Response of Cacao Seedlings to Fertilizer

By Thomas Oberthür, Marianne Samson, Noel Janetski, Kate Janetski, and Myles Fisher

Cacao nursery owner and "Cocoa Carer" Mr. Aris (far right) inspecting seedlings in the trial with (left to right) Mr. Noel Janetski, Dr. Thomas Oberthür, and Ms. Kate Janetski.

SUMMARY

Researchers combined a suite of good agricultural practices with fertilizer application. Modest amounts of fertilizer applied to cacao seedlings in the nursery increased seedling growth and nutrient concentrations. There were no significant responses if fertilizer application rates were doubled. Results find it likely that adequate and well-timed supplies of fertilizer nutrients in the nursery will translate into better long-term agronomic performance in farmers' fields.

KEYWORDS:

cacao fertilization; seedling growth; good agricultural practices

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; B = boron.

IPNI Project IDN-27

http://doi.org/10.24047/BC102420

Production of cacao in Indonesia has increased from 27,000 t in 1984 to almost 730,000 t in 2014 (FAOSTAT 2017), yet average yields of the smallholders, who produce about 96% of the crop, are very low at 400 kg/ha. The yield potential of cacao has been estimated to be 11,000 kg/ha (Corley, 1983). Despite the lack of research on cacao (Carr, 2012; van Vliet and Giller, 2017), there is an obviously large yield gap that can be exploited. The narrowing of the yield gap depends on improved management at all growth stages of the crop. In small-plot trials, high-yielding clones produce more than 6,000 kg beans/ha (Chan and Lim, 1986), while commercial growers may exceed 4,000 kg/ha (Bosshard and Von Uexküll, 1987).

Little is known about the effect of different management practices in nurseries on seedling growth and subsequent performance in the field. Seedlings are typically grown in nurseries for six months before they are transplanted to the field. Commercial nurseries use best-guess fertilizer schedules, but do not measure plant growth or other performance indicators, seeking mainly to minimize costs. Based on expe-

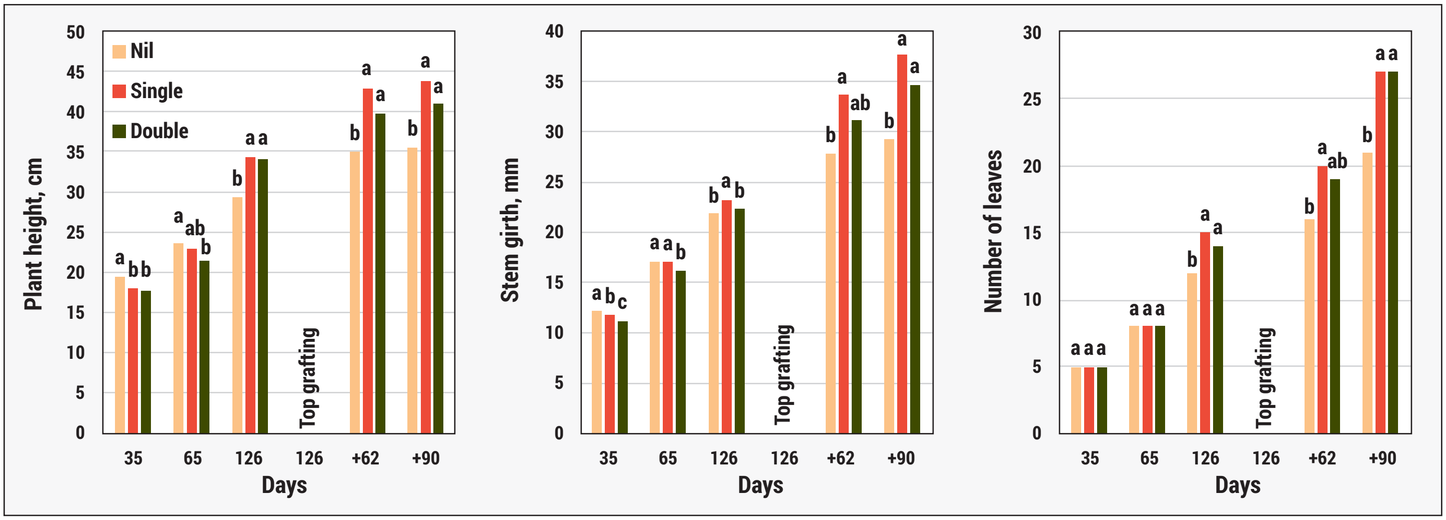

Figure 1. Effect of fertilizer on the growth of cacao seedlings. Numbers on the x-axis are days since germination and those since grafting on day 126. Columns with the same letter and date did not differ significantly (p>0.05).

rience with other crops, literature, and considering soil analyses (**Table 1**), a balanced fertilizer mixture was formulated that was judged to allow for near-optimum performance.

Table 1. Soil properties.

pH	Organic matter, %	Total N, %	Bray 2 P, ppm	B, ppm	Exchangeable cations, cmol/kg K	Mg	Ca	Texture, % Clay:sand:silt
7.4	2.0	0.09	74	11	0.31	3.4	22.1	41:42:17

Commercial-scale batches of seedlings were grown to assess the performance of cacao seedlings at two fertilizer rates, compared with an unfertilized control.

A randomized block experiment with four replicates was conducted in a cacao nursery in Soppeng, South Sulawesi. The treatments were three levels of applied N, P, K, Mg, and Ca:

1) No fertilizer
2) Single rate: 1.2 g N, 0.5 g P, 1.4 g K, 0.4 g Mg, and 1.3 g Ca (total per plant)
3) Double rate: 2.3 g N, 1.0 g P, 2.7 g K, 0.8 g Mg, and 2.6 g Ca (total per plant)

The fertilizer sources were an NPK compound (15-15-15), ammonium sulfate, potassium chloride, dolomite, and kieserite. Soil was mixed with 25% of the fertilizer treatment before filling each bag and the remainder was applied to the soil surface—25% after grafting, and the remainder six weeks later.

Polybags (20 cm x 25 cm) were filled with a mixture of sieved local topsoil and sand (**Table 1**). The final texture marginally exceeded 40% clay. A single pre-germinated seed of PBC123 variety was placed in each bag on 3 August, 2017. The seedlings emerged 3 to 6 days later. All seedlings were grafted with a high-yielding TR 45 clone at three months of age and the experiment ended after about seven months, the age at which nurseries sell grafted seedling to farmers.

Each treatment replicate consisted of 50 seedlings. Twenty seedlings were selected at random within each treatment replicate for detailed measurement. Ten seedlings were harvested at grafting and the remaining ten at the end of the experiment, which were divided into roots, stems, and leaves. Fresh and dry weight were measured for each component and subsamples were analyzed for N, P, K, Mg, Ca, and B. Plant height, stem diameter (used to calculate the

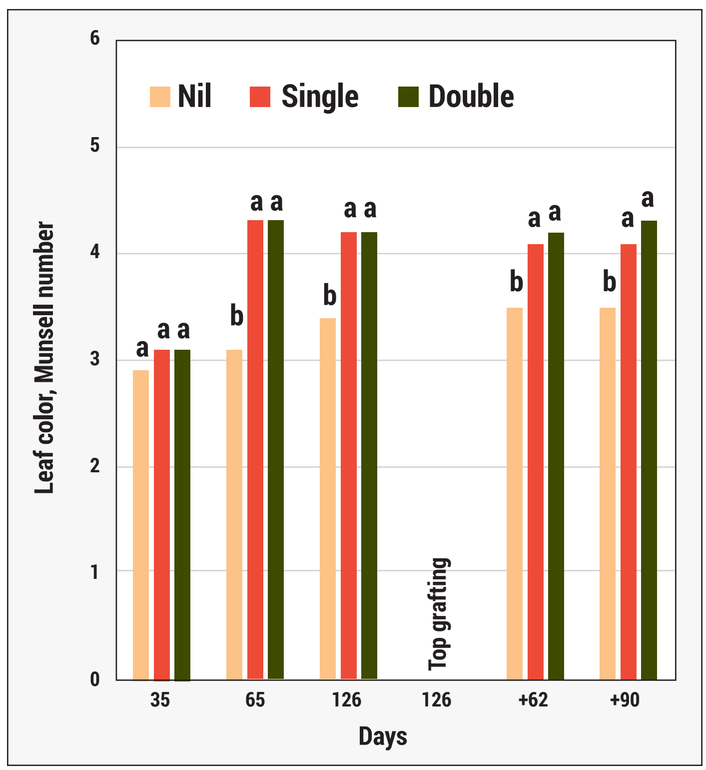

Figure 2. Effect of fertilizer on the greenness of cacao seedlings. Numbers on the x-axis are days since germination and those since grafting on day 126. Columns with the same letter and date do not differ significantly (p>0.05).

stem girth data reported), and leaf number were measured each month before grafting and the remaining ten measurement seedlings twice more after grafting. The greenness of the youngest fully-expanded leaf was estimated using Munsell color chips.

Results

The experiment had two stages, growth of the rootstock before grafting, 126 days after emergence, and subsequent growth of the scion, to which continued growth of the rootstock contributed.

Rootstocks of cacao seedlings grown with fertilizer prior to grafting were taller, more robust (**Figure 1** and **2**) and had higher tissue concentrations of the nutrients that were applied (**Tables 2** and **3**). Doubling the amount of applied fertilizer gave no significant increase.

> **TAKE IT TO THE FIELD**
>
> Application of mixed fertilizer to cacao seedlings gave more robust, taller, leafier and greener plants at sale time compared with unfertilized controls. Doubling the amount of fertilizer rate had no agronomic advantage and so gives no increased economic advantage.

The length of the grafted scion or the level of the graft were not recorded, so it is difficult to draw conclusions from the plant height data from the post-grafting stage. However, the fertilizer treatments were greener, the rootstock had thicker girth and the scion grew more leaves in the last month in the nursery than the nil control (**Figure 1**). Doubling the rate of fertilizer gave no significant advantage.

Although we have analyses for all three plant components (i.e., leaves, stems, and roots), data for the leaves demonstrate the important features. We caution that these are data for representative samples of all the leaves from the seedlings within each replicate of each treatment. They are not comparable with the data for the last fully-expanded leaf used to assess nutrient sufficiency in mature plants.

Fertilizer increased dry matter yield by about 50%, but increases in mean nutrient element concentrations of the whole leaf fraction was somewhat less (**Tables 4** and **5**). There was no significant response in nutrient element uptake at the double rate compared with the lower, single rate.

Table 2. Dry matter yield and nutrient uptake of the rootstocks immediately before grafting at 126 days after emergence.

Treatment	Dry weight	N	P	K	Mg	Ca	B
	------------	------------	------------	g/plant	------------	------------	------------
Nil	8.3 a	0.09 b	0.012 b	0.10 a	0.033 a	0.071 b	0.019 a
Single	10.2 a	0.16 a	0.017 a	0.13 a	0.035 a	0.112 a	0.017 a
Double	9.4 a	0.16 a	0.015 a	0.11 a	0.033 a	0.100 ab	0.016 a

Numbers within columns followed by the same letter do not differ significantly (p<0.05).

Table 3. Concentration of nutrient elements in the whole leaf fraction immediately before grafting at 126 days after emergence.

	N	P	K	Mg	Ca	B
Treatment	------------	------------	%	------------	------------	*ppm*
Nil	1.66 b	0.18 a	1.20 b	0.488 a	1.22 a	35.7 a
Single	2.25 a	0.18 a	1.35 a	0.330 b	1.12 a	20.7 b
Double	2.46 a	0.18 a	1.36 a	0.383 b	1.10 a	20.8 b

Numbers within columns followed by the same letter do not differ significantly (p<0.05).

Table 4. Dry matter yield and nutrient uptake at the end of the experiment, on 10 March 2018, 216 days after emergence and 90 days after top-grafting the scion (equivalent to the ready-to-sell stage).

	Dry weight	N	P	K	Mg	Ca	B
Treatment	------------	------------	------------	g/plant	------------	------------	------------
Nil	14.5 c	0.14 b	0.029 a	0.16 b	0.052 b	0.16 b	0.038 b
Single	22.9 a	0.34 a	0.033 a	0.30 a	0.080 a	0.28 a	0.062 a
Double	19.4 b	0.29 a	0.031 a	0.25 ab	0.069 a	0.27 a	0.056 a

Numbers within columns followed by the same letter do not differ significantly (p<0.05).

Table 5. Concentration of nutrient elements in the whole leaf fraction at the end of the experiment.

	N	P	K	Mg	Ca	B
Treatment	------------	------------	%	------------	------------	ppm
Nil	1.61 b	0.18 a	1.35 a	0.520 a	1.62 a	47.8 a
Single	2.12 a	0.16 a	1.42 a	0.458 b	1.55 a	44.0 a
Double	2.12 a	0.18 a	1.46 a	0.475 ab	1.70 a	46.6 a

Numbers within columns followed by the same letter do not differ significantly (p<0.05).

Discussion

The improved growth, height, yield, and nutrient concentration given by fertilizer applied at the single rate produced plants at the end of the experiment that were more visually attractive. It seems logical that these plants may offer long-term agronomic advantages (faster establishment, earlier fruiting, higher yield potential). If so, they should be financially attractive for the farmers, who may therefore be willing to pay a premium for them. They should also be advantageous for the nursery in terms of a more attractive product that commands a premium price. It may also be more profitable, although that would depend on the overall business plan and the local regulatory climate. It would also require more investment of money and labor and hence increase the nursery's financial risk.

Both possibilities are plausible, but we could find no relevant evidence on the topic to allow us to discuss the issue further. Further monitoring in the field is required, which we propose to do over the next 3 to 4 years. The data presented here provides the justification for this plan.

One of the four full fertilizer treatment replicates with 50 top grafted cacao seedlings.

Conclusion

Most nurseries in the region will not use fertilizer at all. Hence, our "zero fertilizer control" treatment represents the usual practice. Nurseries try to reduce costs where possible. On the other hand, previously accepted "best practice", which has the addition of SP36 (double superphosphate) in the planting media, combined with the use of foliar applications, has been used and is still used where a premium product may be sold. Our nursery "cocoa carer", Mr. Aris, was impressed by the single fertilizer rate results when compared to the previously accepted "best practice." The consensus was that the fertilizer treatment gave much better results. An initial analysis suggests that the fertilizer treatments cost much less for materials and labor than the accepted "best practice." Specifically, the application frequency was reduced to three soil-based fertilizer application rounds, compared to one soil and up to ten foliar applications performed in the previously accepted "best practice." The nursery of Mr. Aris has already started to incorporate the practice, which gives practical support for our conclusions. **BC**

Dr. Oberthür (e-mail: toberthur@ipni.net) and Ms. Samson are with IPNI Southeast Asia, Penang, Malaysia. Mr. and Ms. Janetski are with Community Solutions International's Cocoa Care Program, Bali, Indonesia, Dr. Fisher is with Centro Internacional de Agricultura Tropical CIAT, Cali, Colombia.

Acknowledgement

This research was supported financially by Lautan Luas Tbk., Indonesia, and IPNI and its members.

References

Agriculture Department of Indonesia. 2016. Tree crop estate statistics of Indonesia 2014–2016. Cocoa, Secr. Dir. Gen. Estates, Agricultural Department of Indonesia.

Bosshard, R.P. and H. Von Uexküll. 1987. Paper presented at the Seminar on Palm Kernel Utilization and Recent Advances in Cocoa Cultivation, 11-13 June 1987, Tawau, Sabab, Malaysia.

Carr, M.K.V. 2012. Cambridge, UK: Cambridge University Press.

Chan, Y.H. and H.K. Lim. 1986. *In:* E. Pushparajah and P.S. Chew, eds. Kuala Lumpur, Malaysia: Inc. Soc. Planters, pp. 45-60.

Corley, R.H.V. 1983. Expl. Agric. 19:217-237.

FAOSTAT. 2017. Database: http://www.fao.org/faostat/en/#home

van Vliet, J.A. and K.E. Giller. 2017. *In:* Adv. Agron., pp. 185-270.