Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS

Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2021.509.515

Research Article
Growth and Development of Cassava Cv. CMR 33-38-48 under Different Fertilizer Application

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Abstract
Background and Objective: To decrease the chemical fertilizer in cropping systems, improve cassava yield quality and natural resources. The application of compost with chemical fertilizer may provide a higher yield than does the chemical fertilizer only. This research aimed to investigate the effect of organic fertilizer on the growth and yield of cassava variety Cross Manihot Rayong (CMR) no. 33-38-48 under rainfed conditions. **Materials and Methods:** The nine treatments used were TR1) negative control, TR2) 468.75 kg ha^{-1} of chemical fertilizer 15-7-18+1.562.50 kg ha^{-1} of organic fertilizer, TR3) 312.50 kg ha^{-1} of chemical fertilizer 15-7-18+3.125 kg ha^{-1} of organic fertilizer, TR4) 156.25 kg ha^{-1} of chemical fertilizer 15-7-18+4,687.50 kg ha^{-1} of organic fertilizer, TR5) 468.75 kg ha^{-1} of chemical fertilizer 15-7-18, TR6) 312.50 kg ha^{-1} of chemical fertilizer 15-7-18, TR7) 156.25 kg ha^{-1} of chemical fertilizer 15-7-18, TR8) 625 kg ha^{-1} of chemical fertilizer 15-7-18, TR9) 6.250 kg ha^{-1} of organic fertilizer for observation and experimental purposes. **Results:** The results illustrate that only chemical fertilizer managements in TR5, TR6 and TR8 tend to increase storage root fresh weight of CMR 33-38-48. **Conclusion:** The optimum of compost to reduce the amount of chemical fertilizer use is organic fertilizer instead of 100% (TR9), 50% (TR3) and 25% (TR2) chemical fertilizer. Farmers should harvest CMR 33-38-48 at 8 months to avoid the rainy season which caused the loss of cassava storage root fresh weight.

Key words: Best practices, cassava, growth organic fertilizer, yield

Citation: Sungthongwises, K., A. Polthanee, A. Laoken and P. Harakotr, 2021. Growth and development of Cassava Cv. CMR 33-38-48 under different fertilizer application. Asian J. Plant Sci., 20: 509-515.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) plays an important role in terms of food security, employment creation and income generation for farm families in Northeast Thailand. Cassava is a widely important tropical crop under very challenging environmental conditions[1]. Farm management for cassava production in the country is mostly based on the use of inorganic fertilizer. The information on the use of both organic and inorganic fertilizer for cassava production is meagre. Both soil fertility and crop yields decline over time[2]. Cassava removes substantial amounts of nutrients with the harvested roots, the highest being K, followed by N, Ca, Mg and P[3]. Without the application of fertilizers, soil nutrients are depleted. Yield depressions have been reported in many cases under cassava-based cropping systems. The decline in soil fertility is especially serious in tropical regions where the soil lacks adequate plant nutrients and organic matter due to leaching and erosion of topsoil by intense rainfall. Organic inputs which are often proposed as alternatives cannot meet crop nutrients demand for large scale production because of their relatively lower nutrient composition. The combined use will increase synchrony and reduce losses by converting inorganic N into organic forms[4]. It also reduces the environmental problems that may arise from the use of sole inorganic fertilizers and improves the microbial properties of the soil[5]. Therefore, it is important to develop the suitable use of organic fertilizer combined with chemical fertilizer for cassava variety CMR 33-38-48 in Yasothon soil. In this study organic fertilizers used as a method for adjusting the chemical fertilization to improve the quality yield, to reduce the amount of chemical fertilizer as well as increase the opportunities for farmers to have sustainable production systems over the long term.

MATERIALS AND METHODS

Planting material preparation: Cassava material preparation was conducted at the Mahasarakham Research and Development Agriculture Centre, Mahasarakham province, Thailand in 2018. The soil type was sandy loam with pH = 5.36, total N = 0.02%, available P = 9.88 mg kg^{-1}, exchangeable K = 26.70 mg kg^{-1} and organic matter = 0.35%. Total rainfall of 1.216 mm occurred during the crop growth period of 10 months. The maximum and minimum temperatures were recorded as 33 and 23°C, respectively. The cassava cultivar CMR 33-38-48 was used in these studies. The stem of cassava was cut 25 cm in length in stakes pieces before growing. The stakes of 25 cm length had 67.28% moisture content and low nutrient nitrogen and potassium, 0.04 and 0.01%, respectively, before planting. The stakes were planted vertically with 1×0.8 m spacing.

Field experiment: The field experiment was conducted at the experimental farm, Faculty of Agriculture, Khon Kaen University, Thailand from April, 2019 to April, 2020. The soil type was sandy loam with medium acid soil pH 5.64, which is suitable for the nutrient uptake of general plants. Total nitrogen was quite low at 0.03%, available phosphorus, exchangeable potassium, calcium and magnesium and available zinc were quite high at 33.83, 74.68, 279.45, 126.34 and 0.52 ppm, respectively. Extractable sulphur was of medium abundance and the amount of organic matter was very low at 0.43%. The electrical conductivity of saline soil is an obstacle to the growth of crops (15.80 ds cm^{-1}) and cation exchange capacity was very low at 3.52 me 10^{-2} g. Total rainfall of 916.10 mm occurred during the period of crop growth. The maximum and minimum temperatures were recorded as 34.28 and 22.34°C, respectively. The study was laid out in randomized complete block design with four replications. The nine treatments were used expressed in Table 1 into two times: at the growing stage and 4 months after planting. The stakes were soaked with imidacloprid at a concentration of 3 g per 20 L of water for 10 min, for all treatments. The 25 cm stakes were planted vertically with 1×0.8 m spacing. Weed control was carried out using pre-emergence herbicide S-metolachlor at a rate of 175 mL per 80 L of water combined with flumioxazin at a concentration of 10 g per 80 L of water and hand weeding at 1 month after planting. The germination percentage was measured 30 days after planting. Cassava growth and development were measured for 4, 8 and 12 months after planting.

Macronutrient content: The different parts of cassava were measured for nitrogen (N), phosphorus (P) and potassium (K) content. For each sample, N content was measured by the micro-Kjeldahl method with indophenol blue, P content by wet oxidation and spectrophotometry and K content by wet oxidation and flame photometry, at Northeast Agriculture Research and Development Center in the Faculty of Agriculture, Khon Kaen University.

Table 1: Fertilizer treatments were used on cassava growth

Treatments	Fertilizer application
TR1	Negative control
TR2	468.75 kg ha^{-1} of chemical fertilizer 15-7-18+500 g of plant growth-promoting rhizobacteria no. 3 (PGPR3) per 20 kg of chemical fertilizer+1,562.50 kg ha^{-1} of organic fertilizer
TR3	312.50 kg ha^{-1} of chemical fertilizer 15-7-18+500 g of plant growth-promoting rhizobacteria no. 3 (PGPR3) per 20 kg of chemical fertilizer+3,125 kg ha^{-1} of organic fertilizer
TR4	156.25 kg ha^{-1} of chemical fertilizer 15-7-18+500 g of plant growth-promoting rhizobacteria no. 3 (PGPR3) per 20 kg of chemical fertilizer+4,687.50 kg ha^{-1} of organic fertilizer
TR5	468.75 kg ha^{-1} of chemical fertilizer 15-7-18
TR6	312.50 kg ha^{-1} of chemical fertilizer 15-7-18
TR7	156.25 kg ha^{-1} of chemical fertilizer 15-7-18
TR8	625 kg ha^{-1} of chemical fertilizer 15-7-18
TR9	6,250 kg ha^{-1} of organic fertilizer+500 g of PGPR3 per 500 kg of organic fertilizer

Total starch and amylose content of cassava storage roots: Total starch was measured by measurement of specific gravity in the storage root with starch percentage scales in cassava roots. Amylose content was measured by cassava storage roots were ground in a flour mill. Then, 0.10 g of the flour was weighed and put in a 100 mL volumetric glass bottle that was completely dry. First, 1 mL of 95% ethyl alcohol was added and shaken gently to spread the powder evenly. Then, 9 mL of 2 N sodium hydroxide concentrations was added. A magnetic stirring rod was put into the glass bottle and the sample was stirred with a magnetic stirrer for 10 min. Then, the magnet was removed from the glass bottle and the volume was adjusted with distilled water to 100 mL, the cork was inserted and the bottle was shaken well. A new 100 mL capacity glass bottle was prepared. Then, approximately 70 mL of distilled water was added and 2 mL of glacial acetic acid and 2 mL of (0.2 g iodine mix with 2 g of potassium iodide) were added. Afterwards, 5 mL of starch solution was added to the prepared glass bottle. The volume was adjusted with distilled water to 100 mL. The cork was inserted and the bottle was shaken well. Then it was set aside for 10 min. The colour intensity of the solution was measured with a spectrophotometer by reading the absorbance at 620 nm wavelength, after adjusting the machine with a blank to absorbance equal to 0 (zero). To make the blank, 2 mL of glacial acetic acid and 2 mL of (0.2 g iodine mix with 2 g of potassium iodide) were added and the volume was adjusted with distilled water to 100 mL. The absorbance value was converted to the percent amylose by comparing the standard curve provided in Notification of the[6].

Statistical analysis: An analysis of variance was conducted on data obtained for each parameter in each treatment. All analyses were carried out using Statistics version 8.0. The Least Significant Differences (LSD) were calculated at a significance level of 0.05 to test for significant differences among treatments.

RESULTS AND DISCUSSION

Germination and growth of CMR 33-38-48 at 4 months after planting: After cassava variety CMR 33-38-48 was planted under fertilizer management for 1 month, the germination percentage was not significantly different for the different treatments. CMR 33-38-48 had germination percentage between 68 and 71% if planting in April. Opposite from the previous experiment[2] which is the germination percentages of CMR 33-38-48 was 98.57-99.55% when planting at the beginning of the rainy season (June). When CMR 33-38-48 grew for 4 months, plant heights, leaf areas and petiole dry weights were significantly higher than negative control in all fertilizer applications in Table 2. Chemical fertilizer TR5 tended to promote plant height with 140.63 cm, 33,336 cm^2 of leaf area/plant and 67.80 g of petioles dry weight/plant better than other fertilizer management's. However, TR2, TR3 and TR4 tended to build storage roots faster and had more storage root number per plant with 13.50, 12.63 and 12.00, respectively. Similar to another study[2] chemical fertilizer should use at the ratio of 2:1:2 and the fertilizer recommended is 15-7-18 or 15-15-15 for loamy sand at the rate of 468.75 kg ha^{-1}, for sandy loam and sticky loam at the rate of 312.50 kg ha^{-1} and the rate of 156.25 kg ha^{-1} for brown, red and black clay.

Growth of CMR 33-38-48 in the stems and leaves, in the beginning, resulted in the accumulation of nitrogen, potassium and phosphorus, especially in the leaves under fertilizer management between 3.30-3.70% N, followed by the 0.76-1.13% N of stems and 0.81-1.23% N of petioles in Table 3. Potassium and phosphorus play a role in the transport of nutrients to different parts and the initiation of tuber roots. However, management with chemical and organic fertilizer will not only promote the growth of the crops but also increase plant nutrient absorption and maintain soil fertility[7]. Nutrient absorption and distribution are closely related to the plant growth rate, which depends on soil fertility and climatic

Table 2: Effect of fertilizer management on cassava growth at 4 months after planting

Treatments	Height (cm)	Leaf area/ plant (cm^{2})	Storage root number/plant	Leaf dry weight/plant (g)	Petiole dry weight/plant (g)	Stem dry weight/plant (g)
TR1	99.70^{b}	19,127^{c}	11.13	79.69	37.87^{b}	81.34
TR2	126.80^{a}	26,623^{abc}	13.50	95.10	51.56^{ab}	98.49
TR3	122.56^{a}	22,221^{c}	12.63	92.14	47.13^{ab}	101.39
TR4	119.92^{ab}	24,620^{abc}	12.00	96.01	54.91^{ab}	114.07
TR5	140.63^{a}	33,336^{a}	11.25	111.12	67.80^{a}	134.13
TR6	134.08^{a}	33,235^{ab}	11.75	121.03	63.69^{a}	129.83
TR7	129.50^{a}	33,275^{ab}	11.00	121.09	65.98^{a}	127.22
TR8	121.44^{a}	23,070^{bc}	11.50	95.05	49.49^{ab}	113.44
TR9	122.81^{a}	26,052^{abc}	9.25	106.10	51.43^{ab}	120.65

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 156.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18, TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3. Different letters indicate a significant difference at $p \leq 0.05$

Table 3: Macronutrient content of cassava at 4 months after planting

	Stem (%)			Petiole (%)			Leaf (%)		
Treatments	N**	P*	K*	N**	P	K*	N*	P*	K*
TR1	0.65^{e}	0.16^{ab}	0.45^{b}	0.99^{b}	0.13	0.44^{b}	2.59^{b}	0.18^{ab}	1.01^{ab}
TR2	1.13^{a}	0.12^{b}	0.80^{a}	0.81^{c}	0.10	0.92^{a}	3.50^{ab}	0.16^{b}	1.30^{a}
TR3	0.81^{cd}	0.22^{ab}	0.75^{a}	0.80^{c}	0.15	0.85^{ab}	3.55^{a}	0.19^{ab}	1.00^{ab}
TR4	0.76^{de}	0.20^{ab}	0.72^{ab}	1.23^{a}	0.12	0.85^{ab}	3.68^{a}	0.16^{b}	0.85^{b}
TR5	1.09^{ab}	0.22^{ab}	0.80^{a}	0.90^{bc}	0.17	0.96^{a}	3.98^{a}	0.20^{ab}	0.89^{b}
TR6	1.02^{ab}	0.23^{ab}	0.65^{ab}	0.89^{bc}	0.18	0.64^{ab}	3.59^{a}	0.23^{a}	0.86^{b}
TR7	0.95^{bc}	0.24^{a}	0.53^{ab}	0.89^{bc}	0.18	0.68^{ab}	3.70^{a}	0.21^{ab}	0.77^{b}
TR8	1.05^{ab}	0.18^{ab}	0.71^{ab}	0.99^{b}	0.11	0.89^{a}	3.70^{a}	0.19^{ab}	0.93^{b}
TR9	0.80^{cd}	0.21^{ab}	0.70^{ab}	0.82^{c}	0.15	0.87^{ab}	3.30^{ab}	0.19^{ab}	0.79^{b}

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 156.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18, TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3. Different letters indicate a significant difference at $p \leq 0.05$* and 0.01**

conditions as well as on varietal characteristics. In poor soils, fertilizers can markedly increase plant growth and nutrient absorption. At 2-3 months after planting, the storage roots become the major sink of dry matter.

Growth of CMR 33-38-48 at 8 months after planting: The growth rate of the above-ground portions of the plants relative to the roots decreased after the age of 4 months because most photosynthates are used to form storage roots and accumulate dry weight in the stem in Table 4 including storage root fresh weight. The leaf area per plant decreased due to drought impact on CMR 33-38-48 growth after 4 months, causing some cassava leaves to fall and others to decrease in size, especially with TR4. TR8 had more storage roots number per plant with 14.75 but were not significantly different from 13.75 of TR2 and 13.00 of TR3 and the storage root size was smaller. TR5 tended to produce higher storage root fresh weights 75,500 kg ha^{-1}, followed by 65,250 kg ha^{-1} of TR6 and 63,000 kg ha^{-1}of TR8 at 8 months after planting. Different results from other study[8] who reported that the rate of 15-15-15 formula chemical fertilizer affected starch yield and above-ground biomass. The higher rate significantly gave the higher above-ground biomass than did the lower rate. The higher rate of chemical fertilizer released larger amounts of major plant nutrients than did the lower rate, therefore these nutrients could enhance cassava growth and subsequently gave better yield. In the previous research[9], cassava variety CMR 33-38-48 was grown under drought conditions with fertilizer used according to soil analysis. Throughout the growth stages, therefore, the fresh storage roots were produced at an average of 15,093.75 kg ha^{-1} at 6 months after planting, while using 312.50 kg ha^{-1} of chemical fertilizer 15-15-15 before growing provide fresh storage roots between 10,962.50-18,775 kg ha^{-1}.

Regarding the amounts of nutrients accumulated in different parts of CMR 33-38-48 after growing for 8 months, the cassava growth rate decreased with the decrease of phosphorus and potassium in various parts of the plant, especially in the 0.04-0.12% P and 0.20-0.46% K of stem and 0.01-0.15% P and 0.19-0.24% K of petiole in Table 5. Potassium plays a role in the accumulation of total starch and amylose content in the storage roots. At harvest, dry matter is always highest in the storage roots, usually followed by stems, fallen leaves, leaf blades and petioles. Total nutrient absorption was highest for N, followed by K and P. The stem generally accumulated more N and K, while leaf blades and petioles were high in N. Similar results were reported by another study[2] that the amounts of nutrients in the storage roots or the whole plant were quite variable but tended to be very high when yields were high and quite low when yields were low. Similar to other study[10] an increasing NPK sorption of cassava plant would increase the total plant dry weight of cassava. Similarly, increasing NPK sorption of cassava root would increase the total root dry weight of cassava. The growth and yields of cassava had been reported to respond to adequate fertilizers. The rather close fit of the experimental data reported in the literature for the relationship between P and K with dry storage roots yield indicates that yields may be more closely associated with the concentrations of P and K in the storage roots than with that of N.

Cassava yield at harvest stage: The number of storage roots per plant was not increased when the CMR 33-38-48 was allowed to grow for a longer time. While storage root fresh weight per plant tended to decrease after 8 months, TR5 provided better storage root fresh with 48,906.25 and 14,400.63 kg ha^{-1} of dry weights than other methods in Table 6. Opposite from previous study[11] the highest total root fresh weight was found in a combination dose of inorganic and organic fertilizers of (N45P36K120OP 1,000 kg ha^{-1}) both for 2012-13 and 2013-14 growing seasons and the lowest was at control. Cassava is a plant that stores food in the roots. When plants have created food from the leaves and green parts, will accumulate in the form of carbohydrates, namely starch in the roots. The ability to create and accumulate starch in the roots is the link to the cassava varieties, harvesting time, the amount of rainfall before harvesting and other factors. Cassava aged 12 months the received sufficient rainfall and no heavy rain during harvest, the starch content in the cassava storage roots was 25.87-41.88 per 100 g. In general cereal flour such as corn flour, wheat flour and sorghum flour has an estimated 22-30% amylose content[12], while root and tuber starch such as cassava flour, potato flour and sago flour contains the lower amylose is in the range of 18-24%. From the experiment, the percentage of amylose and starch increased as the plant age increased. Under TR2, it was significantly lower in 29.21 and 12.95%, respectively than all other treatments at 8 months and under TR3, it was significantly lower in 31.09 and 13.78%, respectively than all other treatments at 12 months in Table 7. However, planting area and harvesting period affect starch percentage, if cassava planted in the rice fields after rice harvesting, cassava storage

Table 4: Effect of cassava varieties and growing methods on growth at 8 months after planting

Treatments	Height* (cm)	Leaf** area/ plant (cm^2)	Storage root number/plant	Leaf dry** weight/plant (g)	Petiole dry* weight/plant (g)	Stem dry weight/plant (g)	Storage root fresh weight/plant (kg)	Storage root fresh weight ha^{-1} (kg)	Income ha^{-1} (USD)
TR1	134.50^{c}	6,100^{bcd}	10.75	45.62^{bc}	20.93^{ab}	249.06	4.20	32,000	2,065
TR2	147.92^{bc}	4,769^{cd}	13.75	32.12^{c}	16.66^{b}	288.19	4.98	39,750	2,565
TR3	137.65^{c}	4,885^{cd}	13.00	35.19^{c}	16.79^{b}	201.02	5.50	45,000	2,903
TR4	140.63^{c}	4,021^{d}	11.75	31.66^{c}	16.39^{b}	163.11	4.40	34,000	2,194
TR5	177.36^{a}	8,690^{ab}	12.75	51.17^{ab}	21.84^{a}	318.97	8.55	75,500	4,871
TR6	162.72^{abc}	7,323^{bc}	13.88	44.29^{bc}	20.87^{ab}	322.40	7.53	65,250	4,210
TR7	145.38^{bc}	4,353^{cd}	13.75	34.83^{c}	16.98^{b}	270.92	6.18	51,750	4,210
TR8	172.79^{ab}	11,598^{a}	14.75	61.98^{a}	22.85^{a}	430.26	7.30	63,000	4,065
TR9	147.52^{bc}	4,947^{cd}	12.13	35.40^{c}	16.58^{b}	274.50	5.88	48,750	3,145

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 156.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18, TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3. Different letters indicate a significant difference at $p \leq 0.01$** and $p \leq 0.05$*. Income per hectare were not erased the production cost yet, the cassava price per kg is 2 baht and 1 USD = 31 bath

Table 5: Macronutrients content of cassava at 8 months after planting

	Stem (%)			Petiole (%)			Leaf (%)		
Treatments	N	P	K	N	P	K	N	P	K
TR1	1.52	0.07	0.18	1.04	0.03	0.24	3.60	0.14	0.52
TR2	1.47	0.09	0.46	1.02	0.01	0.20	3.53	0.16	0.45
TR3	1.55	0.12	0.41	1.07	0.04	0.23	3.75	0.16	0.46
TR4	0.95	0.09	0.20	1.01	0.03	0.24	3.67	0.10	0.49
TR5	0.99	0.09	0.32	1.01	0.03	0.21	3.49	0.1	0.42
TR6	1.04	0.05	0.25	0.97	0.02	0.2	3.64	0.16	0.43
TR7	1.26	0.04	0.26	1.14	0.05	0.23	3.57	0.16	0.44
TR8	1.26	0.09	0.32	1.07	0.01	0.19	3.68	0.15	0.42
TR9	1.22	0.08	0.39	1.11	0.15	0.22	3.58	0.13	0.44

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 156.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18, TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3

Table 6: Effect of fertilizer managements on cassava yield at 12 months after planting in yasothon soil series

Treatments	Storage root number/plant	Storage root fresh weight /plant (kg)	Storage root fresh weight ha^{-1} (kg)	Storage root dry weight/plant (kg)	Storage root dry weight ha^{-1} (kg)	Income ha^{-1} (USD)
TR1	6.38^{c}	1.90^{b}	23,831.25^{b}	0.52^{b}	6,523.75^{b}	420.89^{b}
TR2	11.00^{ab}	2.51^{ab}	31,406.25^{ab}	0.75^{ab}	9,362.50^{ab}	604.01^{ab}
TR3	8.50^{bc}	2.25^{ab}	28,156.25^{ab}	0.62^{ab}	7,740.63^{ab}	499.40^{ab}
TR4	9.13^{bc}	2.30^{ab}	28,750.00^{ab}	0.70^{ab}	8,710.00^{ab}	561.96^{ab}
TR5	9.88^{abc}	3.91^{a}	48,906.25^{a}	1.15^{a}	14,400.63^{a}	929.09^{a}
TR6	9.75^{abc}	2.93^{ab}	36,562.50^{ab}	0.88^{ab}	10,943.13^{ab}	706.01^{ab}
TR7	10.38^{ab}	2.65^{ab}	33,125.00^{ab}	0.75^{ab}	9,426.25^{ab}	608.17^{ab}
TR8	13.13^{a}	3.23^{ab}	40,312.50^{ab}	0.97^{ab}	12,140.00^{ab}	783.23^{ab}
TR9	10.25^{ab}	2.99^{ab}	37,343.75^{ab}	0.98^{ab}	12,246.25^{ab}	790.10^{ab}

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 1 56.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18 , TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3. Different letters indicate a significant difference at $p \leq 0.05$. Income per hectare were not erased the production cost yet

Table 7: Total starch and amylose content of cassava storage root at 8 and 12 months after planting

	8 months		12 months	
Treatments	Amylose** (%)	Starch** (%)	Amylose* (%)	Starch (%)
TR1	33.49^{b}	14.84^{b}	39.39^{a}	17.46^{a}
TR2	29.21^{c}	12.95^{c}	36.42^{ab}	16.14^{ab}
TR3	34.87^{b}	15.45^{b}	31.09^{b}	13.78^{b}
TR4	33.58^{b}	14.89^{b}	34.76^{ab}	15.40^{ab}
TR5	37.80^{a}	16.76^{a}	38.82^{a}	17.20^{a}
TR6	34.53^{b}	15.31^{b}	35.99^{ab}	15.95^{ab}
TR7	34.75^{b}	15.40^{b}	35.32^{ab}	15.66^{ab}
TR8	35.63^{ab}	15.79^{ab}	37.92^{ab}	16.81^{ab}
TR9	34.56^{b}	15.32^{b}	35.79^{ab}	15.86^{ab}

TR1: Negative control, TR2: 468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer, TR3: 312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer, TR4: 156.25 kg ha^{-1} of 15-7-18+PGPR3+4,687.50 kg ha^{-1} of organic fertilizer, TR5: 468.75 kg ha^{-1} of 15-7-18, TR6: 312.50 kg ha^{-1} of 15-7-18, TR7: 156.25 kg ha^{-1} of 15-7-18, TR8: 625 kg ha^{-1} of 15-7-18, TR9: 6,250 kg ha^{-1} of organic fertilizer+PGPR3. Different letters indicate a significant difference at $p \leq 0.01$** and $p \leq 0.05$*

roots may face the soil moisture until they are rotten. Moreover, a short period of cassava plantation may affect the low percentage of starch. Also, heavy rain before harvesting affects the reduction of starch percentage. Suitable soil characteristic for cassava planting should be loam, sticky sandy loam and loam sticky.

CONCLUSION

Planting cassava variety CMR 33-38-48 in Yasothon soil series under rainfed conditions, farmers should harvest fresh storage roots at the age of 8 months to get the highest amount of storage roots weight. The optimum fertilizer management is chemical of 15-7-18 between 312.50-625 kg ha^{-1}. Moreover organic fertilizer replacing between 25-100% of the chemical fertilizer appear interesting as a practice to reduce the amount of chemical fertilizer use.

SIGNIFICANCE STATEMENT

This study discovered the optimum fertilizer management methods are chemical fertilizer managements TR5 (468.75 kg ha^{-1} of 15-7-18), TR6 (312.50 kg ha^{-1} of 15-7-18) and TR8 (625 kg ha^{-1} of 15- 7-18) for planting cassava variety CMR 33-38-48 in Yasothon soil series under rainfed conditions. This study will help the researchers to uncover organic fertilizer replacing 100% of t he chemical fertilizer as in TR9 (6,250 kg ha^{-1} of organic fertilizer+PGPR3), to replace 50% of the chemical fertilizer as in TR3 (312.50 kg ha^{-1} of 15-7-18+PGPR3+3,125 kg ha^{-1} of organic fertilizer) and to replace 25% of the chemical fertilizer as in TR2 (468.75 kg ha^{-1} of 15-7-18+PGPR3+1,562.50 kg ha^{-1} of organic fertilizer) appear interesting as a practice to reduce the amount of chemical fertilizer use. Thus to get the highest amount of storage roots weight and income per land area, farmers should harvest at 8 months.

ACKNOWLEDGMENT

This research was supported by General Research Grant 2019 to Khon Kaen University, Mahasarakham Research and Development Agriculture Centre, Mahasarakham province, Agronomy section and the North East Agriculture Research and Development Centre at the Faculty of Agriculture Khon Kaen University, Thailand.

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