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Effect of Nutrient Management on Root Yield and Economic Value of Cassava Grown after Rice under Rainfed Conditions

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ABSTRACT

Background: Rainfed lowland rice crops are grown only once a year in the rainy season. In general, the fields are left fallowed after harvest of rice in the dry season. Cassava a drought tolerant-crop has the potential to grow the following rice. One of the methods to sustain production is through the application of beneficial microorganisms such as plant growth-promoting rhizobacteria and foliar bio-extracted fertilizer.

Methods: Cassava was planted in the dry season (December-June). Nutrient management treatments included; 1) application of chemical fertilizer as recommendation rate (CFR), 2) application of CFR combined with plant growth-promoting rhizobacteria (PGPR), 3) application of 80% of CFR combined with PGPR and 4) application of CFR combined with bio-extracted pig manure (BPM) which laid out in randomized complete block design.

Result: Interaction between CFR and PGPR gave the maximum storage root yield of 23.1 t ha^{-1} without significant differences with the application of CFR alone (20.3 t ha^{-1}). Such treatment also provides higher net income than those of the other treatments in the present experiment.

Key words: Bio-fertilizer, Cassava, Plant growth promoting rhizobacteria, Rice-based cropping system.

INTRODUCTION

Paddy land remains fallow after the rainy season because of limited soil moisture available, which irrigated area is 16% of total agricultural land (Polthanee, 2006). Northeast Thailand has a semi-humid tropical climate, which is characterized by rainy (May-October) and dry (November-April) seasons (Goto *et al*., 2008). Rice (*Oryza sativa* L.) is the most extensively grown crop in northeast Thailand, occupying nearly 5.76 million hectares (61%) of land area (Office of Agricultural Economics, 2020). Hence, the cropping intensity may be increased by growing the second crop during the post-rainy season.

In general, cassava (*Manihot esculenta* Crantz) is grown in upland fields and it is harvested from 8-12 months. However, cassava is grown after the rice is harvested from 6-7 months. Due to cassava is efficient adaptable to a wide range of environments and tolerant to drought and acidic soil conditions (Food and Agriculture Organization, 2001; EL-Sharkawy, 2007). Hence, cassava is a tolerable crop to grow after rice in the dry season without supplemental irrigation. In the northeast, farmers are also practice growing cassava after rice to earn cash income in the dry season, especially in the area where rice produced low yield due to seasonal drought during the rainy season (Polthanee *et al*., 2014). Short-duration cassava genotypes provide advantages to smallholder farmers for effective utilization of resources (Suja *et al*., 2009). In Thailand, CMR 33-38-48 genotype is recommended for short growth duration cassava (DOA, 2011). As mentioned above, cassava is grown after rice may be exposed to drought stress during the growing season. Plant growth-promoting rhizobacteria (PGPR) have gained worldwide importance and acceptance for their agricultural benefits through alleviate the negative effects of stress and to optimize nutrient cycling, which allows increases in crop yield (Figueuredo *et al*., 2016; Perez-Pazos and Sanchez-Lopez, 2018; Suresh *et al*., 2014). Fermented bio-extract is used to reduce various chemicals for plant growth promoters and pest controls (Phornphisuttimas, 2012). On the other hand, pig manure includes too much nitrogen relative to available organic carbon. It can enhance the leaching of phosphates, nitrates and increase the oxygen to the organic matter in water extracts according to Vamvuka and Raftogianni (2021). Therefore, the objective of this experiment was to evaluate the effects of chemical fertilizer combined with PGPR or bio-extracted pig manure on growth, root yield and starch content, as well as economic values of cassava grown after rice under rainfed conditions.

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MATERIALS AND METHODS

Experimental site

A field experiment was carried out from December 2017 to May 2018 at Kokklang village, Mahasarakham province (latitude 16.129412 and longitude 103.086261), Thailand, in a lowland rain-fed rice. The soil of the research site is sandy with pH 4.85 and characterized by low organic matter (0.12%), available P (8.49 ppm) and exchangeable K (9.30 ppm). The field capacity (FC) and permanent wilting point (PWP) values of this soil was about 14.62 and 6.15 (%w/w), respectively. The total amount of rainfall was about 430 mm during the growth period with a maximum amount of 238 mm in April. The average maximum (30°C) and minimum (18°C) temperature were observed in April and January, respectively (Fig 1).

Experimental design and treatment

The randomized complete block design with four replications was used in this experiment. The treatments consist of four fertilizer application methods; (1) chemical fertilizer recommendation based on soil analysis (CFR) by DOA (2019), (2) CFR combined with PGPR, (3) 80% of CFR combined with PGPR and (4) CFR combined with BPM. PGPR was used by soaking planting material (stake) for 30 minutes in dissolved PGPR in water with a ratio of 1 kg (PGPR): 20 liters (water). For bio-extracted pig manure preparation, pig manure 1 kg was dissolved in water 10 liters for 24 hours. Before using, extracted pig manure solution was mixed with water again at a ratio of 1:70 and sprayed to the crop canopy at rate of 500 liters ha^{-1} at 1, 2 and 3 months of age (MOA). The short-duration cassava CMR 33-38-48 was used in this study. After rice harvest, rice straws were cut at 3-5 cm above the soil surface. There after, rice straws were removed from the paddy field. The land was prepared by four wheels tractor with ploughing twice, ridging was made after the last plowing with 50 cm wide bed, 20 cm wide-furrow and 30 cm in height. The spacing between plants was about 0.80 meters. Chemical fertilizer as recommended based on soil analysis at a rate of 46.9-21.9-56.3 kg ($N\text{-}P_2O_5\text{-}K_2O$) /ha was applied at 1 and 3 MOA. The cassava stakes (15-20 cm length) at 10 MOA soaked in Thiametosam (25% WG) 4 gm dissolved in 20 liters of water for 10 minutes to reduce the incidence of mealybug (Ferrisiavirgata Cockerell). Then, the stakes were inserted into the soil in the middle of the bed. Hand weeding was done twice at 1 and 3 MOA.

Ground water level and soil moisture measurement

Observation wells of perforated polyvinyl chloride (PVC) tubes were installed at 150 cm soil depth in the middle of the experimental field. Ground water level below soil surface was recorded at planting day and thereafter two weeks interval entire the growth period. Soil moisture content was measured by gravimetric method at 0-15 and 15-30 cm depth at planting day and thereafter two weeks interval throughout the growth period according to Donahue *et al*. (1983).

Growth and yield components measurement

At harvest, five plants were randomly selected outside the harvest sampling area to determine the above-ground fresh weight. Then, the same samples were recorded the number of storage roots and fresh storage roots weight. The single storage root weight was measured as storage roots fresh weight divided by the number of storage roots.

Storage root yield and starch content measurement

At harvest, the storage roots were sampled from the area of 6×3 meters through the middle of the plot as a fresh weight to be calculated as root yield per ha The starch content (%) was determined by the Reimann scale balance according to Bainbridge *et al*. (1996).

Nutrient concentration measurement

The third, fourth and fifth of leave from the top of the main stem were sampled for analyzing total N, P and K at 3 and 5 MOA.

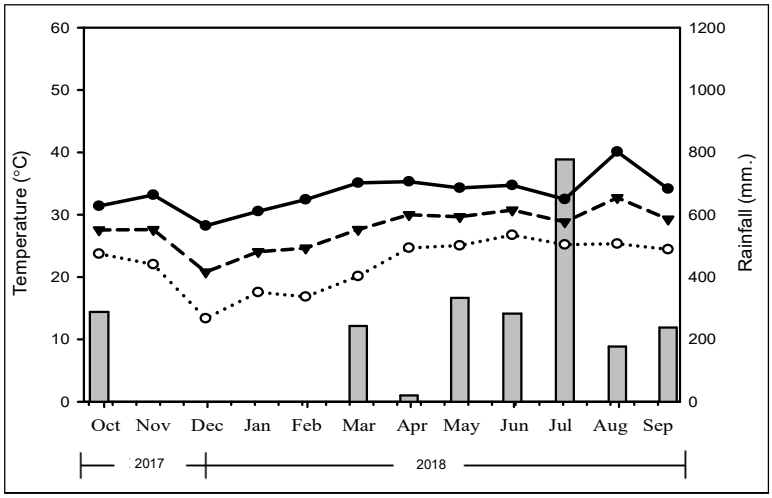


Fig 1: Rainfall (bar graph), maximum (--●--), minimum (--O--) and average (--▲--) temperature during the growth period.

Statistical analysis

Data of cassava growth, yield and yield components were subjected to analysis of variance (ANOVA) at first. Then the significance of differences between the treatments was determined by Duncan's multiple range test (DMRT) using Statistix software (Analytical software, 2013). The net return was computed as a benefit (yield × price) subtracted by production cost (materials+labour+land preparation cost).

RESULTS AND DISCUSSION

Ground water level and soil moisture content

During the growth period, the ground water level initiated about 120 cm below the soil surface at planting time. Then, the ground water level dropped to 145 cm below the soil surface and came up to 90 cm again below the soil surface (Fig 2). Soil moisture content (SMC) at 15-30 cm depth presented in the available ranges (between FC and PWP) at planting time to 35 DAP (day after planting). Thereafter, SMC dropped below PWP to 140 DAP and came up above PWP until harvest (Fig 3). This can indicate that SMC adequate for plant growth during the early growth stage. Then, SMC showed below during PWP level at 30 cm soil depth. Cassava roots may uptake restricted soil moisture at 30 cm soil depth. However, SMC below 30 cm depth may be presented in available ranges and roots located beyond such depth are able to uptake adequate soil moisture.

Nutrient concentration of leaf

Nutrient management methods (NMM) had no significant effect on P and K concentration of leaf at 3 and 5 MOA, but a significant difference was observed in N concentration (Table 1). The highest N was achieved in CFR+PGPR treatment both at 3 and 5 MOA. This was associated with the presence of rhizobacteria responsible for fixing atmospheric N, solubilizing K and phosphate, which enhance uptake by plants (Chauhan *et al*., 2015; Pii *et al*., 2015). PGPR belongs to the genus Bacillus that can produce IAA and thereby chlorophyll biosynthesis as reported by K.C. *et al*. (2020).

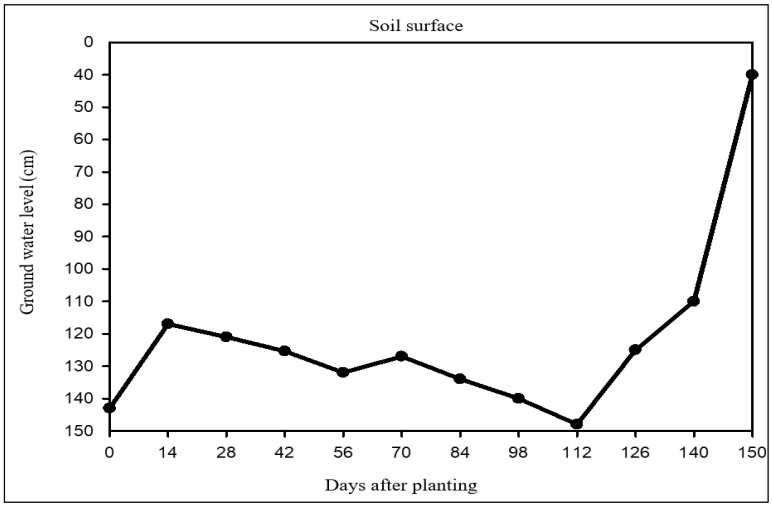


Fig 2: Ground water level during the growth period.

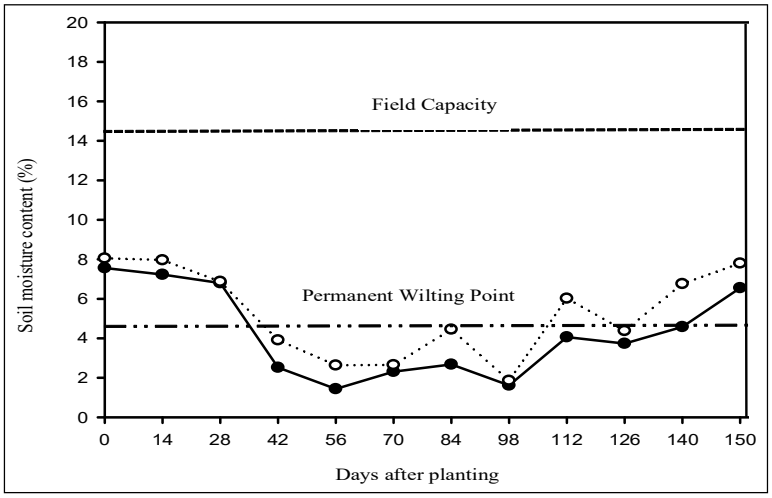


Fig 3: Soil moisture content (% w) at 0-15 cm (--●--) and 15-30 cm (--O--) depth during the growth period.

Growth, yield and starch content

NMM was significantly different ($p \leq 0.05$) in above-ground fresh weight, single storage root fresh weight and storage root yield of cassava, but no significant difference in storage root number and starch percentage (Table 2). CFR+PGPR treatment produced the maximum of above-ground fresh weight, single storage root fresh weight and storage root yield of cassava. CFR+PGPR gave higher storage root yield than that of application CFR alone by 14%. This can be due to improvement of plant development related to the presence of rhizobacteria treated the cassava stakes. Application of PGPR can result in the nutrient acquisition and the synthesis of phytohormones (Compant *et al*., 2010). It is known that PGPR is the rhizobacteria that can fix N and positively affect plant growth (Bashan and de-Bashan, 2010; Duca *et al*., 2014). Similar to N, the uptake of K and P may be mediated by PGPR when interacting with their host plant (Lugtenberg and Kamilava, 2009; Richardson and Simpson, 2011). Besides improved plant nutrition, the biosynthesis of phytohormones is also considered to directly stimulate plant growth. Auxin, gibberellin, cytokinin, ethylene and abscisic acid are phytohormones produced and released (Spence and Bais, 2015), Application of CFR+PGPR gave significantly higher single storage root fresh weight than that of CFR alone. This may be associated with auxin produced in meristematic areas and linked to cell elongation. Alteration in root morphology and development in plants inoculated with PGPR auxin producer was reported by Spence and Bais (2015). Cassava stakes treated with PGPR (*Bacillus* sp. Strain CaSUT007) increased root and shoot lengths by more than 30% and increased fresh and dry weights by more than 25% compared to distilled water control, auxin to be the primary compounds of phytohormone (Buensanteai *et al*., 2013). Regarding starch content, different nutrients management methods gave a similar effect on the starch percentage of storage root (Table 2).

Table 1: Nutrients concentration (g kg^{-1}) in leaf at 3 and 5 months of age of cassava grown after rice under rainfed conditions.

Treatments	3 months			5 months		
	N	P	K	N	P	K
T1= CFR	72.10b	3.22	10.42	77.77a	3.37	10.30
T2= CFR + PGPR	76.85a	3.20	10.87	78.20a	3.45	10.67
T3= 80% CFR + PGPR	73.67b	3.15	9.90	74.67b	3.17	9.75
T4= CFR + BMP	71.27b	3.07	10.05	75.77ab	3.20	10.22
F-test	*	ns	ns	*	ns	ns
CV (%)	2.1	4.9	7.9	2.3	7.6	6.41

Note: Indicates significant differences at $p \leq 0.05$ by DMRT and ns= Not significant; CFR= Chemical fertilizer recommendation rate, PGPR= Plant growth promoting rhizobacteria and BPM= Bio-extracted pig manure.

Table 2: Growth, yield components, root yield and starch content at harvest of cassava grown after rice under rainfed conditions.

Treatments	Above ground fresh weight (t ha^{-1})	Storage root number (per plant)	Single weight storage root (g)	Storage root yield (t ha^{-1})	Starch content (%)
T1= CFR	13.2ab	6.9	237.3ab	20.3ab	14.92
T2= CFR + PGPR	17.6a	7.0	261.7a	23.1a	15.25
T3= 80% CFR + PGPR	9.8b	4.7	216.2b	12.8b	15.82
T4= CFR + BMP	11.6b	5.9	225.5b	16.8ab	14.30
F-test	*	ns	*	*	ns
CV(%)	25.2	24.3	7.0	27.1	14.3

Note: Indicates significant differences at $p \leq 0.05$ by DMRT and ns= Not significant; CFR= Chemical fertilizer recommendation rate, PGPR= Plant growth promoting rhizobacteria and BPM= Bio-extracted pig manure.

Table 3: Yield, production cost, gross income and net income of cassava grown after rice under rainfed conditions.

Treatments	Root yield (t ha^{-1})	Material cost (USD. ha^{-1})	Benefit (USD. ha^{-1})	Net return (USD. ha^{-1})
T1= CFR	20.3	569.9	1074.7	504.8
T2= CFR + PGPR	23.1	606.6	1222.9	616.3
T3= 80% CFR + PGPR	12.8	586.0	677.6	91.6
T4= CFR + BMP	16.8	625.0	889.4	264.4

Note: CFR= Chemical fertilizer recommendation rate, PGPR= Plant growth promoting rhizobacteria, BPM = Bio-extracted pig manure; material cost= CFR+PGPR+BPM.

Net return from different nutrient management methods

The economics of the different nutrient management methods are presented in Table 3. The highest net return over materials cost was achieved by the treatment of CFR+PGPR (619 USD ha^{-1}). In the present study, production costs did not include labour. Although the smallholder farmers normally used household labour for cassava grown after rice., a sufficient net return for them. In this concern, Polthanee *et al*. (2014) reported that cassava grown after rice provides a net income of about 556-1,104 USD ha^{-1}, depending on different paddy fields.

CONCLUSION

Application of CFR+PGPR increased the storage root yield of cassava grown after rice over the application of CFR alone. On the other hand, application of CFR+BPM did not show any advantage when compared with the BPM application. Cassava that grown after rice can give net return ranges 92-616 USD ha^{-1}, depending on different nutrients management methods.

Conflict of interest: None.

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