Cacao Fertilizer Response to Various Environments in Indonesia

Cacao (*Theobroma cacao* L.), one of the most important perennial crops grown in the humid tropics is primarily used in the production of chocolate. The global demand for cacao has been continuously increasing to 4.6 million tons in 2014 (FAOSTAT, 2017), and is expected to exceed supply by 1 million tons in 2020 (Schmitz and Shapiro, 2012).

Although cacao is a very important commodity, its productivity is low in Indonesia with yields averaging 400 to 500 kg/ha. Many factors contribute to the low yields, among them soil degradation, low soil fertility, and lack of soil moisture. Cacao yield is largely determined by rain rather than other ecological factors (Alvim and Alvim, 1980). The growth and fruit production is regulated by the amount and distribution of rainfall. Trees that grow on soils with low fertility are very susceptible to water stress in drier years.

In Southeast Asia, the El Niño Southern Oscillation (ENSO) events represent threats to the intensive cacao cultivation in the region. It is predicted to increase in severity with the climate warming in the equatorial region (Timmermann *et al.*, 1999; Sheffield and Woods, 2008). Under conditions of drought, cacao bean yields are greatly reduced. In a simulated El Niño drought experiment in Central Sulawesi, Indonesia (Moser *et al.*, 2010), bean yield was reduced (670 kg ha^{-1} y^{-1}) in the water-stressed treatment compared to the control (740 kg ha^{-1} y^{-1}).

In 2014, IPNI and Cocoa Care partnered with Indonesian farmers to study the impact of good agricultural practices and 4R nutrition on cacao bean yields over 2 years. In one section of the farmer's cacao farm, good agricultural practices without fertilizer was implemented (GAP), while in another section, GAP with 4R-consistent nutrient management was imposed (GAPN). GAP involved regular pruning, weeding and phyto-sanitation. With 4R Nutrient Stewardship, the right source of fertilizer is used at the right rate, time, and place.

In 2014, the rainfall was well distributed with only 3 months (August to October) of dry season with less than 60 mm rainfall/month. In 2015, a strong El Niño occurred from July to November, causing reduction in cacao bean yields, with at least 5 months having less than 60 mm rainfall. Cocoa bean yields started to decline around September 2015, with no yields obtained for about 5 months from December 2015 to April / May 2016. This decline is likely the result of reduced fruit set and ripening during the period of intense drought.

Table 1 shows the average cacao dry bean yields from the two treatments (GAPN and GAP) for 2014 and 2015. In both years, GAPN had higher yields (25% and 34% in 2014 and 2015, respectively) compared to GAP. In 2014, bean yields were higher for GAP and GAPN compared to 2015, demonstrating the effect of drought on the cacao bean yields. In 2015, when there was drought, cacao bean yields in farms that had only good agricultural practices had 19% yield reduction, while yields in the farms that had fertilizer in addition to GAP only reduced by 7%. The results show that adequate and balanced nutrition is very important under water-stressed environments, suppressing the effect of drought under these conditions.

Table 1. Average cacao bean yields from 16 farmers in 2014 and 2015 in the Soppeng area of Sulawesi, Indonesia.

	GAP	GAPN	Difference, (kg/ha)	Difference, (%)
2014	734 kg/ha	977 kg/ha	242	25
2015	595 kg/ha	909 kg/ha	313	34
Difference, (kg/ha)	-139	-68		
Difference, (%)	19	7		

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