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Nitrogen requirements of cassava in selected soils of Thailand

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Abstract

Cassava (*Manihot esculenta*) is one of the most important export crops in Thailand, yet the nitrogen requirement is unknown and not considered by growers and producers. Cassava requirements for N were determined in field experiments during a period of four years and four sites on the Satuk (Suk), Don Chedi (Dc), Pak Chong (Pc), and Ban Beung (BBg) soil series in Lopburi, Supanburi, Nakhon Ratchasima, and Chonburi sites, respectively. The fertilizer treatment structure comprised 0, 62.5, 125, 187.5, 250 and 312.5 kg N ha $^{-1}$ as urea. At each site cassava was harvested at nine months and yield parameters and the minimum datasets were taken. The fertilizer rate which resulted in maximum yield ranged from 187.5 kg N ha $^{-1}$ in Supanburi and Chonburi (fresh weight yield of 47,500 and 30,000 kg ha^{-1} respectively) to 250 kg N ha^{-1} in Lopburi and Nakhon Ratchasima (fresh weight yield of 64,100 and 46,700 kg ha^{-1} respectively). Yield appeared to decrease at the higher, 312 kg ha $^{-1}$, at Supanburi and Lopburi, and 250 kg ha^{-1} (Chonburi) fertilizer N rates. Net revenue was 70.4 and 72.9 % higher than where no N was applied at Lopburi and Nakhon Ratchasima sites. Net revenue at the Supanburi and Chonburi sites were 53.8 and 211.0 % higher than that where no N was applied. This study suggests that at all sites improved cassava production and net revenue could be obtained with the judicious application of higher quantities of N. The results provide needed guidance to nitrogen fertilization of the important industrial crop cassava in Thailand.

Keywords: *Manihot esculenta*, nitrogen response, economic dominance

1 Introduction

Cassava (*Manihot esculenta*, Crantz), is cultivated for its starchy tuberous roots and is grown exclusively in tropical regions of the world. Cassava is the third largest source of carbohydrate in the tropics following rice and corn, and is a staple for over 650 million people (FAO, 2002).

In Thailand, cassava is one of the most important economic crops. Farmers in marginal soil and climate conditions are able to produce food using this crop. In Thailand cassava is also grown for exportation to the European Union (EU). The total acreage of cassava in Thailand reached a maximum at about 1,327 thousand ha in 2009 but has been reported to be 1,168 thousand ha in 2010. As a result total production decreased from 30,088 to 22,005 thousand tons in 2010 (FAO, 2010).

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Cassava utilization patterns are quite different in different parts of the world. Cassava is widely used in the tropics for human food, animal feed and industrial raw material. In Thailand, however, cassava has been developed as an export-oriented cash crop, rather than a subsistence staple. Eighty percent of cassava exported from Thailand is for starch for industrial use and pellets for animal consumption in the European Economic Community (EEC) countries (Mandal, 2006). In Africa, by contrast, about 90 % of the total production is used for human consumption; while in the Americas, about 33 % is used as animal feed. For Asia, about 88 % of the root is consumed as food, either in direct or in processed form, especially in India, Indonesia and the Philippines.

Nitrogen is the second nutrient, after potassium, most used by cassava (Howeler, 2002; Ayoola & Makinde, 2007). Nitrogen enhances growth in general, increases the efficiency of photosynthesis, increases leaf area index (LAI) and increases the yield (Cock, 1975; Howeler, 2002). However, large nitrogen applications can also reduce the harvest index (HI), root yield and starch content while increasing the HCN content of the root (Edwards & Kang, 1978).

In tropical regions such as Thailand, nutrient management for a specific site can be highly variable due to variability in soil, weather, and crop conditions. For this reason specific recommendation are very important for farmers. The lack of farmer experience in selecting and using fertilizers has resulted in nutrient losses and low yield. Site specific nitrogen management has been recommended as one means of increasing the efficiency of N fertilizer use as well as reducing environmental impact (Ferguson *et al.*, 2002). Koch *et al.* (2004) reported that less N fertilizer (6–46 % less) was used in a site-specific managed approach and was more economic than blanket-applied N, even when identical total amounts of N were applied. Similarly, Attanandana *et al.* (2005) show that accurate, site-specific fertilization maize can reduce production costs. Attanandana *et al.* (2005) also report that site-specific fertilization increased farm production with a 10–15 % increase in yield. In Thailand increased production of cassava is needed to sustain production as the production area is decreased. The objective of this research was to determine the optimum N fertilizer rate for cassava on selected, representative soils of Thailand.

2 Materials and methods

2.1 Field experiments

Sites: Field experiments were conducted to determine the optimum application of N fertilizer at four sites in Thailand. The sites were selected because they represent the primary regions of cassava production. The first site was located on a highly weathered, coarse-textured soil - a isohyperthermic, Typic Paleustult of the Satuk (Suk) series located at the regional Center for Research and Development for Farmers, Panied, Koksamrong, Lopburi, 15.04 °N Latitude and 100.79 °E Longitude. At this site cassava was grown for the period April to December, 2009. The Satuk soil series was brown to dark brown in color, with high sand content of 810 g kg^{-1}, and a soil pH of 5.8 and 16.8 g kg^{-1}of organic carbon. This soil is representative of large regions of the Northeast of Thailand. The second site was located on a Typic Dystrustepts of the Don Chedi (DC) series. The Dc soil series was brown in color, also with a high sand content of 690 g kg^{-1}, a soil pH 5.2 and 5.3 g kg^{-1} of organic carbon. This site was on a cassava farmers' fields in Nongyhasai, Supanburi, 14.84 °N Latitude and 99.89 °E Longitude. At this site cassava was grown during the July 2010 to April 2011 season. The third site, on another contrasting soil, represented large expanses of the cassava growing region located in Nakhon Ratchasima. The experiment was located at the Nakhon Ratchasima Animal Nutrition Research and Development Center, Pak Chong, Nakhon Ratchasima, 14.42 °N Latitude and 101.25 °E Longitude. At this site the widely used Pak Chong soil series (Pc) was selected, which is a highly weathered Rhodic Kandiustox. The Pc soil series was reddish in color, with high clay content of 473 g kg^{-1}, soil pH of 6.3 and 25.9 g kg^{-1} of organic carbon. Here cassava was grown during the June 2011 to March 2012 season. The fourth representative yet contrasting site was located on cassava farmers' fields in Banbueng, Chonburi, 13.29 °N Latitude and 101.14 °E Longitude. The soil selected at this site was a Ban Bueng soil series (Bbg), which is an Oxyaquic Quartzipsamment. The Bbg soil series was russet in color with high sand content of 783 g kg^{-1}, a soil pH 5.5 and only 3.2 g kg^{-1} of organic carbon. Soil samples were taken before planting for chemical and texture analysis.

Rainfall: During the crop growth period of 9 months, the Lopburi, Supanburi, Nakhon Ratchasima, and Chonburi sites received rainfall of 1,027, 1,205, 1,031, and 818 mm, respectively. No supplemental irrigation was applied.

Soil data: see Table 1

2.2 Experimental design and nitrogen treatments

All experiments were conducted using a randomized complete block design (RCBD). There were six treatments and three replications at the Lopburi and Supanburi sites and five treatments and four replications at the Nakhon Ratchasima and Choburi sites. The individual plot size at all sites was 6×5 m (30 m^2) with a plant spacing of 1 m by 1 m and the spacing between plots was 2 m. The widely grown open pollinated cassava (*Manihot esculenta*, Crantz, variety "Kasetsart 50") was grown at all four sites. The same rates of fertilizer application were selected for each site, except the highest rate which was omitted from the Nakhon Ratchasima and Chonburi sites (Table 2). Nitrogen was applied at 30 and 90 days after planting, one-half of the total at each time. The fertilizers were placed uniformly by hand, 10–15 cm below the soil surface in form of urea at 46 % N, triple super phosphate 46 % P_2O_5, and potassium chloride at 60 % K_2O, respectively (Table 2). Unfortunately, the high rate of 312.5 kg N ha^{-1} was discontinued for locations at Nakon Ratchasima and Chonburi. The high rate caused premature wilting and the plants had an unhealthy appearance (personal observation, 2009).

2.3 Plant data collection

Cassava was grown for 9 months after planting. Harvests took place in December 2009, April 2011, March 2012, and June 2012 at the Lopburi, Supanburi, Nakhon Ratchasima, and Chonburi sites, respectively. The harvested portion of the plot was the middle row of the three rows, $3\,m \times 2\,m$ plot. Leaves, stems and roots were weighed and air-dried until the weight was constant. Fresh weights of leaf, stem, and root were recorded for the harvested portion and the air-dried fractions.

Table 1: *Soil properties of the soils at selected sites before the experiment.*

Soil Properties	*Soil Series*			
	Lopburi Satuk (Suk)	*Supanburi Don Chedi (Dc)*	*Nakon Ratchasima Pak Chong (Pc)*	*Chonburi Ban Bueng (Bbg)*
Texture	Sandy loam	Sandy loam	Clay	Loamy sand
Sand (g kg^{-1})	801	691	343	783
Silt (g kg^{-1})	7	209	184	105
Clay (g kg^{-1})	192	100	473	112
pH H_2O 1:1	5.8	5.2	6.3	5.5
OC (g kg^{-1})	16.8	5.3	25.9	3.2
Total N (g kg^{-1})	0.76	0.52	1.6	0.58
Ext. P (mg kg^{-1})	7.43	67	6	16
Ext. K (mg kg^{-1})	4.12	143.2	174	23.7
CEC ($cmol_c$ kg^{-1})	5.52	5.58	13.4	4.61

Table 2: *Nitrogen, phosphorus and potassium fertilizer rates at each of the four sites.*

Treatment	*Fertilizer rates (kg ha^{-1})*			
	Lopburi [1] *(Suk)*	*Supanburi* [1] (Dc)	*Nakon Ratchasima* [1] (PC)	*Chonburi* [1] (Bbg)
N1 – P_2O_5 – K_2O	0 – 62.5 – 125	0 – 62.5 – 125	0 – 62.5 – 125	0 – 62.5 – 125
N2 – P_2O_5 – K_2O	62.5 – 62.5 – 125	62.5 – 62.5 – 125	62.5 – 62.5 – 125	62.5 – 62.5 – 125
N3 – P_2O_5 – K_2O	125 – 62.5 – 125	125 – 62.5 – 125	125 – 62.5 – 125	125 – 62.5 – 125
N4 – P_2O_5 – K_2O	187.5 – 62.5 – 125	187.5 – 62.5 – 125	187.5 – 62.5 – 125	187.5 – 62.5 –125
N5 – P_2O_5 – K_2O	250 – 62.5 – 125	250 – 62.5 – 125	250 – 62.5 – 125	250 – 62.5 – 125
N6 – P_2O_5 – K_2O	312.5 – 62.5 –125	312.5 – 62.5 –125	–	–

[1] Locations of the regional experiments. Respective soil series are given in parentheses (Suk – Satuk, Dc – Don Chedi, Pc – Pak Chong, and Bgg – Ban Bueng)

2.4 Data analysis

Cassava yields of treatments were statistically analyzed for linear and quadratic effects using regression analysis (PROC GLM of the SAS® 9.2 program). A probability level of 0.05 was used to assess statistical significance. The Sigmaplot® program was also used to fit linear and quadratic equations to the yield response to nitrogen. Figures were prepared using Sigmaplot®.

2.5 Dominance analysis

The net revenue associated with the nitrogen fertilizer rates was determined at the four sites to aid farmers' decisions on selection and adoption of appropriate rate of nitrogen fertilizer in each site. An economic dominance analysis (Harrington, 1988) involved estimation of costs that vary and net revenue. The costs that varied with treatments included costs incurred in purchase of nitrogen fertilizers in form of urea with 46 % N. The price of kg fresh weight of cassava was used to calculate gross revenue (Table 3).

Table 3: *Cost and prices used in the calculation of economic dominance.*

	Cost (Baht / kg) *
Cost of Urea (46 % N)	16.4
Price of kg fresh weight cassava **	1.5

* 1 US$ = 31.5 Baht Thai,
** percentage of starch at 22–25 % for Kasetsart 50 variety

3 Results

The response to yield differed considerably at the four sites. At the Lopburi site, overall fresh root yields were more than at other sites when compared at the same rate (Fig. 1). In contrast, the fresh root yield at the Chonburi site was less than that at other sites for all of nitrogen levels. This may well have been due to the higher rainfall at the Lopburi site (1,027 versus 818 mm). The lowest yields of the experiment, occurring at the Chonburi site, may have been related to both the low rainfall and the coarse-textured soil with low water retention capacity. The soils with sandy loam or loamy sand texture (all but the Pc soil at Nakon Ratchasima) supported some of highest yields. A result of importance given the extensive area of coarse-textured soils in Thailand.

The fresh root yields of cassava increased with increasing rate of nitrogen fertilizer and in relation to the control treatment (0 kg N ha^{-1}). The fertilizer rate which resulted in maximum yield ranged from 187.5 kg N ha^{-1} at Supanburi and Chonburi (fresh weight yield of 47,500 and 30,000 kg ha^{-1} respectively) to 250 kg N ha^{-1} at Lopburi and Nakhon Ratchasima (fresh weight yield of 64,100 and 46,700 kg ha^{-1}, respectively). Yield depression occurred at both the Lopburi and Supanburi sites where higher fertilizer rates were applied. Unfortunately, the highest rate of N was not applied at Nakhon Ratchasima or Chonburi, but if a similar trend occurs at these sites then it seems likely that maximum yield at Nakhon Rathasima would also have occurred at 250 kg N ha^{-1}.

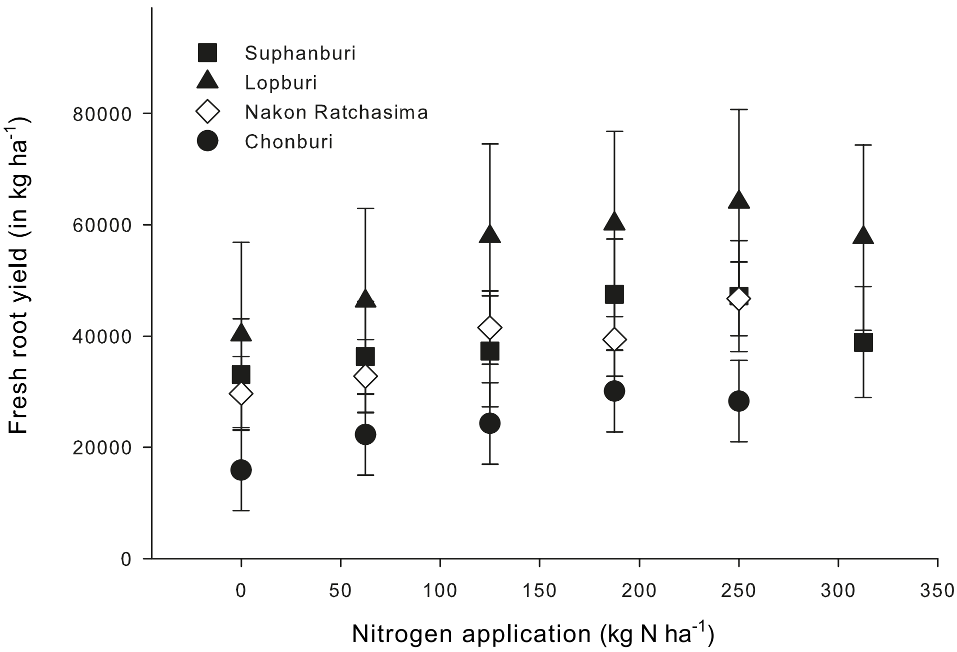

Fig. 1: *Cassava fresh root yield response to applied nitrogen fertilizer at four sites in Thailand.*

A regression analysis was performed to quantify the yield response to N fertilizer and to determine whether the response was linear or quadratic (Table 4). The linear coefficient was significant in the Nakhon Ratchasima and Chonburi sites but the quadratic was not significant for any treatment in any site. The relationship between cassava yield and nitrogen rates was linear and positively correlated with a regression equation Yield = 29885 + 64.9*N and Yield = 17637 + 52.28*N in Nakhon Ratchasima and Chonburi, respectively.

An estimate of soil N, based on the response curve was obtained by extrapolation of the linear response equation back to the X axis where the predicted yield equaled zero. Such rough estimates of soil N at the Supanburi site were very high when compared with the other sites at 1,083 kg ha^{-1} followed by Lopburi, Nakhon Ratchasima, and Chonburi at 684, 460, and 337 kg ha^{-1} respectively. We note that these estimates of soil N seem quite unrelated to soil C at the various sites – the Chonburi site with only 3.2 g kg^{-1}, while the Nakon Ratchasima site contained 25.9 g kg^{-1}.

The net revenue was highest at 77,000 baht ha^{-1} at Lopburi, 53,000 baht ha^{-1} at Supanburi, 51,000 baht ha^{-1} at Nakhon Ratchasima, and 27,000 baht ha^{-1} at Chonburi, which were obtained with 250, 187.5, 250, and 187.5 kg N ha^{-1} respectively (Table 5). At Lopburi and Nakhon Ratchasima, the net revenues at 250 kg N ha^{-1} were 70.4 and 72.9 % higher than that of the control. Net revenues at 187.5 kg N ha^{-1} at Supanburi and Chonburi sites were 53.8 and 211.0 % above that with the control treatment. Dominance analysis indicated that increasing the amount of N from 0 to 250 kg ha^{-1} in Lopburi and Nakhon Ratchasima, 0 to 187.5 kg ha^{-1} in Supanburi and Chonburi led to maximum net revenue and thus were the economically dominant N application rates.

4 Discussion

The results clearly show that in each site of cassava cultivars differ in their response to N fertilizer application and maximum fresh root yield probably due to varying soil properties and weather conditions in each region. Other studies have also reported differing yield response to nitrogen fertilizer for cassava in Thailand. Pisancharoen *et al.* (2008) reported that yield of cassava variety Rayong 9 responded to nitrogen fertilizer

Table 4: *Statistical analysis results of fresh root weight response of cassava to applied nitrogen.*

Location	*Linear Regression Coefficients*	*Quadratic*	*Probability of a similar result by chance alone (linear coefficient)*	*intercept*	*Estimated Soil N* (kg ha^{-1})*
Lopburi	64.70	NS	0.0708	44,280	684
Supanburi	32.38	NS	0.1485	34,968	1,083
Nakhon Ratchasima	64.90	NS	0.0008	29,885	460
Chonburi	52.28	NS	0.0082	17,637	337

* Extrapolated back to the X axis using the linear equations.

Table 5: *Dominance analysis for varying N levels in the four study sites.*

Treatment (kg N ha^{-1})	*Net revenue (Baht ha^{-1})**			
	Lopburi	*Supanburi*	*Nakhon Ratchasima*	*Chonburi*
0	45,000	34,000	29,000	9,000
62.5	53,000	38,000	33,000	17,000
125	69,600	39,000	45,000	19,000
187.5	72,000	53,000	40,000	27,000
250	77,000	51,000	51,000	23,000
312.5	66,000	38,000	–	–

* 1 US$= 31.5 Thai Baht

in Khon Kaen and Chanthaburi on Nam Phong soil series (loamy) and Warin soil series (fine-loamy). They report that the fertilizer rate which resulted in maximum yield was 200 kg N ha^{-1}at Khon Kaen (the yield was 30,000 kg ha^{-1}) and 100 kg N ha^{-1} at Rayong (with a yield of 42,000 kg ha^{-1}) sites. At the Rayong site, fresh root yields of cassava variety Kasetsart 50, Rayong 5, and Hauybong 60 indicated maximum yields at nitrogen fertilizer rates of 281.3 kg ha^{-1} (Youngmod *et al.*, 2006). In India, Kamaraj *et al.* (2008) reported yield response to nitrogen fertilizer at the Puthiragoundanpalayam site on Thulukkanur series (sandy clay loam) and at Paravakkadu on Salem series (sandy loam). Maximum yield was obtained at 90 kg N ha^{-1} at both the Puthiragoundanpalayam site and at the Paravakkadu site. Maximum yields were approximately 50,000 kg ha^{-1}.

At the Supanburi site, estimates of soil N were very high when extrapolated the linear equation back to the X axis. This large estimate may be an artifact of the low response to fertilizer N or there may have been residual nitrogen fertilizer at this site.

A comparison of yields at the two sites where 250 kg ha^{-1} was maximum reveal that nitrogen use was somewhat more efficient at the former, yielding 64 kg ha^{-1} yield increase with each kg ha^{-1} of applied N, while the same mean ratio was 42 kg ha^{-1} at the lower yielding sites. Because yields vary this metric may be useful to estimate new N requirements if field experiments are not possible.

The results clearly show that net revenue also differs greatly with region. Chomboot (2008) determined the optimal rate of fertilizer and associated costs for cassava variety Kasetsart 50 on the Maha Sarakham series (sandy loam). They reported that the application of fertilizer according to recommendations of the Department of Agriculture (15–15–15, 660 kg ha^{-1}) gave a higher net revenue at 37,000 baht ha^{-1} a lower rate of application fertilizer (15–15–15, 130 kg ha^{-1}) resulted in a net revenue of 32,000 baht ha^{-1}. The recommendations of Land Development Department were (12–10–4, 312.5 kg ha^{-1}), which provided a net revenue of 29,000 baht ha^{-1}, while the traditional application (15–15–15, 312.5 kg ha^{-1}) resulted in a net revenue of 28,000 baht ha^{-1}. The data provided by this experiment suggest that all of the recommendations were extremely low considering both productivity and net revenue. Although the application of fertilizer according to the results of this experiment resulted in both highest production and the highest net revenue, it also required a high initial cost and a higher cost of production. Such high initial costs may be a constraint to cash-strapped producers.

5 Conclusions

Cassava yield improved with the application of nitrogen fertilizer at all sites, as expected. However, these data suggest much more N should be applied to achieve maximum yield and maximum revenue. A concern not addressed in this study is the amounts of N that might be leached into groundwater to associated waterbodies. Possibly a factor needing follow-up research. At Lopburi and Nakhon Ratchasima, sites, maximum yields were 64,100 and 46,700 kg ha^{-1} with net revenues of 77,000 and 51,000 baht ha^{-1}, respectively. These two sites, contrasting sharply in soil texture (sandy loam and clay) illustrate that high yields are possible on the extensive coarse-textured soils of the cassava growing region. Maximum yield was obtained with the application of 250 kg N ha^{-1}. At Supanburi and Chonburi sites, the maximum yield was 47,500 and 30,000 kg ha^{-1} with net revenues of 53,000 and 27,000 baht ha^{-1}, respectively. At these sites maximum yield was obtained with the application of 187.5 kg ha^{-1} urea. The application of nitrogen fertilizer gave net revenue increases of 70.4 %, 53.8 %, 72.9 %, and 211.0 %, respectively. This study suggests that at all sites improved production and net revenue could be obtained with the judicious application of higher quantities of N. These results also suggest an upward revision in fertilizer recommendations for cassava producers.

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