Cassava-Legumes inter-cropping: A potential food-feed system for dairy farmers

A Polthanee, S Wanapat, M Wanapat* and C Wachirapokorn*

Department of Agronomy, Faculty of Agriculture,Khon Kaen University, Khon Kaen 40002, Thailand

* *Department of Animal Science, Faculty of Agriculture, Khon Kaen University*

Abstract

When cassava is intercropped with legumes the cassava root yield generally decreases compared with when cassava is planted alone. This is due to the competition of the component crops for light, water and nutrients. However, cassava-legume intercropping systems usually increase the land use efficiency and economic return over solely cassava. Because of the current low market price for cassava roots, dual-purpose production of cassava for both root and fodder should be developed. Cassava hay is a good fodder for dairy cows, and legume crops, such as cowpea and peanut whose residues also provide good fodder for livestock, can be intercropped with cassava.

When cowpea was row and strip intercropped with cassava, it produced fodder yields of 1.7 to 2.4 tons/ha, depending on the cowpea cultivar. Cowpea seeds and young green pods are eaten by humans. A food-feed system based on cassava-cowpea strip intercropping has been successfully developed by dairy farmers in Mahasarakham province in Northeast Thailand. Peanuts and mungbean are also high-potential legume crops for food-feed systems for dairy farmers.

Key words: Cassava, inter-cropping, cowpea, forage yield

Introduction

The Northeast region of Thailand is considered to be the largest producer of cassava (*Manihot esculenta* Crantz) in the country. This crop has been recognized as one of the most important cash crops after sugarcane. A sole crop of cassava, which in this context may be considered a long-season crop, does not efficiently use the available light, water and nutrients during its early growth stages due to its slow initial development. Thus a short-duration second crop may be inter-planted to make more efficient use of these growth factors. The legume crops have been considered to be suitable crops for use in intercropping systems with cassava. They could possibly be used in improving soil fertility through their root nitrogen fixation and crop residues (Ashokan et al 1985). On the other hand, legumes can be used as fodder, where green material is used for grazing or, more commonly, cut and mixed with dry cereals for stall feeding (Tarawali et al 1997). This paper reviews cassava-legumes inter-cropping systems in the context of growth and yield, agronomic advantages for human food and fodder crops. Nutrient removal from soil, land use efficiency and economic returns are also discussed.

Climate and soil

Approximately 80 percent of the 20 million people in Northeast Thailand are engaged in agriculture, of which more than 80 percent are heavily dependent upon rain-fed agriculture. Although the region has an average annual rainfall greater than 1,200 mm, the seasonal distribution is poor, as almost all of the rainfall falls from April to October. The date of onset of the rainy season, and the quantity and continuity of rainfall at the beginning of the rainy season vary considerably from year to year, and the end of the rainy season also varies. In addition there is usually a dry period occurring in June or July (Polthanee and Marten 1986).

Another important constraint is soil quality. There are 35 different soil types in Northeast Thailand, but, with the exception of some upland limestone areas, they are derived from sandstone, shale or silt-stone and are therefore inherently low in phosphorus, calcium and magnesium and have extremely low organic matter and cation-exchange capacity (Craig and Pison 1988). Therefore, the lowest per capita income is found in this region of the country due to the instability in the rain-fed farming system, poor soil quality, and fluctuation in market demand and price for the major crops of rice, cassava, sugarcane, kenaf and maize.

Cassava and rice-based farming systems

Cassava adapts to a wide range of ecological conditions and is known for its tolerance to drought. It can grow in areas with as little as 750 mm rainfall per year and it survives in areas with dry periods of 5 to 6 months (Cock 1984). Cassava grows remarkably well on poor soils and will grow on extremely acid soils and give reasonable yields when most other crops would either fail or give very poor yields (Cock and Howeler 1978). The requirements for K, N and Ca are similar to those for growth of other crops, but when the supply to these nutrients is limited, growth is reduced less than in most crops (Edwards et al 1977). Therefore, cassava is usually suitable for growing in the unfavorable environments of Northeastern Thailand and other similar areas. The farmers usually say that cassava serves as the security crop in the farm. In addition, the period of planting, weeding and harvesting for cassava do not compete with rice cultivation, which is the most important crop in Northeast Thailand (Figure 1). This indicates that a rice-based farming system that includes cassava results in better household farm labor distribution.

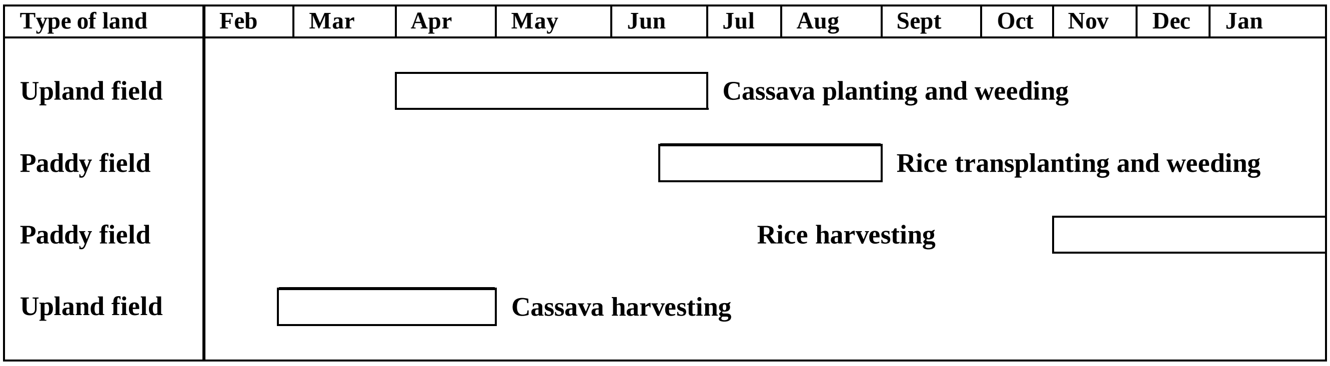

Figure 1. Seasonal distribution of labor for a farmer cultivating upland and paddy fields

Cassava and soil fertility

Cassava cultivation for several years usually results in a decline in soil fertility. This is due to (1) wide spacing, slow development of soil cover in the first three to four months, traditional soil tillage and clean weeding practices at the onset of the rainy season, which can result in high soil losses, (2) the above-ground part of the plant is not reincorporated into the soil (as the stem is used for planting material), (3) no-root residues remain in the soil (the root is removed and sold), (4) short turn around time for soil recovery (long growth duration) and (5) farmers apply small amounts of fertilizer.

Polthanee et al (1998) determined nutrient balances for the cassava system under farmer management using a crop-cut study procedure. The results show that N balances were slightly negative, P balances slightly positive, but K balances were highly negative (Table 1).

Table 1. Nutrient balances for the cassava systems at Nong Pak Top village

	Amount (kg/ha)		
	N	**P**	**K**
Compound fertilizer (15-15-15)	28.1	12.2	23.3
Rainfall	2.21	1.72	1.03
Planting material	0.95	0.08	0.74
Total inputs	*+ 31.2*	*+14.0*	*+25.1*
Cassava roots	28.5	4.31	55.
Cassava stems	15.5	1.33	12.0
Total outputs	*-44.1*	*-5.64*	*-67.5*
Balance	**-12.8**	**+8.43**	**-42.3**

Adapted from Polthanee et al (1998)

Inter-cropping systems

Inter-cropping is usually defined as growing two or more crops simultaneously on the same field (Andrews and Kassam 1976). Inter-cropping can be practiced in four different ways (Andrews and Kassam 1976):

- Mixed inter-cropping – the simultaneous growing of two or more crop species in an irregular arrangement - i.e. without a well-defined planting pattern.
- Row inter-cropping – the simultaneous growing of two or more crop species in a well-defined row arrangement.
- Strip inter-cropping – the simultaneous growing of two or more crop species in strips wide enough to allow independent cultivation but, at the same time, sufficiently narrow to induce crop interactions.
- Relay inter-cropping – planting one or more crops within an established crop in a way that the final stage of the first crop coincides with the initial development of the other crops.

An advantage commonly claimed for intercropping systems is that they offer greater yield stability than sole cropping (Baker1980; Rao and Willey 1980; Rao and Morgado 1984). For subsistence farmers, greater stability in the production of food crops in inter-cropping systems is particularly meaningful, since this characteristic of the production system tends to better insure their sustainability and substantially reduces the risk of total crop loss. There is evidence that some combinations may suffer less yield reduction than sole crops in the event of moisture stress (Natarajan and Willey 1986). Some intercropping combinations have been shown to reduce the incidence or severity of pest and disease attack compared with sole cropping (Altieri and Liebman 1986).

Inter-cropping systems often result in better land use efficiencies than do sole cropping systems, and are usually associated with greater production of total dry matter (Natarajan and Willey 1980 a, 1980b; Sivakumar and Virmani 1980). Land use efficiency in general was determined by calculating the land equivalent ratio outline by Mead and Willey (1980). The monetary returns per ha are appreciably higher under intercropping systems, and is mainly due to the higher value of intercrops (Prabhakar et al 1996).

Cassava-cowpea inter-cropping

Cowpea (*Vigna unguiculata L.*) is a drought tolerant crop and better adapted to acidic soils, similar to cassava. There seems to be a good compatibility of the two crops growing in the environment of Northeastern Thailand. Polthanee (unpublished data) carried out a study on cassava intercropped with two cowpea cultivars (bush plant type, climbing plant type) at the experimental farm of Khon Kaen university. Cassava root yields and dry weight per storage root were significantly influenced by inter-cropping. Cassava inter-cropped with cowpea decreased root yield by 11 to 17% (Table 2).

Table 2. Yield and yield components of cassava in cassava-cowpea inter-cropping and sole cropping systems.

Cropping system	Root dry weight (t/ha)	Roots per plant (no.)	Dry weight per root (g)
Sole cassava	19.2^{a}	9.3	125.8^{a}
Cassava+cowpea (B)	17.1^{ab}	9.7	114.0^{b}
Cassava+cowpea (C)	15.9^{b}	9.3	110.5^{b}
F-test	*	NS	*

** = significant at 5% level; NS = not significant. B = bush plant type; C = climbing plant type*

Cowpea seed yields and yield components were significantly influenced by inter-cropping. The highest seed yield was produced when cassava was inter-cropped with the climbing plant type cowpea cultivar (Table 3).

Table 3. Yield and yield components of cowpea in cassava- cowpea inter-cropping and sole cropping systems

Cropping system	Seed yield (kg/ha)	Pods per plant (No)	Seeds per pod (No)	100-seed weight (g)
Sole cowpea (B)	$1,946^{b}$	24.9^{b}	13.4^{b}	14.8^{a}
Sole cowpea (C)	$2,597^{a}$	34.7^{a}	16.6^{a}	10.5^{b}
Cassava + cowpea (B)	$1,681^{c}$	18.6^{c}	12.5^{b}	15.2^{a}
Cassava + cowpea (C)	2.427^{a}	30.6^{a}	16.4^{a}	10.1^{b}
F-test	**	**	**	**

*** = Significant at 1% level; B= Bush plant type ; C= climbing plant type*

Cowpea cultivar C (climbing plant type, long growth duration) and cowpea cultivar B (bush plant type, short growth duration) when inter-cropped in the cassava rows produced dry-matter yields (fodder yield) at harvest of 2.4 and 1.7 t/ha, respectively.

Land use efficiency and economic returns

Cassava-cowpea inter-cropping increases the land use efficiency by 72-76% over sole cropping. In economic terms, cassava-cowpea inter-cropping also gave higher net returns over sole cropping (Table 4).

Table 4. Gross return, material cost and net return of cassava-cowpea inter-cropping and sole cropping systems.

	Gross return (baht/ha)		Material cost		Net return (baht/ha)
Cropping system	**Cassava**	**Cowpea**	**Cassava**	**Cowpea**	
Sole cassava	27,750	-	4,594	-	23,156
Sole cowpea (B)	-	15,568	-	2,581	12,987
Sole cowpea (C)	-	20,776	-	2,581	18,195
Cassava + cowpea (B)	23,250	13,448	4,594	2,581	29,523
Cassava + cowpea (C)	21,750	19,416	4,594	2,581	33,991
B= Bush plant type ; C= climbing plant type					

Okoli (1996) assessed the effect of inter-cropping three cassava genotypes, of different plant archetype, with cowpea, having different growth habits and maturity regimes. Inter-cropping with cowpea reduced dry matter yield and number of cassava roots significantly. Inter-cropping cassava had no effect on cowpea yield and increased land use efficiency by 42-70%. Inter-cropping with cowpea reduced cassava yield by 14 to 24% (Mason et al 1986a) and 19 to 38% (Mason and Leihner 1988). However, inter-cropping cassava with cowpea resulted in 20 to 100% greater land use efficiency than for either crop grown alone (Leihner 1983). Other studies indicated that inter-cropping cassava with cowpea increased land use efficiency by 48-56% (Mason et al 1986a).

The climbing plant type cowpea cultivar with long growth duration had higher nutrient uptake than that of the bush plant type cowpea cultivar with short growth duration (Table 5). Considering nutrient balances (gain by incorporated crop residue into the soil and removal by seed yields), the two cowpea cultivars in the inter-cropping system added nutrients to the soil when the crop residues were incorporated into the soil (Table 5).

Table 5. Nutrient uptake of the crop residue (stem+leaf) and seed yield of cowpea at harvest in cassava-cowpea intercropping stems.

Cowpea cultivar	N (kg/ha)*			P (kg/ha)			K (kg/ha)		
	Crop residue	Seed	Balance	Crop residue	Seed	Balance	Crop residue	Seed	Balance
Bush type	+43.2	-26.2	+17.0	+12.9	-6.4	+6.5	+49.1	-27.2	+21.9
Climbing type	+80.0	-52.7	+27.3	+17.9	-9.5	+8.4	+96.7	-39.6	+57.1

** Not including N-fixing by roots*

Mason et al (1986c) reported that cassava-cowpea inter-cropping removed 15.5, 2.1 and 14.3 g/m^2 of N, P and K, while sole cassava removed 11.2, 1.7 and 10.8 g/m^2 of N, P and K, respectively. In this experiment, the fodder yields (crop residue) would provide crude protein yields of 238 and 336 kg/ha for the bush type and climbing type cowpea cultivars, respectively.

The planting of strips of component crops has also been attempted in farmers in dairy farms in Mahasarakham Province, with strips of cassava (6 rows) planted with strips of cowpea (4 rows) in order to increase the cassava fodder yields (cassava hay) with close spacing (50x25 cm). The fodder yield includes residues from both green cassava and cowpea. Cassava produced a mean fodder yield of 2.9 t/ha/year (3 cuttings). At the same time the cowpea KVC-7 cultivar, which has green pods that are preferred by humans, was also introduced to the system. Cowpea produced fodder yields (crop residue) of 1.9 t/ha/year and green pod yields of 18.9 t/ha/year (2 cycles). Estimates of the nutritive value of fodder included (% of dry matter): crude protein 14.2, NDF 50.9, ADF 32.4, ADL 6.4 and total ash 17.2.

Trials on fodder varieties of cowpea under inter-cropping gave fodder yields of 431 to 2,292 kg/ha (Singh et al 1994). Dry matter yields can be positively associated with days to flower, and the longer the vegetative period, the more forage was produced (Tyagi et al 1978). Relwani et al (1970) reported the nutritive value of cowpea haulms (% dry matter basis): ether extract 2.25 to 3.25, crude fiber 18.7 to 28.0, N-free extract 32.1 to 50.8, total ash 10.1 to 12.9% and crude protein 16.5 to 26.4. Relwani (1970) recommended the use of cowpea in combination with cereals and other crops in an intensive scheme for lactating cows, to maintain milk yields of 5 litres/cow/day. The KVC-7 cultivar developed by the Department of Agronomy, Faculty of Agriculture, Khon Kaen University, provides young green pods that are a nutritious food for humans. In general the people in the Northeast of Thailand prefer to use young green pods in a salad " Som Tam".

Cassava-peanut inter-cropping

Peanut (*Arachis hypogaea L.*) is a drought tolerant crop and is therefore suitable to intercrop with cassava in Northeast Thailand. Polthanee et al (1998) reported that cassava root yield and yield components were influenced by inter-cropping. The maximum root yield was obtained when cassava was inter-cropped with 1 row of peanut (Table 6).

Table 6. Cassava yield and yield components as influenced by peanut inter-cropping

Cropping system	Root yield (t/ha)	Roots per plant (no.)	Fresh weight per root (g)
Sole cassava	22.3[a]	11.2	197.3[b]
Cassava (100x 100cm) + P1	25.2[a]	12.4	203.2[a]
Cassava (100x50cm) + P2	18.8[b]	9.8	191.8[b]

Cassava (200x50 cm) + P3	15.7[b]	9.5	169.5[c]
F-test	**	Ns	*

** = significant at 5%; ** = significant at 1%; NS = not significantP1= peanut 1 row (plant density ; 87,500 plants/ha); P2= peanut 2 row (plant density ; 37,500 plants/ha); P3= peanut 3 row (plant density ; 37,500 plants/ha)*

Peanut seed yield and pod number per plant were affected by cassava inter-cropping. The highest seed yield was obtained with cassava inter-cropped with 1 row of peanuts at the highest plant density.

Table 7. Peanut seed yield and yield components as influenced by cassava-peanut intercropping

Cropping system	Seed yield	Pods / plant	Seeds / pod
	(t/ha)	(no.)	(no.)
Sole peanut	1.96[a]	21.8[a]	1.80
Cassava (100x100) +P1	1.66[a]	16.9[b]	1.73
Cassava (200x50) + P2	1.13[b]	20.9[a]	1.73
Cassava (200x50) +P3	1.18[b]	20.9[a]	1.70
F-Test	*	*	NS

** = Significant at 5%; NS = not significant; P1 = Peanut 1 row; P2 = Peanut 2 rows; P3 = Peanut 3 rows*

Cassava-peanut inter-cropping increased the land use efficiency by 30 to 98% over sole cropping and increased the net return by 3,431-11,950 baht/ha over sole cassava (Table 8)

Table 8. Gross return , material cost and net return of sole cassava and cassava- peanut Inter-cropping systems (bath/ha)

	Gross return		Material cost		Net return
Cropping system	Cassava	Peanut	Cassava	Peanut	
Sole cassava	16,575	-	4,063	-	12,513
Cassava (100x100)+ P1	18,900	16,563	4,063	6,938	24,463
Cassava (200x50) + P2	14,113	11,250	4,063	3,781	15,944
Cassava (200x50)+ P3	12,038	11,750	4,063	3,781	15,944
P1 = Peanut 1 row; P2 = Peanut 2 rows; P3 = Peanut 3 rows					

Cassava with a plant spacing of 100x100 cm inter-cropped with 1 row of peanut gave the highest nutrient uptake (Table 9). Regarding nutrient balances (gain by incorporated crop residues into the soil minus removal by seed yields), N and P showed negative values, while K showed positive values.

Table 9. Nutrient uptake of the crop residues and seed yield of peanut at harvest in cassava-peanut intercropping systems

	N (kg/ha)*			P (kg/ha)			K(kg/ha)		
Intercropping pattern	Crop residue	Pod	Balance	Crop residue	Pod	Balance	Crop residue	Pod	Balance
Cassava (100x100 cm)+P1	+30.9	-45.8	-14.9	+1.4	-2.75	-1.35	+17.1	-13.1	+4.03
Cassava (200x50cm) + P2	+11.9	-26.7	-14.8	+0.54	-1.63	-1.08	+7.44	-7.03	+0.41
Cassava (200x50cm)+P3	+14.8	-27.9	-13.1	+0.67	-1.63	-0.96	+8.56	-7.63	+0.93

** Not including N- fixing by roots; P1 = Peanut 1 row; P2 = Peanut 2 rows; P3 = peanut 3 rows*

Peanuts for fodder and human food

After the pods have been removed from the stem, the residues provide good fodder for livestock. In this experiment, crude protein yields from fodder were 74 to 193 kg/ha. Kotchasatit (1999) reported that peanut gave a fodder yield of 0.9 to 1.7 t/ha in cassava – peanut inter-cropping, with a crude protein yield of 66.4 to 129 kg/ha.

Peanuts are most commonly grown for their edible seeds, which are often boiled for home consumption. Their protein content ranges from 17.9 to 25.1% on a dry weight basis (Kotchasatit 1999).

Cassava-mungbean inter-cropping

Polthanee and Kotchasatit (1999) reported that yield and yield components of cassava were not affected by inter-cropping patterns. Cassava-mungbean inter-cropping increased the land use efficiency by 66% to 97% as compared with sole cropping. Mungbean seed yield and pods per plant were affected by the inter-cropping pattern, but there were no effects on grains per pod and 1000 grain weights (Table 10).

Table 10. Yield and yield components of mungbean as influenced by inter-cropping pattern

	Seed yield (kg/ha)	**Pods per plant (no.)**	**Seeds per pod (no.)**	**1000 grain weight (g)**
Cassava (100x100 cm)+ M1	411.3	18.5	10.5	55.8
Cassava (100x50cm) + M2	640.0	13.5	9.7	58.5
Cassava (200x50cm) + M3	545.0	15.3	12.3	59.3
Cassava (200x50cm) + M4	712.7	14.4	11.5	59.6
Sole mungbean	737.3	15.3	11.0	58.8
LSD (.05)	90.2	3.6	NS	NS

M1= 1 row of mungbean ; M2= 2 rows ; M3= 3 rows; M4= 4 rows of mungbean in between rows of cassava plants

With regard to the total amount of soil nutrients taken up by both cassava and mungbean plants, the amounts of nitrogen (N), phosphorus (P), and potassium (K) taken up by the plants in all inter-cropping patterns and sole crop of cassava were similar. In this study, N and K were removed to a greater extent than P (Table 11).

Table 11. Comparison between cassava sole crop and inter-cropping pattern (whole plants of cassava plus mungbean) on nutrient (NPK) removal from soil

	N (kg/ha)	**P (kg/ha)**	**K (kg/ha)**
Intercropping			
Cassava (100x100 cm)+M1	194.7	5.9	120.3
Cassava (100x50cm) + M2	201.3	6.2	115.6
Cassava (200x50cm)+M3	206.8	6.3	115.9
Cassava (200x50cm)+M4	224.0	7.1	124.9
Sole cassava	190.8	4.9	111.6
LSD (0.05)	NS	NS	NS

Mungbean as fodder and human food

After the pods are removed from the stem, crop residues provide good fodder for livestock. In this study, fodder yield (crop residue) and crude protein yield were 715 kg/ha to 2,080 kg/ha and 75 kg/ha to 217 kg/ha, respectively (Table 12).

Table 12. Fodder yield and crude protein yield of mungbean as influenced by cassava-mungbean inter-cropping

	Fodder yield (kg/ha)	Crude protein yield (kg/ha)
Intercropping		
Cassava (100x100 cm) + M1	715	75
Cassava (100x50cm) + M2	2,080	217
Cassava (200x50cm) + M3	1,540	161
Cassava (200x50cm) + M4	1,133	118

Mungbeans are grown most commonly for their edible seeds, which are often boiled for home consumption. Their protein content has been reported to be 15.4% of dry weight (Polthanee and Kotchasatit 1999).

Implications for Research

When cassava is intercropped with grain legumes, the crop residues could be incorporated into the soil to maintain soil fertility after harvest. In case of using crop residues as a fodder crop, nutrients in the crop residues would not be returned into the soil. The practice of using animal manure as fertilizer thus is significant in efficiently recycling nutrients within the farm system. Tawil (1997) reported that cow manure consists of N (0.3 to 0.8%), P_2O_5 (0.3 to 0.5%) and K_2O (0.2 to 0.5%) on a dry weight basis. Future research into nutrient balance analysis with application of animal manure to the cassava-legumes intercropping system should be investigated. Furthermore, more research is needed concerning the biomass produced from the inter-cropped cassava-legumes systems in terms of seasonal availability, quality and feeding value for livestock.

References

Altieri M A and Liebman M 1986 Insect, weed, and disease management in multiple cropping. In: Multiple Cropping Systems (ed: Francis C A), New York, Macmillan. pp.183-218.

Andrews D J and Kasam A H 1976 The importance of multiple cropping in increasing world food supplies. In: Multiple Cropping, ASA special Publication no.27.American Society of Agronomy, Madison, Wisconsin. pp.1-10

Ashokan P K., Vikraman R and Sudhadara K 1985 Studies on cassava-legume intercropping systems for the Oxisols of Kerala State, India. Trop. Agric. 62(4). pp.313-318.

Baker E F I 1980 Mixed cropping in Northern Nigeria .IV. Extended trials with cereals and groundnuts. Exptl. Agric. 16:pp. 361-369

Cock J H 1984 Cassava In: The Physiology of Tropical Field Crops (eds. Goldsworthy P R and Fisher N M), John Wiley and Sons Ltd., U.S.A. pp. 529-549

Cock J H and Howeler R C 1978 The ability of cassava to grow on poor soils. In: Crop Tolerance to Sub Optimal Land Conditions (Ed. Jung, G A) American Society of Agronomy Special Publication No.32 145-154.

Criag I A and Pisone U 1988 Methodologies for rainfed agriculture in Northeast Thailand. NERAD Project Technology Documentation Working Paper No.10, Northeast Reginal Office of Agriculture, Tha Phra, Khon Kaen.

Edwards D G, Asher C J and Wilson G L 1977 Mineral nutrition of cassava and adaptability to low fertility conditions. In: Proc. IV Symposium of the International Society for Tropical Root Crops (Eds. Cock, J H., MacIntyre R and Ghaham M), Cali, Colombia. pp. 124-130.

Kotchasatit A 1999 Growth, yield and nutrient uptake of cassava and peanut in cassava/peanut intercropping systems under rained conditions at Khon Kaen Province. M.S Thesis, Faculty of Agriculture, Khon Kaen University.

Mason S C, Leihner D E and Vorst J J 1986a Cassava-cowpea and cassava-peanut intercropping.1. Yield and land use efficiency. Agron J.78: 43-46.

Mason S C, Leihner D E and Vorst J J 1986c Cassava-cowpea and cassava -peanut intercropping. III. Nutrient concentration removal.

Mead R and Willey R W 1980 The concept of a "land equivalent ratio" and advantages in yield from intercropping. Exptl. Agric. 16:217-218.

Natarajan M and Willey 1980a Sorghum/pigeon pea intercropping and effects of plant population density. I. Growth and yield. J.Agric. Sci. 95(4): 51-58

Natarajan M and Willey R W 1980b Sorghum/pigeon pea intercropping and effects of plant poulation density. II.Resource use. J.Agric. Sci. 95(5): 59-65

Okoli O O 1996 Effect of planting dates and growth habits of cassava and cowpea on their yield and compatibility. Trop . Agric. 73(3):169-174

Polthanee A and Marten G 1986 Rainfed cropping systems in Northeast Thailand. In: Traditional Agriculture in Southeast Asia, (ed. Marten G), Westview Press, Boulder and London. pp. 103-131.

Polthanee A, Treeloges V, Rouysoongnern S and Patanothai A 1998 Sustainability analysis of existing land-use systems in Northeast Thailand. In: Land Degradation and Agricultural Sustainability, (ed. Patanothai A), Khon Kaen Printing Ltd., pp.117-132

Polthanee A, Wanapat S and Mangprom P 1998 Row arrangement of peanut in cassava-peanut intercropping: I . Yield, land use efficiency and economic return. Khon Kaen Agric. J. 26 (2): 85-91

Polthanee A, Wanapat S and Mangprom P 1998 Row arrangement of peanut in cassava-peanut intercropping: II. Nutrient removal and nutrient balance in soil. Khon Kaen Agric.J. 26 (3): 125-131

Polthanee A and Kotchasatit A 1999 Growth, yield and nutrient content of cassava and mungbean grown under intercropping. Pak. J. Biol. Sci. 2(3): 871-876.

Prabhakar M, Nair G M and Ghosh S P 1996 Intercropping legumes with cassava. Agric. Intl. 47(11):126-128

Rao M R and Willey R W 1980 Evaluation of yield stability in intercropping studies on sorghum/pigeon pea. Exptl. Agric. 16:105-116

Rao M R and Morgado L B 1984 A review of maize-bean and maize-cowpea intercrop systems in semi-arid Northeast Brazil. Pesq.Agropec. Bars., Brasilia. 19(2):179-192

Relwani L L 1970 Cropping patterns for high milk production. Indian Farming. 20(9):26-31

Singh B B, Blade S F, Terao T, Bottenberg H and Florini D 1994 Highlights of IITA's cowpea research in 1993 relevant to northern Nigeria. Institute of Agricultural Research, Ahmadu Bello University, Samru, Zaria, Nigeria.

Sivakumar M V K and Virmani S M 1980 Growth and resource use of maize, pigeon pea intercrop in an operation research watershed. Exptl. Agric. 16:377-386

Tarawali S A, Singh B B, Peters M and Blade S F 1997 Cowpea haulms as fodder. In: Advances in cowpea research (Eds. Singh B B, Mohan D R, Dashiell K E and Jackai L E N), Japan International Research Center for Agricultural Science , Tsukuba, Ibaraki, Japan.pp.313-325

Tawil K 1997 Sustainable Agriculture: Land use-fertilizer. Department of Soil Science, Kasetsart University.

Tyagi I D, Pariha B P S, Dixit R K and Singh H G 1978 Component analysis for green-fodder yield in cowpea. Indian J.of Agric. Sci. 48(11):646-649

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