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Effect of Season of Planting and Fertilizer Application on Cassava Production and Profitability in Upland Cropping Systems in the Southeast Cambodia

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សង្ខិត្តន័យ

ការងាកទៅធ្វើឯកវប្បកម្មដំឡូងមីឬពោត ដែលជាការដាំបន្តនៅលើដីដដែលៗ ដោយមិនប្រកាន់រដូវបន្ទាប់ពីប្រមូលផលហើយ ធ្វើឱ្យមានការរេចរឹលដី ការបាត់បង់ដីជាតិដី ការធ្លាក់ចុះទិន្នផល និងការធ្លាក់ចុះប្រាក់ចំណេញចំពោះកសិករខ្នាតតូចនៅតំបន់ខ្ពង់រាបនៃប្រទេសកម្ពុជា។ បញ្ហានេះតម្រូវឱ្យមានការអភិវឌ្ឍបច្ចេកវិទ្យាសម្រាប់ការធ្វើកសិកម្មប្រកបដោយនិរន្តរភាពនៅតំបន់ខ្ពង់រាបក្នុងខេត្តព្រៃវែង និងស្វាយរៀងនៃប្រទេសកម្ពុជា។ ទោះជាមានការបោះពុម្ពផ្សាយស្នាដៃស្រាវជ្រាវផ្សេងៗទាក់ទងនឹងការផ្ទេរបច្ចេកវិទ្យាក៏ដោយក្តី ក៏មិនទាន់មានការសិក្សាណាមួយត្រូវបានធ្វើជាលម្អិតនៅតំបន់ខ្ពង់រាបភាគ អាគ្នេយ៍នៃប្រទេសកម្ពុជានៅឡើយ ជាពិសេស នៅខេត្តព្រៃវែង និងស្វាយរៀង។ ការសិក្សាស្រាវជ្រាវនេះធ្វើឡើងដើម្បីសាកល្បងការកែលម្អដំណាំដំឡូងមី ដោយផ្តោតលើតំបន់ដាំដុះ រដូវកាលដាំដុះ និងការប្រើជីជំនួយការលូតលាស់ ទិន្នផល និងផលចំណេញសរុបនៅភាគអាគ្នេយ៍នៃប្រទេសកម្ពុជា។ ពិសោធន៍ស្រាវជ្រាវនៅចម្ការត្រូវបានធ្វើឡើងដើម្បីសិក្សាពីឥទ្ធិពលនៃរដូវដាំដុះ និងការប្រើប្រាស់ជី លើទិន្នផលដំឡូងមីជាមើមស្រស់ និងប្រាក់ចំណេញ ក្នុងខេត្តព្រៃវែងនិងស្វាយរៀង។ ការពិសោធត្រូវបានរៀបចំឡើងតាម Factorial Randomized Design Experiment (2x2x2x4) ដោយមានកត្តាខេត្ត (ព្រៃវែងនិងស្វាយរៀង), កត្តារដូវដាំដុះ (ដើមរដូវវស្សា៖ ឧសភា-ធ្នូ និងចុងរដូវវស្សា៖ សីហា-មេសា), និងកត្តាជី (មិនប្រើប្រាស់ជី និងប្រើប្រាស់ជី)។ ការវាស់វែងផ្តោតសំខាន់ទៅលើការលូតលាស់ដំណាំគិតជាភាគរយ (%) និងទិន្នផលមើមស្រស់គិតជាតោនក្នុងមួយហិកតា។ ប្រាក់ចំណេញនៃបច្ច័យពិសោធន៍ត្រូវបានកំណត់ដោយការវិភាគប្រាក់ចំណេញសរុប។ លទ្ធផលពិសោធន៍បានបង្ហាញថា ការលូតលាស់និងផលិតផលដំឡូងមីនៅភាគអាគ្នេយ៍នៃប្រទេសកម្ពុជាបានរងឥទ្ធិពលដោយតំបន់ដាំដុះ ពេលវេលាដាំដុះ និងជីជាតិដី។ កសិករទទួលផលដំឡូងមីនិងប្រាក់ចំណេញនៅខេត្តស្វាយរៀងខ្ពស់ជាងខេត្តព្រៃវែង។ ការដាំដំឡូងមីនៅដើមរដូវវស្សាផ្តល់ផលនិងផលចំណេញសរុបខ្ពស់ជាងនៅចុងរដូវ

វស្សា។ ដំឡូងមីមានការលូតលាស់ល្អនៅលើដីមានជីជាតិ ប៉ុន្តែ ការប្រើប្រាស់ជីមិនបានផ្តល់អត្ថប្រយោជន៍សេដ្ឋកិច្ចលើដីដែលមានផលិតភាពទាបនោះទេ។ ដើម្បីបង្កើនផលិតភាពដំឡូងមី និងដើម្បីរក្សាជីជាតិដីនៅភាគអាគ្នេយ៍នៃប្រទេសកម្ពុជា កសិករចាំបាច់ត្រូវជ្រើសរើសតំបន់ដាំដុះឱ្យបានសមស្រប ការដាំដុះត្រូវធ្វើនៅដើមរដូវវស្សា និងការប្រើប្រាស់ជីឱ្យបានសមស្រប ដោយផ្អែកលើការវិភាគជីជាតិដីជាមុន។ ដើម្បីរក្សាជីជាតិដីសម្រាប់ការលូតលាស់និងផលដំឡូងមីល្អបំផុត កសិករមិនត្រូវដាំតែមួយមុខជាប់រហូតទេ ចាំបាច់ត្រូវដាំផ្លាស់វេនគ្នាជាមួយដំណាំផ្សេងៗ។

Abstract

The shift towards continuous mono-cropping of cassava and maize has led to soil degradation, loss of soil fertility, declining yield and profit for smallholder farmers in upland cropping areas of Cambodia. This requires the development of technologies for sustainable agricultural production in the uplands of Prey Veng and Svay Rieng provinces in Cambodia. However, studies regarding technology transfer have been published by various existing research, and none of the research has yet been conducted in Southeast Cambodia. This paper has investigated the effect of varying planting dates and fertilizer applications on cassava production and profit in South-Eastern Cambodia. Field experiments were carried out to investigate the effect of season of planting and fertilizer application on cassava fresh tuber yield and profitability in Prey Veng and Svay Rieng provinces. The experiment was arranged in a 2x2x2x4 Factorial Randomized Design Experiment with factor Province (Prey Veng, Svay Rieng); Season (early wet season: May-December, late wet season: August-April); and fertilizer (nil, plus). Measurements were taken for crop establishment (%) and yield of wet tuber (ton.ha^{-1}). The profitability of experimental treatments was determined using gross margin analysis. The experimental result showed that the growth and production of cassava in Southeast Cambodia are influenced by planting area, planting time, and fertilization. Cultivating cassava in Svay Rieng Province results in higher growth, production, and profits than in Prey Veng Province. Cultivating cassava in the early wet season results in higher growth, production, and gross margins compared to the late wet season. Cassava is very responsive to fertilization but the application of fertilizer has not provided economic benefits on land conditions with low productivity. To increase cassava productivity and maintain soil fertility in South-Eastern Cambodia, it is necessary to select an appropriate planting area, plant during the early wet season and apply fertilization based on soil analysis. The application of intercropping and crop rotation is necessary in order to obtain fertile soil for optimal cassava growth and production.

Background

Cassava is the main upland commodity in Cambodia, but in the last 5 years, there has been a decline in productivity from 22.90 tons/ha to 18.83 tons/ha (MAFF, 2021). Last research, the fresh root cassava, the yield ranged from 8.40 to 37.26 ton. ha^{-1}, with an average of 20.57 ton. ha^{-1} (Peuo et al., 2021). The productivity of cassava is less than that of Indonesia at 23.99 ton.ha^{-1} (Rozi et al, 2021), India of 31.40 ton.ha^{-1}, Thailand of 22.92 ton.ha^{-1} (Howoler, 2007). By improving the treatment, cassava can be increased productivity to 41.3-51.8 ton. ha^{-1} (Rozi et al., 2022).

Various factors caused this decline in productivity. Most cassava in Cambodia is cultivated with little or no fertilizer inputs (Sopheap, 2008). Howeler (2002) reviewed the results of 15 experiments reported in the literature on nutrient removal by cassava roots, with fresh root yields ranging from 6 to 65 t ha^{-1}. He found that the quantities of nutrients removed varied with the yield levels, ranging from 13 to 162 kg N, 0.9 to 28.2 kg P and 4 to 137 kg K ha^{-1}. Thus, like other crops, continuous planting of cassava without fertilization will result in a decline in soil fertility and an associated reduction in crop yields (Howeler et al., 2000). Nutrient depletion and yield decline have been shown in several areas where cassava has been grown for many years (Chan, 1980; Howeler, 1991; Nguyen, 1998; Sittibusaya, 1993; Tongglum et al., 2001).

Cassava needs sufficient water to grow and produce optimally. This affects the timing of cassava planting. The growth of cassava continues to develop and advance to maturity during the rainy season; cassava growth and yield will be maximum if rainfall is above 940 mm/year (Boansi, 2017). In general, yields were found to be higher when cassava was planted in the early part of the rainy season (May-June in most countries, October-November in Indonesia) or the early spring (February-March in North Vietnam and China). In many countries, some cassava was also planted at the end of the rainy season, such as in August-September in Kerala, India, or in September-November in Thailand and South Vietnam (Sinthuprama et al., 1983). In Hainan Island of China, cassava can be planted throughout the year due to high rainfall when harvested 12 months after planting, but only from Feb-May when harvesting 8 months after planting; starch contents were always highest when the roots were harvested in the dry and cold months of Nov-March (Zhang et al., 1998).

Most farmers in Northwest Cambodia plant cassava in the hottest months of the dry season (March or April). Farmers in this region usually attempt to plant crops after occasional storms in the late dry season (February-

April). Crops sown at these times are at high risk of crop failure (Touch et al., 2016). In 2016, an estimated 10,289 ha in total of cassava area was also affected because of drought where farmers replanted cassava two to three times before significant rainfall was received in Samlout and Pailin (PDA-BB, 2017); small-scale farmers lost a lot of money due to crop failures in the early wet season. The results of a two-year study in Northwest Cambodia by Phan et al. (2021), showed that planting cassava in April, which is the driest and hottest month in this area, produced lower yields than cassava which is planted in May and June. Cassava planting in May is a suitable planting time to get high cassava yields.

In tropical regions with distinct dry and wet seasons and mono-modal rainfall distribution, the best time to plant is early in the wet season, i.e., as soon as enough soil moisture allows for adequate germination of planted stakes. In those areas with a bimodal rainfall distribution, such as in Kerala, India, planting at the start of the second rainy season, i.e., in Aug or Sept, will also result in high yields (George et al., 2001). In the southern hemisphere the wet and dry seasons are reversed in comparison with the northern hemisphere, and the wet season generally starts in Nov-Dec and ends in April-May. In that case, the highest cassava yields are obtained when planted in Dec (Wargiono et al., 2001). However, high yields may also be obtained when cassava is planted towards the end of the wet season. Rayong got highest yields in Thailand were obtained when cassava was planted in August-November. In this case, plants get well established during the last months of the rainy season, grow slower during the dry season and have an additional period of fast growth during the following wet season. In this case, weed competition tends to be less severe as plant canopies are already well-established during the early part of the second wet season (Tongglum et al., 2001).

Cassava is also grown in subtropical regions, such as southern China and north Vietnam. These regions are characterized by cold and dry winters (with occasional frost at higher latitudes) and hot and wet summers with relatively long daylight. Cassava yields were little affected by the date of planting when cassava was harvested at 12 months, but yields markedly declined when planted in late summer (Aug-Nov) and harvested after 8 months in April to July. When harvested at 8 months after planting (MAP), both root yields and starch content were lowest when roots were harvested during the hot months of June and July. In that case, root yields were positively and highly significantly correlated with both temperature and rainfall during the 3rd to 5th month after planting, i.e., at the time of maximum growth rate of cassava, while starch content was negatively correlated with temperature and rainfall during the last month before harvest (Howeler, 2001).

It may be concluded that the highest yields are generally obtained when cassava is planted as early as possible in the wet season or in early spring, while starch contents are highest when plants are harvested in the middle of the dry season. At planting time there should be enough soil moisture to get at least 80-90% germination, while soils should not be so wet as to prevent adequate aeration and root formation (Howeler, 2017).

A study carried out from 2017 to 2019 in Southwestern Nigeria showed that existing cassava fields planted at different months were visited, and the planting dates were recorded. Harvesting for each planting month was done at 9, 11, and 13 months after planting (MAP). Fresh root yield and starch content varied across planting months. For all crop ages, the highest fresh root yields were recorded when planted in September and December. The highest root starch content was observed in 9- and 13-month-old cassava when planted in March and November, respectively. Cassava fresh root yield and starch content varied across Julian day of harvest, with the lowest yields obtained between Julian day 60–120 (March and April) which coincides with the beginning of rainfall. The highest fresh root yields and starch content were attained between Julian day 180–330. Revenue showed seasonal variation and was dependent on Julian's day of harvest. Gross revenue was lowest between Julian day 60 and 120 (March and April) and highest from Julian day 180 (July). The lowest incomes or profits were recorded when cassava was harvested between Julian day 60 and 120 (March and April). About 9.1% of farmers had negative revenues or lost income when they harvested at 9 MAP, hence losing between 150 and 200 USD ha 1, compared with 2.8 % of farmers that lost income when harvesting was done at 11 and 13 MAP, losing between 100 and 150 USD ha 1. Thus, farmers' income generation critically depends on cassava planting and harvest dates. Choosing the right time to plant and harvest cassava is one of the most important decisions farmers can make to maximize profit (Enesi et al., 2022).

Poor management of cassava cultivation results in serious soil degradation. When harvesting cassava in the land it also means taking and eliminating soil nutrients that are in the crop yields. Cassava that is planted for years in the same field without fertilizer application causes yields to drop. Cultivation of cassava for four consecutive years, root yields decreased from 18.9 ton. ha^{-1} in the first year to 6.4 $ton.ha^{-1}$ in the fourth year, or only 34% of the first-year yield. More drastically, the yield of upland rice planted in the same experiment also decreased from 2.55 tons ha^{-1} in the first year to no yield at all in the fourth year (Siem, 1992). A study in Colombia found that yields of monocropped, unfertilized cassava dropped from 37 tons to 12 tons per ha over a period of nine years (FAO, 2013).

Cassava actually extracts more nutrients from the soil than other crops such as sweet potato, maize, bean, rice, soybeans and groundnut. The amount of nutrients taken from the soil in the crop product. Under harvest conditions, the yield of fresh roots was relatively high at 35.7 ton.ha^{-1} or 13.53 ton.ha^{-1} dry roots. These roots contained 55 kg N, 13.2 kg P, and 112 kg K (Howeler 1991). Experiments conducted over nearly 2 years in Sri Racha, Thailand, showed that, in two consecutive harvests, the total plant dry matter production was 14.9 ton.ha^{-1} while the root dry matter was 5.2 ton.ha^{-1} or equivalent to fresh roots yield at 15 ton.ha^{-1}. If only the roots are harvested, the soil nutrients uptake are 48 kg/ha N, 7 P, 60 K, 14 Ca, and 6 Mg, but if the whole plant is harvested, it will be 284 kg/ha N, 39 P, 192 K, 167 Ca, and 42 Mg. If cassava was grown for forage production, stems and leaves were harvested at 3-month intervals over the same 22-month period, dry matter harvested from forages and roots was higher, and nutrient uptake was also higher, indicating that this management system requires a high input of all nutrients to prevent rapid depletion of soil nutrients. (Putthacharoen et al.,1998).

Cassava removes much less nitrogen (N), phosphorus (P) and potassium (K) than most other crops. This is because most nutrients, except K, are mainly present in cassava leaves and stems. Therefore, if the leaves and stems are returned to the soil, nutrient removal will be minimal. In contrast, in the areas where leaves and stems are also utilized and removed from the field, nutrient removal will increase. In this case, nutrient depletion can become a serious concern if soil fertility is not maintained properly. Returning leaves and stems to the soil is an essential first step in preventing nutrient depletion and maintaining soil fertility. It is, therefore, important to avoid the burning of cassava and other crop residues (Howeler, 2014a). Cassava fertilization can reduce soil loss from 41.92 to 29.06 ton. ha^{-1} (Wagiono et al., 2021).

Cassava is classified as responsive to the use of fertilizers like other plants that are fertilized traditionally, and the application of fertilizers to cassava increases economic value (Howeler, 2017). Intake of soil nutrients through the resulting crop products can be a guideline for the amount of fertilizer that must be added to the soil to produce optimal plant growth and yields. The results of research in Kwadaso, Ghana fertilizing cassava with NPK can increase the yield of fresh roots by 68% - 278%. Fertilization as much as NPK: 30:30:45 produced fresh tubers of 20.3 ton. ha^{-1}, NPK:60:30:45 produced 27.17 ton.ha^{-1}, NPK:45:30:45 produced 33.67 ton.ha^{-1}; while without fertilizing, the yield is 12.07 ton.ha^{-1} (Agbaje et al., 2004). Experimental application of 60 kg N+ + 16 kg P + 138kg K/Ha on cassava variety BEN86052 in Hayakpa, Africa, for three successive cropping cycles produced 21.9 t fresh cassava tubers compared to 12.9 ton.ha^{-1} without fertilization (Carsky and Toukourou, 2005). Research in Indonesia, Adira 1 cassava fertilization with 250 kg of Phonska, 200 kg of Urea, 50 kg of KCL, and 750 kg of dolomite can produce as much as 48.9 ton.ha^{-1} of fresh tubers compared to fertilizing 250 kg of Phonska and 200 kg of Urea only produces 41.3 ton.ha^{-1} (Rozy et al., 2022). The soil fertility of cassava production areas is rather low; therefore, annual fertilization to increase soil fertility and crop productivity is generally needed. A recommended fertilization to produce 25-35 ton.ha^{-1} of fresh roots for monocropping cassava is 60 kg N+40 P2O5+60 K2O/ha, while that for intercropping systems to produce 20-30 ton.ha^{-1} fresh roots, 2 ton.ha^{-1} dry grain of maize and rice as well as 1 ton.ha^{-1} of legumes is 180 kg N + 90 P2O5 + 180 K2O/ha (Wargiono et al., 2021). Trial in Pailin, Cambodia, fertilization with 50 kg N, 25 kg P and 50 kg K in the conventional system yielded 29.74 ton. ha^{-1}; while no tillage yielded 26.13 ton.ha^{-1} (Phan et al., 2021).

The location of cassava planting is related to soil fertility and nutrient availability. Soil textures in Cambodian provinces vary. Cassava productivity in 5 provinces in Cambodia ranges from 5.18 to 14.15 tons/ha with a clay composition of 20 to 74% and sand 11 to 69%. The higher the clay composition, the higher the productivity (Jie et al., 2001). Soil fertility levels for maximum cassava yield growth can be obtained if the soil nutrient content is pH 7-8, organic matter > 4%, Al saturation 75 to 80%, salinity 0.5 to 1 mS/cm, Na saturation 2 to 10%, P > 15 ppm, K >0.25 me/100g, Ca >5 me/100g, Mg>1 me/100g, S>70 ppm, Boron 1 to 2 ppm, Cu 1 to 5 ppm, Mn 100 to 250 ppm, Fe >100 ppm, and Zn 5 to 50 ppm (Howeler, 1996; Howeler, 2014b).

As a cassava development area, there has not been much research on cassava cultivation in the Prey Veng and Svay Rieng Provinces, including soil fertility analysis for optimal yields and production of cassava. Research is needed to determine the suitability of location, planting season and fertilization on the success of cassava growth and yield. Accordingly, the objective of this study was to determine the yield variations and causal factors for cassava production, especially planting time in Prey Veng and Svay Rieng provinces in Cambodia. We focus (1) the importance of monthly rainfall for cassava production and profitability, (2) Growth, yield, expense, income and profit from cassava production, (3) costs of planting cassava with/no fertilization per hectare, and (3) soil Analysis for cassava production.

Research Methodology

Field experiments were conducted in eight basic production units on farms in the study areas: 4 areas in Prey Veng province at latitude 11.48682, longitude 105.32533, and coordinate 11°29'11" N, 105°19'41" E and 4 areas in Svay Rieng province at 11.08785000, longitude 105.79935000, and coordinate 11°09'28" N, 105°49'29" E. The soil group is described as Prey Khmer (White et al., 1997). These soils are classified under the Entisol order (USDA, 2017). Prey Khmer soils occur on old alluvial terraces or colluvial-alluvial plains and have a sandy textured profile extending to a depth of 50 cm or deeper. The experiment was designed in a 2 X 2 X 2 factorial design with treatments consisting of planting location, Province, (Prey Veng, Svay Rieng); Season (early wet season-May 2013, late wet season-August 2013); and fertilizer (nil, plus). As a replication, one set of experiments was carried out at 4 locations in one Province. One experimental unit consists of a plant plot measuring 7x10 $m^{2,}$ which contains 175 plants.

Land Preparation and Planting Methods

Land preparation involved initially plowing the whole trial site by a four-wheel tractor, and low beds are formed at a raw spacing of 1 m. Seeds are planted at different plant spacings for each plant. Local varieties of cassava seeds in the form of stem cuttings 30 cm long are planted in rows with a spacing of 40 cm. Local varieties of cassava seeds in the form of stems were planted upright in rows with a spacing of 40 cm, resulting in a population of 175 plants per plot. Fertilization consists of a combination of Urea (46-0-0) and DAP-Diammonium phosphate (18-46-0) at 200 kg. ha^{-1} and Urea rate of 150 kg.ha^{-1}. Fertilizer is applied to adjacent lines planting rows at the initial planting time as much as 50% and at the age of 1 and 3 months after planting each as much as 25%. Plant maintenance includes mechanically weeding and hilling during plant growth until harvest. Plants are harvested when they are 8 months old.

Observations

Observations were made on measurement for crop growth establishment (%), plant height (cm), yield of wet tuber (ton.ha^{-1}), starch content (%) and gross margin ($). Starch content is calculated by comparing the dry weight of peeled cassava and the wet weight of fresh cassava tubers. Gross margin analysis is calculated based on the difference between total costs incurred and cassava cultivation income per hectare. Expenditures calculated include seeds, fertilizer, pesticides, transportation, land processing costs, labor wages and land rental. Income is calculated based on the number of harvests and selling prices at that time.

Data collected are growth (%), plant height (cm), yield (ton.ha^{-1}), starch content (%) and profit ($/ha). Production yield data is converted in Ha units with the formula: Yield (ton.ha^{-1}) / Profit ($/ha) = (10,000/70) x Yield (kg/70 m2)/Profit ($/70 m2).

Statistical analyses were carried out using SPSS for Windows (Version 16.0). The one-way ANOVA test was applied to determine the significance of differences between treatment means. Paired samples t-testing was performed to certify the differences in provinces, seasons and fertilizer application. Means were considered to be significantly different, where $p < 0.05$.

Results and Findings

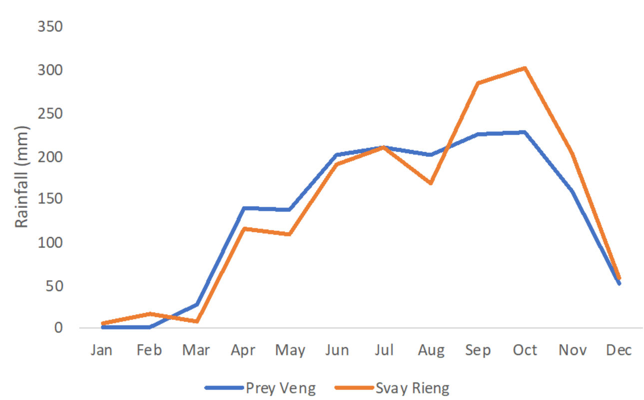
Importance of Monthly Rainfall for Cassava Production and Profitability

The average annual rainfall at Prey Veng and Svay Rieng between 2013 and 2017 was 1,592 mm and 1,679, respectively. Rainfall was similar for the provinces, except that rainfall in the late wet season was greater in Svay Rieng, with the wettest month being October in both provinces (Fig. 1).

In Prey Veng, rainfall was greater in the EWS (May-August) than in the LWS (September-December) in all years. Rainfall was similar for 2013 and 2014 and somewhat less for 2015. In Svay Rieng, rainfall was similar for EWS and LWS in 2013, greater in EWS in 2014 and greater in LWS in 2015 (Fig. 2).

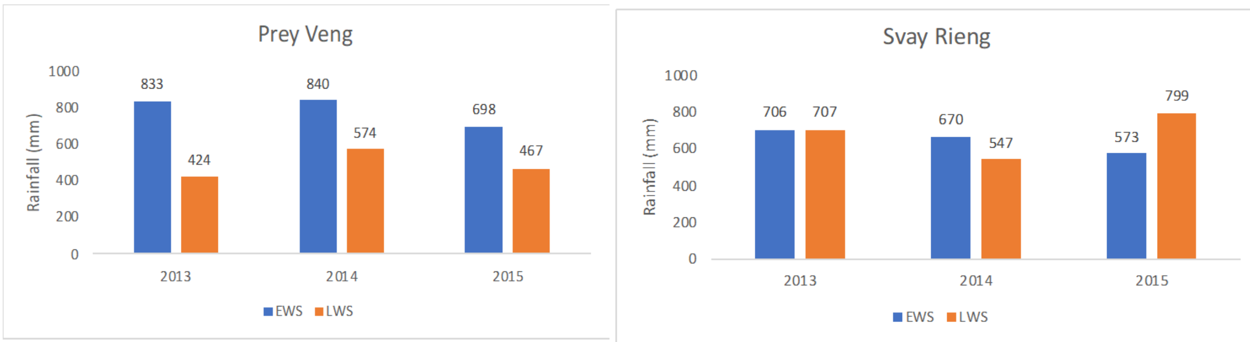
There were no significant differences for cassava establishment which averaged 99.4% (Table 1). Yield was significantly affected by the main effects of Province and season of planting but not by fertilizer application. However, the Province X Season, Province X Fertilizer, Season X Fertilizer, and Province X Season X Fertilizer interactions were all not significant. The main effects of Province and season were significant for yield and profit but the main effect for fertilizer was not significant. The effect of fertilizer was significant for yield only.

The yield of cassava wet tuber at Svay Rieng (9.69 ton. ha^{-1}) was significantly greater than for Prey Veng (8.33 ton. ha^{-1}). Profit at Svay Rieng (202.20$) was significantly more than for Prey Veng (74.84$). Moreover, the plant height at Svay Rieng (186.31cm) was significantly taller than Prey Veng (178.75cm). But, growth, plant height and starch content in Svey Rieng and Prey Veng were not significantly different (Table 2).



Source: Ministry of Planning (2014), MAFF (2015), MAFF (2016), MAFF (2017)

Fig. 1: Average monthly rainfall at Prey Veng between 2013 and 2017



Source: Ministry of Planning (2014), MAFF (2015), MAFF (2016)

Fig. 2: Rainfall at Prey Veng (left) and Svay Rieng (right) during EWS and LWS for 2013, 2014 and 2015.

Table 1: Analysis of variance for effect of Province, planting season and fertilizer application on cassava production and profitability.

Variable	*Location (L)*	*Season (S)*	*Fertilizer (F)*	*L X S*	*L X F*	*S X F*	*L X S X F*
Growth (%)	NS[1]	NS	NS	NS	NS	NS	NS
Plant Height (cm)	*	*	NS	NS	NS	NS	NS
Yield ($ton.ha^{-1}$)	*	**	*	NS	NS	NS	NS
Starch content (%)	NS	***	NS	NS	NS	NS	NS
Profit ($/ha)	**	***	NS	NS	NS	NS	NS

Source: Author's data collection, 2017
Note: 1 NS = not significant, * is significant, p <0.05, ** is significant, p <0.01, *** is significant at p <0.001.

Growth, yield, expense, income and profit from casava production

The yield for cassava wet tuber planted in the early wet season (EWS) was 9.96 $ton.ha^{-1,}$ which was significantly greater than for planting in the late wet season (LWS), 8.05 $ton.ha^{-1}$. Profit of EWS was 222.92$, which was significantly more than for LWS, 54.13$. Starch content in the early wet season was 21.74%, which was significantly higher than LWS 20.03%. Moreover, the plant height in EWS (186.44cm) is taller than LWS (178.63cm). But, the emergence in Svey Rieng and Prey Veng was not significantly different (Table 3).

Application of fertilizer significantly increased the wet tuber yield of cassava by 1.19 $ton.ha^{-1}$ (14.12%) from 8.41 $ton.ha^{-1}$ with zero fertilizer to 9.60 $ton.ha^{-1}$ with application of fertilizer. But for growth, plant height, starch content and profits of the application of fertilizer, there are no real difference between giving and without fertilizing (Table 4).

The yield of cassava wet tuber at Svay Rieng (9.688 $ton.ha^{-1}$) was significantly greater than for Prey Veng (8.325 $ton.ha^{-1}$). The yield for cassava planted in the early wet season (EWS) was 9.963 $ton.ha^{-1}$ which was significantly greater than for planting in the late wet season (LWS), 8.050 $ton.ha^{-1}$. Fertilizer application increased yield by 1.19 $ton.ha^{-1}$ from 8.41 $ton.ha^{-1}$ with nil fertilizer to 9.60 $ton.ha^{-1}$ with fertilizer application (Fig. 3).

Costs of planting cassava with/no fertilization per hectare

The total man-day for cassava cultivation with fertilization is 15.8 man-day; while without fertilization, it is 14.8 man-day. The average total variable costs of cassava production in the experiment with fertilizer application were \$760.62 ha^{-1} and variable costs without fertilizer application \$642.65 ha^{-1} (Table 5). These costs are less than those reported by the World Bank (2015) where variable costs were \$823/ha for small-scale farms. These lower costs are associated with farmers in Prey Veng and Svay Rieng spending less on planting material compared to the national average and in addition, lower costs are associated with lower yields and lower harvesting costs.

The profit (gross margin) growing cassava at Svay Rieng (\$216/ha) was significantly greater of \$48/ha, than for Prey Veng. The profit for growing cassava in

Table 2: Growth, yield, expense, income and profit in 8 experiments carried out in Prey Veng and Svay Rieng in 2017

Variables	*Prey veng*	*Svay rieng*	*% Deviation*	*T-Test*
Growth (%)	99.19	99.56	0.37	NS
Plant Height (cm)	178.75	186.31	4.23	*
Yield ($ton.ha^{-1}$)	8.33	9.69	16.33	**
Starch content (%)	20.73	21.03	1.45	NS
Profit ($/ha)	74.84	202.20	170.18	**

Source: Author's data collection, 2017

Table 3: Effect of planting time on growth, yield, expense, income and profit in 8 experiments carried out in Prey Veng and Svay Rieng in 2017

Variables	*EWS*	*LWS*	*% Deviation*	*T-Test*
Growth (%)	99.44	99.31	(0.13)	NS
Plant Height (cm)	186.44	178.63	(4.37)	*
Yield (ton.ha^{-1})	9.96	8.05	(19.18)	**
Starch content (%)	21.74	20.03	(8.54)	***
Profit ($/ha)	222.92	54.13	(75.72)	**

Source: Author's data collection, 2017

Table 4: Effect of fertilizer application on germination, yield, expense, income and profit in 8 experiments carried out in Prey Veng and Svay Rieng in 2017

Variables	*Nill (F-)*	*Plus (F+)*	*% Deviation*	*T-Test*
Growth (%)	99.38	99.38	0.00	NS
Plant Height (cm)	180.38	184.69	2.39	NS
Yield (ton.ha^{-1})	8.41	9.60	14.12	**
Starch content (%)	20.85	20.91	0.29	NS
Profit ($/ha)	145.07	131.98	(9.02)	NS

Source: Author's data collection, 2017

the EWS was $221/ha, which was significantly greater than $44/ha than for planting in the LWS. The effect of fertilizer on gross margin was not significant (Fig. 4). With a selling price of cassava tubers of $92.26 per ton, the difference in yield with fertilizer application was 1.19 tons, resulting in an additional profit of $109.79. The value of this increase is almost the same as the fertilizer costs incurred of $117.95; based on this research, it is concluded that growing cassava with fertilizer is not economically profitable.

The yield of cassava wet tuber at Svay Rieng (9.688 ton.ha^{-1}) was significantly greater than for Prey Veng (8.325 ton.ha^{-1}). The yield for cassava planted in the early wet season (EWS) was 9.963 ton.ha^{-1} which was significantly greater than for planting in the late wet season (LWS), 8.050 ton.ha^{-1}. Fertilizer application increased yield by 1.19 ton.ha^{-1} from 8.41 ton.ha^{-1} with nil fertilizer to 9.60 ton.ha^{-1} with fertilizer application (Fig. 4). This result is very low when compared to the average productivity of Cambodian cassava in 2019 (20.59 ton.ha^{-1}; Ministry of Planning, 2021), 20.57 ton.ha^{-1} (Peuo et al., 2021), the average productivity of Asia (12.84 ton.ha^{-1}) ha; FAOSTAT, 2015), Indonesia (23.99 ton.ha^{-1}. Rozi et al., 2021), India of 31.40 ton. ha^{-1}, Thailand of 22. ton.ha^{-1} (Howeler, 2005). By improving the treatment, cassava can be increased productivity to 41.3-51.8 ton.ha^{-1} (Rozi et al., 2022).

Soil Analysis for Casava Production

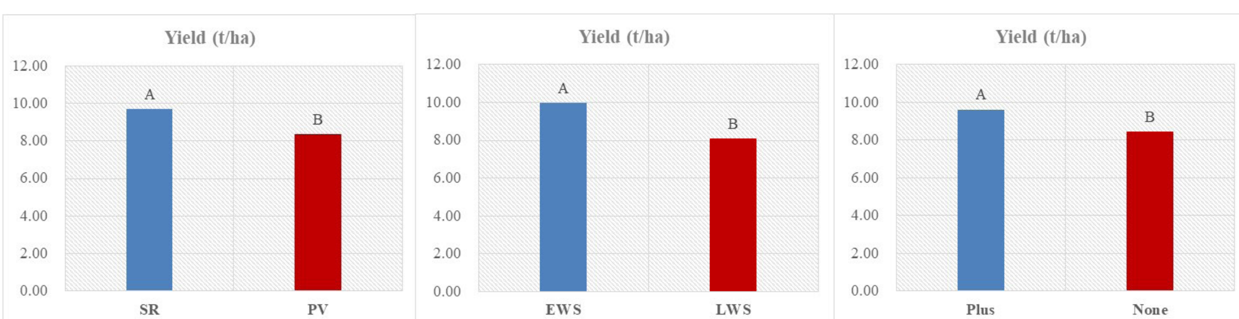
Based on laboratory analysis, the soil in Prey Veng and Svay Rieng is composed of sand, silt and clay of 66.27, 25.88 and 7.85%, respectively, with a loamy sand texture (Table 6). Soil texture with this composition is classified as less fertile (Pereira et al., 2017)

The chemical properties of the soil in Prey Veng and Svay Rieng are classified as less balanced in chemical composition and classified as less fertile (Table 7).

Discussion

When comparing the results of soil analysis (Tables 6 and 7) and the need for sufficient soil nutrients for cassava growth (Howeler, 1996), the land in the Provinces of Prey Veng and Svay Rieng is classified as infertile and the level of soil acidity is low. Soil nutrient content is insufficient for cassava growth and production. To produce optimal growth and production, land in this area requires fertilization and liming. With the addition of lime, as much as 2 tons/ha on land with a pH of 4.5 can increase the yield of dry cassava from 12 tons to 19 tons (Kaluba et al., 2022).

Based on the planting season, it was found that planting cassava in the Early Wet Season (EWS) produces the same growth, but the yield and gross margin are higher than in the Late Wet Season (LWS). This is because the amount of rainfall during the first four months in



Source: data processed from observation results

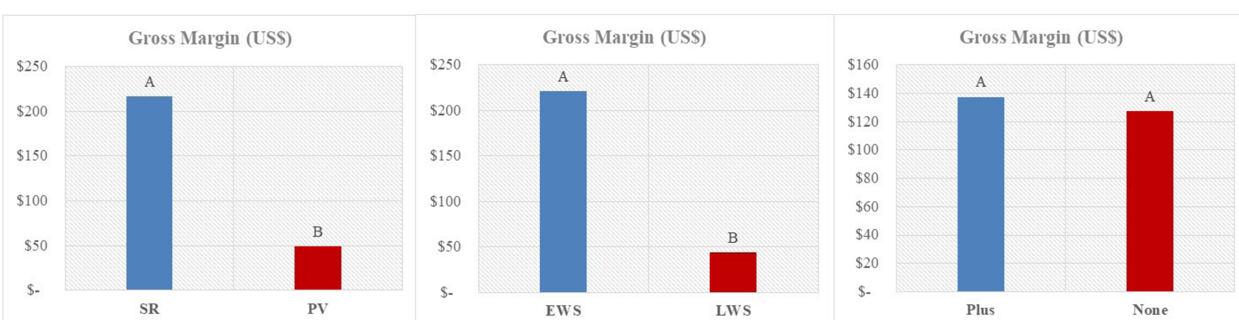
Fig. 3: Effect of Province, season and fertilizer on yield of fresh tuber (ton.ha-1). This means in columns with the same letter are not significantly different according to the Tukey HSD multiple range test at $p < 0.05$

Table 5: Variable costs of planting cassava with/no fertilization per hectare

Description	*Unit*	*Qty*	*Cost*	*Total*
Stem cutting	Bundle	250	$0.77	$192.31
Fertilizer	Bag (50 kg)	3	$30.77	$92.31
Pesticide	Bottle	2	$20.51	$41.03
Transport	Ha	1	$25.64	$25.64
First Land preparation (disc plough)	Ha	1	$33.33	$33.33
First Land preparation (disc plough)	Ha	1	$38.46	$38.46
Labor for planting	Ha	1	$76.92	$76.92
Labor for weed-cutting	Ha	1	$30.77	$30.77
Labor for fertilizer application	Ha	1	$25.64	$25.64
Labor for herbicides and pesticides	Ha	1	$30.77	$30.77
Labor for harvesting	Ton	9.8	$4.62	$45.23
Land rental fee	Ha	1	$102.56	$102.56
Other	Ha	1	$25.64	$25.64
Total cost for growing cassava with fertilizer application				$760.62
Total cost for growing cassava without fertilizer	$642.65			

Source: Author's data collection, 2017

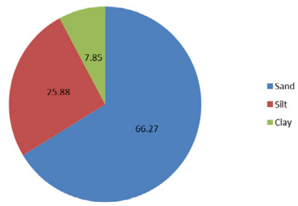
EWS (783 mm) is higher than LWS (499 mm), so the amount of water for growing cassava in the EWS season is higher than LWS. The growing season is different in places when it comes to yields. In many countries, some cassava was also planted at the end of the rainy season, such as in August-September in Kerala, India, or in September-November in Thailand and South Vietnam (Sinthuprama et al., 1983). In Hainan Island of China, cassava can be planted throughout the year due to high rainfall when harvested 12 months after planting, but only from February-May when harvested at 8 months after planting; starch contents were always highest when the roots were harvested in the dry and cold months of Nov-March (Zhang et al., 1998). The results of a two-year study in Northwest Cambodia Phan et al. (2021), showed that planting cassava in April, which is the driest and hottest month in this area, produced lower yields than cassava, which is planted in May and June. Cassava planting in May is a suitable planting time to get high cassava yields. In Indonesia, the highest cassava yields are obtained when planted in December (Wargiono et al., 2001); the rainfall is high in December - March, which is sufficient for the initial growth of cassava. Rayong got highest yields in Thailand were obtained when cassava was planted in Aug-Nov. (Tongglum et al., 2001). The amount of rainfall will determine cassava growth and yield in each season. Optimal results are obtained if cassava is planted in months of high rainfall during the first four months of its growth. The growth of cassava continues to develop and advance to maturity during the rainy season; cassava growth and yield will be maximum if rainfall is above 940 mm/year (Boansi, 2017).



Source: Author's data collection, 2017

Fig. 4: Effect of Province, season and fertilizer on gross margin (USD). This means that columns with the same letter are not significantly different according to the Tukey HSD multiple range test at $p < 0.05$

Table 6: Mean values of the chemical properties of soils in Prey Veng and Svay Rieng

Particle	*Composition (%)*	*Soil triangle*
Sand	66.27	
Silt	25.88	
Clay	7.85	
Texture	Loamy sand	

Source: Author's data collection, 2017

Fertilizer application increased yield by 1.19 ton.ha^{-1} from 8.41 ton.ha^{-1} with nil fertilizer to 9.60 ton.ha^{-1} with fertilizer application. Yields and increases due to fertilization are lower when compared with research in Kwadaso, Ghana. Fertilizing cassava with NPK can increase the yield of fresh roots by 68% - 278%. Fertilization as much as NPK: 30:30:45 produced fresh tubers of 20.3 tons/ha, NPK:60:30:45 produced 27.17 ton.ha^{-1}, NPK:45:30:45 produced 33.67 ton.ha^{-1}; while without fertilizing the yield is 12.07 ton.ha^{-1} (Berchie et al., 2019). Experimental application of 60 kg N+ + 16 kg P + 138kg K.ha^{-1} on cassava variety BEN86052 in Hayakpa, Africa, for three successive cropping cycles produced 21.9 t fresh cassava tubers compared to 12.9 ton.ha^{-1} without fertilization (Carsky and Toukourou, 2005). Research in Indonesia, Adira 1 cassava fertilization with 250 kg of Phonska, 200 kg of Urea, 50 kg of KCL, and 750 kg of dolomite can produce as much as 48.9 ton.ha^{-1} of fresh tubers compared to fertilizing 250 kg of Phonska and 200 kg of Urea only produces 41.3 ton.ha^{-1} (Rozy et al., 2022).

The increase in yield due to cassava fertilization is low because the yields are low, so the compensation for fertilizing costs is not balanced with income from increased yields. In this study, the increase in yield was only 1.19 ton.ha^{-1} (14.78%) lower than the increase of 18-289 % by Berchie et al., 2019; Carsky and Toukourou, 2005; Rozy et al., 2022.

Low and declining cassava yields are not unexpected because Cambodian farmers grow cassava continuously on the same field and do not intercrop with other crops (Wenjun et al., 2016). Furthermore, farmers apply little or no organic and inorganic amendments to cassava fields. In 2013, the cassava production cost was US$ 845 ha/ha in Kampong Cham and US$ 981 kg/ha in Pailin. Of this, labor costs for harvesting account for 30 and 38% in these provinces, respectively. Farmers generated a gross margin of 682 USD/ha in Kampong Cham and 834 USD/ha in Pailin. In Cambodia, cassava yields can be markedly improved by growing better-adapted cassava varieties and by improving soil fertility management and erosion control.

Declining yields under cassava land-use is are associated with excessive spoil disturbance and low fertilizer use. Srean et al. (2023) found that the conversion of forest to cultivation of cassava reduced the abundance and richness of soil fauna, whereas the decrease in abundance and richness was not significant under mango. However, the high variability of the richness of soil fauna under mango suggests that richness could potentially recover under a fruit tree crop land-use. The excessive soil disturbance associated with cassava production degrades soil structure and water aggregate stability and depletes soil organic carbon. Implementation of Conservation Agriculture (FAO, 2023) is an option to address declining crop yields, soil erosion and soil fertility depletion. Apart from fertilization efforts, to get a larger gross margin, it is necessary to plant superior varieties with greater yields.

Sustainable production of cassava in Cambodia will require the adoption of Conservation Agriculture: reduced tillage, crop rotation and retention of crop residues at the soil surface FAO 2023). A preferable alternative to mono-crop cassava is the transformation from annual cropping to perennial fruit tree crops which are more profitable when value-chains are in place, as well as more environmentally sustainable. However, most smallholders face difficulties in transitioning to tree crops because of the high initial cost of establishing the orchard and the delay of several years before the orchard begins production (Ravi et al., 2021).

The low yield of cassava in the trial in Prey Veng and Svay Reang can be caused by various things. Judging from the soil texture, which is sandy loam with a composition of clay 7.85%, silt 25.88%, and sand 66.27% (Figure 3), it is classified as less fertile for cassava. Of the six main cassava cultivation provinces, Kampong Cham is a fertile area for cassava cultivation with a soil texture of clay with a composition of 74% clay, 15% silt and 11% sand and a productivity of 14.5 tons/ha; Meanwhile, Kampot Province is a less fertile area with a soil texture of sandy loam with a composition of 20, 30 and 50% sand and productivity of only 5.18 tons/ha (Jie et al., 2001). Soil

Table 7: Mean values of the chemical properties of soils in Prey Veng and Svay Rieng

Total C	*Total N*	*Organic C*	*Available P*	*Exchangeable cations*				*pH (H_2O)*
(%)	*(%)*	*(%)*	*(ppm)*	*Ca*	*Mg*	*Na*	*K*	
11.94	1.18	2.40	189	2.59	1.68	0.18	0.25	4.6
Very High	Very High	High	Very High	Low	Low	Low	Very Low	Acid

Source: Author's data collection, 2017

fertility conditions both before and after crop rotation and intercropping are relatively low for maximum growth and yield of cassava when compared with the soil fertility requirements for cassava. Cassava grows well in soil with a high clay composition and adequate soil nutrients (Howeler, 1996; Jie et al., 2001; Howeler, 2014b).

The amount of rainfall in both provinces, Prey Veng 424 to 840 mm/year and Svay Rieng (573-779 mm/year) (Figure 2), is not optimal for maximum growth and production of cassava. Cassava growth and yield will be maximum if rainfall is above 940 mm/year (Boansi, 2017). In this study, the growth and yield of cassava in Prey Veng Province was better than in Svay Rieng Province because rainfall in Prey Veng Province was higher than in Svay Rieng Province. The varieties planted in this experiment were local and long-lived varieties with low yields.

Cassava planting in both provinces will be successful if improvements are made such as increasing soil fertility through conservation efforts and adding organic fertilizer, adding irrigation, and planting short-lived cassava varieties. This is mainly to take advantage of sufficient water during the short rainy season. Based on the treatment of cassava growth and yield, cassava development in both provinces must be preceded by efforts to improve soil fertility and water adequacy. Research results can be used as motivation for farmers to be able to carry out sustainable intercropping and crop rotation of cassava; on the other hand, technical culture improvements must be made, such as the use of superior varieties and additional irrigation.

Conclusion

The growth and production of cassava in Southeast Cambodia is influenced by planting area, planting time, and fertilization. Cultivating cassava in Svay Rieng Province results in higher growth, production and profits than in Prey Veng Province. Cultivating cassava in the early wet season results in higher growth, production and gross margins compared to the late wet season. Cassava is very responsive to fertilization but the application of fertilizer has not provided economic benefits on land conditions with low productivity. To increase cassava productivity and maintain soil fertility in South-Eastern Cambodia, it is necessary to select an appropriate planting area, plant during the early wet season and apply fertilization during the early wet season. The application of intercropping and crop rotation is necessary in order to obtain fertile soil for optimal cassava growth and production.

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Declaration of Competing Interest

PIN Tara stated that physical work is paid based on the provincial minimum wage, while observation work, data analysis, and article writing are done voluntarily by the author team. The results of the research may be developed by science enthusiasts freely under academic ethics.

Credit Authorship Contribution Statement

PIN Tara: Equipment installation, research design, data collection and analysis, writing- the original draft of the article, reviewing and editing. MEN Sarom: Reviewing, commenting, and editing. HAHNE Janalisa: Reviewing and commenting. HUON Thavrak: Reviewing, commenting, and editing. RO Sophoanrith: Reviewing and commenting. ROBERT J. Martin: Reviewing and commenting. BUSTAMAM Hendri: Data analysis, figures producing, review, and commenting. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Raw data were collected directly in research sites in Prey Veng and Svay Rieng province, Cambodia, from 2013 to 2017. Soil analysis was conducted at the Soil Science Laboratory, General Directorate of Agriculture (GDA), Ministry of Agriculture, Forestry and Fisheries (MAFF), Phnom Penh, in 2014 and 2017. Secondary climatological data were taken from the Ministry of Planning and Ministry of Agriculture, Forestry and Fisheries report 2014-2017.

Funding Declaration

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Author's Biography

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