over the last 3 years.
- P and K fertilizers did not affect dry bean yield (data not shown).

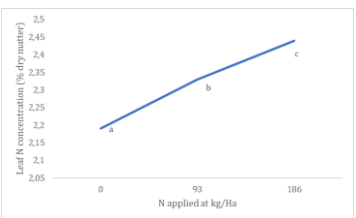

Fig. 2 - N fertilizer effects on leaf N

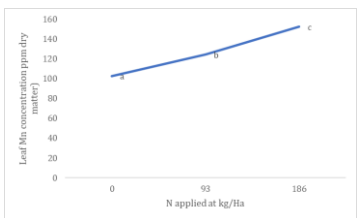

Fig. 3 - N fertilizer effects on leaf Mn

Nitrogen application in mature cocoa not only significantly increased leaf N concentration (Fig. 2), but also leaf Mn (Fig. 3), suggesting the presence of N-Mn interaction. N also interacted with P: high N application rates reduced leaf P concentration in mature cocoa (Fig. 4).

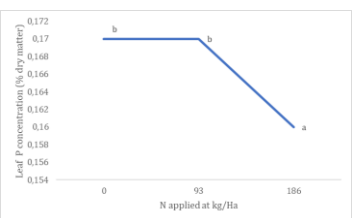

Fig. 4 - N fertilizer effects on leaf P

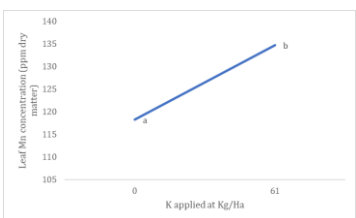

Fig. 5 - K fertilizer effects on leaf Mn

P application did not affect leaf P concentration (data not shown), K fertilizer significantly increased Mn concentrations in cocoa leaves (Fig. 5).

Effect of N, P and K fertilizer soil nutrient

- Plots treated with N fertilizer had higher soil P than the control plot. N application at 93 kg ha^{-1} had almost doubled soil P than the control. Plot receiving high N fertilizer had slightly lower soil P than the low N rate but still higher than the control (Table 1).
- N application did not affect soil K availability, which in N-treatment plots differed less than 0.2 meq/100g from control plots.
- Soil pH seemed to related with N application as we observed a gradual reduction from 6,43 to 6,19 in the control to high N fertilizer, respectively. In contrast, K-fertilized plot had higher soil pH than the control. Soil pH was unaffected by P fertilizer application.

INTRODUCTION

Cocoa is one of Indonesia's primary cash crops, supporting almost one million households. Smallholder farmers produce most Indonesian cocoa beans. However, their dry bean yield is only about half of the yield obtained by private plantation companies. Fertilizer is known to increase cocoa yield, but the yield response to fertilizer varies depending on environmental conditions and agricultural practices.

OBJECTIVE

To determine the best fertilizer combination for optimum yield and profit for cocoa trees planted on brown sandy podzolic soil with distinct wet and dry seasons.

Table 1 - Soil P, K, and Mn contents in the treatment combinations

Treatment	pH	Extr P bray (ppm)	Exc Cation me/100 g				Extr. In CaCl2			
			Al+H	K	Mg	Ca	Zn	Cu	Mn	Fe
0N+0P+0K (control)	6,43	42,18	0,21	1,35	3,55	14,08	1,20	0,26	12,06	3,85
93N+0P+0K	6,22	80,38	0,10	1,15	3,31	15,76	0,89	0,19	21,24	3,38
186N+0P+0K	6,19	57,14	0,11	1,25	3,02	13,33	1,34	0,40	27,51	3,91
0N+80P+0K	6,43	169,39	0,12	1,21	4,09	18,89	1,08	0,47	15,67	3,39
0N+160P+0K	6,41	200,38	0,17	1,22	2,89	17,03	1,85	0,36	13,54	4,69
0N+0P+61K	6,66	53,51	0,18	1,15	3,66	17,54	1,85	0,29	17,63	3,35

- Our data suggest that P application increased soil P availability. Soil P, ranging from 42 to 80 ppm P for non-P treatments and 169-200 ppm P for the P treatments.
- Soil K content ranged from 1.15 to 1.35 meq/100 g, with higher K content in the control soils than in the K-treatment plot (Table 1).
- Soil Mn availability is likely related to N application. The two N-treatments resulted in higher Mn availability than in the control plot, particularly with an N application of 93 kg ha^{-1} when soil Mn almost doubled compared to control. Soil Mn content in the low N application treatment was higher than in the control but lower compared to the higher N application.
- K-treated plot also had higher soil Mn availability than control.

DISCUSSION

- N application increased leaf N concentration and resulted in higher dry bean yield per hectare. These results confirm previous studies that N fertilization improves cocoa productivity by stimulating flowering, increasing pod production, prolonging leaf spa,n and alleviating tree dieback.
- The increased leaf Mn as a result of higher N availability may be related to the acidifying effect of Urea application. As the soil pH decreases, there is an increase of soluble Mn in the soil, thus result in higher tissue concentration.
- The nutritional base cations Ca2+, K+, and Mg2+ in the soil were also reduced by soil acidification as indicated by lower level of the nutrients in the N-fertilized plots than control.
- Increased leaf N concentration due to the application of N fertilizer, if leaf P uptake were similar across all treatments, would lead to decreased shoot P concentrations in N-fertilized treatment compared with control. N-fertilizer induced increases in shoot dry weight will dilute the concentrations of other mineral elements in shoots unless the increase in shoot dry weight is accompanied by increased mineral-absorption rates.
- The higher leaf Mn concentration in the K-fertilized treatment may be related with the higher Mn in the soil solution.
- We demonstrated no positive yield and leaf nutrient response to P and K fertilizer applied over the last 9 years of observation, probably as a result of the high soil P and K status in that period. The soil P and K in this study had higher P and K availability than soil in most cocoa-producing countries worldwide. Moreover, previous studies in Malaysia reported positive yield and nutrient response to P fertilizer only when soil P availability ranges from 7 to 17 ppm. Our results confirmed that yield and nutrient response to P and K applications depend on the soil nutrient status that is influenced by soil type.

CONCLUSIONS

- Nitrogen fertilizers at a rate of 93 kg ha^{-1} year^{-1} applied in two rounds is the most optimum N fertilizer rate for cocoa production on our experimental site in Indonesia.
- P and K fertilizer applications did not affect yield and leaf nutrient uptake, suggesting P and fertilizer are not required for mature cocoa planted in the typical soil of our study site.
- We recommend that P and K fertilization recommendations in cocoa plantations are based on soil nutrient analysis.

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