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Sweet Potato-Based Cropping Systems

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ABSTRACT

Sweet potato (*Ipomoea batatas* L.), a versatile crop used as food, feed and raw material for industries has got the ability to adjust in any cropping systems. It is mainly cultivated in cereal based cropping systems. In China, sweet potato is primarily planted after wheat (*Triticum aestivum* L.) harvest in June and harvested before wheat sowing in October. It is cultivated in the intensive irrigated rice (*Oryza sativa* L.) and sugar cane (*Saccharum officinarum* L.) based cropping systems in Taiwan. In India, sweet potato is rotated with rice and fallow in upland ecosystem to regain soil fertility and suppress weeds and weevil. In many African countries, sweet potato is intercropped with cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.) and a variety of other crops. It is also grown on the borders of the fields in association with maize, cassava, beans (*Phaseolus* spp.), banana (*Musa* spp.) and sorghum. It is grown throughout the year in home gardens under mixed cropping in Philippines. Sweet potato being insurance crop against natural calamities is grown as intercrop in plantation crops. However, further research is needed on agronomic aspects when sweet potato is considered in cropping systems for efficient utilization of natural resources, biotic and abiotic stress management and sustainable production.

Keywords: intercropping, sequential cropping, maize, pigeon pea, sweet potato
Abbreviations: CTCRI, Central Tuber Crops Research Institute; **PNG**, Papua New Guinea; **SPW**, sweet potato weevil

CONTENTS

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a common subsidiary component in many cropping systems of Asia, Africa and America. Its ability to produce stable yields within a short growing season, multiple uses as human food, livestock feed and raw material for starch based industries and its comparatively lower input requirements make this crop very attractive for resource poor farmers. It has the ability to produce higher dry matter per unit area per unit time. In cropping systems its role varies from place to place. In certain cropping systems it is a fallow or catch crop. In some others it may serve as an erosion control crop or livestock feed or even as green manure crop. Sweet potato is grown in a wide range of environmental conditions and is associated with a number of annual and perennial crops. Further, most of the subsistence and semi-commercial farmers follow multiple cropping (intermixed or relay) in one form or the other. In some of the semi commercial enterprises sequential cropping with wet season cereals is in vogue. Monocropping is the ruling practice under commercial farming of sweet potato.

Continuous monocropping of sweet potato results in yield declining (Hartemink *et al.* 2000). Yields are related to rainfall and number of cropping seasons, followed by nutrient availability, nematode and weevil infestation (Hartemink *et al*. 2000). In Orissa, India, sweet potato is rotated with rice and fallow in upland ecosystem to regain soil fertility and suppress weeds and weevil (Nedunchezhiyan *et al*. 2006). Hartemink *et al*. (2000) observed nematode and weevil population buildup when sweet potato was cultivated continuously for three seasons. Hence development of sustainable intensified cropping system is needed to overcome biophysical constraints and to feed ever increasing population. This paper is aimed to present an overview of sweet potato cropping systems and their management practices. Further research needs and research methodology as applicable to cropping systems are also discussed.

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Invited Mini-Review

SWEET POTATO CROPPING SYSTEM

Sweet potato was cultivated in 8.996 million ha in the world during 2006 and Asian countries accounts nearly 5.466 million ha (60.75%) (FAOSTAT 2008). In Africa, America, Oceania and Europe, it is grown in 3.154 (35.06%), 0.256 (2.85%), 0.113 (1.26%) and 0.006 million ha (0.08%), respectively. China is the main producer with 85% of the world's total production. Other Asian countries with significant production are Indonesia, Vietnam, the Philippines, India, Sri Lanka and Bangladesh. In Africa, Ethiopia and Nigeria is the major producer.

Sequential cropping

Sole cropping of sweet potato is very common in Asian countries. It is mainly cultivated in cereal based cropping systems. In China, sweet potato is grown in almost all provinces. Detailed analysis of the cropping systems involving sweet potato in Jiangsu and Hunan provinces of China was reported by Dai (1990). In these provinces sweet potato is primarily planted after wheat (*Triticum aestivum* L.) harvest in June and harvested before wheat sowing in October. This system permits wheat to grow during winter months with good rainfall in April-May. By August, some rains can be expected through unpredictable. Clouds are regularly seeded to make rain. Yet the total rainfall is extremely limiting and only sweet potatoes can grow well without irrigation during the summer months. In areas with higher rainfall the sweet potato may be intercropped with grain legumes. Pig manure is the important fertilizer along with compost and grass ash (grass burned with some soil which is then spread on to the field) as sweet potato cultivation and piggery goes side by side in China.

Sweet potatoes figure in the intensive irrigated rice/ paddy (*Oryza sativa* L.) and sugar cane (*Saccharum officinarum* L.) based cropping systems of Taiwan (Ruthenberg 1980). Sweet potato is grown as winter crop after wet rice to be followed by another rice crop, groundnut/peanuts (*Arachis hypogaea* L.) or soybeans (*Glycine max* L. Merr.). In such system sweet potato is planted directly into the rice stubble or relay planted 20-30 days prior to rice harvest. In sugarcane based cropping system sweet potato is inter planted (in between sugarcane rows of 1.25 m) in early august at the time of planting cane setts.

There are two distinct types of sweet potato production in Indionesia 1) the subsistence farming of Irian Jaya and Nusatenggara 2) the commercial farming in Java and other major Islands. In Irian Jaya, monocropping is predominant with varietal mixture in each plot. Continuous planting and harvesting to meet the food supply of the local people is the main feature of this system. The farmers of the high land valleys and slopes followed checker board system (Thera Sawor 1991). In the foot hills of Irian Jaya extensive shifting cultivation is practiced. The commercial farmers of Java and other major Islands grow sweet potato in rice lands during the post rainy season after the rice crop (Manwan and Dimyati 1989).

In Vietnam sweet potato is an important crop after rice and maize/corn (*Zea mays* L.). In the northern and central parts the crop is mostly grown in marginal soils in sequence with rice and peanuts. In the southern parts of Vietnam sweet potato production is for commercial purpose and so usually monocropping is practiced with an average yield of 15 t ha^{-1} (Chujoy and Kim 1991). In Taiwan sweet potatoes were planted among rice crops before the harvest of the rice crop. Immediately after harvest of the rice, fertilization and other field operations were performed. Sweet potato was harvested before the second crop of rice. This technology was called mud in planting. The acreage planted using this method was about 50,000 ha which was ¼ of the total sweet potato acreage in Taiwan (Yishin *et al.* 2000).

Machida *et al*. (2000) reported that good yield of sweet potato was gained when Italian ryegrass (*Lolium multiflorum* L.) and peanut cultivated as preceding crop of sweet potato due to high harvest index. High amount of potassium was contained in the soil compared to nitrate after harvesting Italian ryegrass in Southern Kyushu, Japan. Another important producer of sweet potato in Asia is Philippines. In the Philippines in terms of area sweet potato is more widely grown in the highlands than other root crops. In semi-commercial and commercial areas sweet potato was rotated with rice, cassava (*Manihot esculenta* Crantz) or corn. Also in the hillside sweet potato is grown in sequence with upland rice.

In India cropping systems involving sweet potato vary from region to region (Nayar 1995). In Orissa the common sequences are maize-sweet potato-fallow and rice-sweet potato-fallow. In Uttar Pradesh sweet potato is usually grown as a *kharif* crop in sequence to cereals or pulses. For Bihar, maize (*kharif*)-sweet potato-onion (*Allium cepa* L.) are the suggested sequences. A net income as high as \$ 444.4 ha^{-1} is generated from such cropping system (CTCRI 1995). In south India especially in the coastal belt, sweet potato is grown during summer following the second crop of rice. Experiments conducted at CTCRI had revealed that crop sequences like rice-rice-sweet potato; rice-sweet potato-rice and rice-sweet potato-cowpea (*Vigna unguiculata* L.) are profitable and capable of reducing weevil damage in sweet potato (CTCRI 1996).

In a five year study conducted at CTCRI, Thiruvananthapuram, India revealed that rice-sweet potato-cowpea produced maximum returns (\$ 740.2 ha^{-1}) and was therefore the most economic cropping sequence followed by rice-rice-sweet potato (\$ 484.6 ha^{-1}) and colocasia/taro (*Colocasia esculenta* L.)-sweet potato (\$ 455.2 ha^{-1}). Rice-sweet potato-rice was also found to be economical (\$ 442.5 ha^{-1}) (Ravindran 2002). These treatments were also found to be highly effective to reduce sweet potato weevil (SPW) (*Cylas formicarius*) infestation (Pillai *et al*. 1996).

Nedunchezhiyan *et al*. (2011a) reported that sweet potato can be planted under zero tillage immediately after harvest of rice, when the soil is marshy. In such system of planting sweet potato recorded above 90% root yield of conventional method of sweet potato planting in rice based system. Further, the zero tillage allowed planting of sweet potato 15-20 days advance.

In Bangladesh sweet potatoes are grown mainly in the river beds and Char areas. In these lands only one crop of sweet potato is grown during the period October-November to March-April. However, in some relatively higher lands broad casted Aus paddy is grown immediately after the harvest of sweet potato. Where the land is medium high broadcasted Aus paddy transplanted Aman paddy-sweet potato pattern is found (Elias 1985). In Sri Lanka sweet potato is grown in sequence to rice or vegetables (Balasurya 1991).

Brazil, Paraguay, parts of Northern Peru and the Caribbean, sweet potato is grown in the sequence of rice-sweet potato-rice in irrigated poza. In Caribbean and Northern Peru sweet potato is planted on the wide mounds that separate the rice fields (Prain and Fano 1991). In Uganda, Rwanda, Barundi and Madagascar, sweet potato is grown on almost every farm in the mid-elevation (1200-2000 msl) regions of the above countries and eastern Zaire. Sweet potato is relay cropped with cassava, maize, sorghum (*Sorghum bicolor* L.) and a variety of other crops (Ewell and Mutuura 1994).

Under the tropical ultisols conditions of southern Nigeria, sweet potato is rotated with mucuna (*Mucuna* spp.) fallows. Njoku *et al*. (2002) found higher sweet potato root yield when two years of mucuna fallow was followed.

Planting of peanuts or winged bean (*Psophocarpus tetragonolobus*) in rotation with sweet potato was found reduce pests and diseases incidence. Further the same rotation was also followed to maintain soil fertility in Papua New Guinea (PNG) (Bourke and Ramakrishna 2009). In some highlands of PNG vegetables were rotated with sweet potato. In this system vegetables were grown using fertilizers and the residues also benefit the subsequent sweet potato plantings (Bourke and Ramakrishna 2009). Rama-

krishnan *et al*. (2001) reported sweet potato variety Sree Bhadra planted as preceding crop for flue cured virginia tobacco (*Nicotiana tobaccum* L.) nursery reduced 82.8% initial root-knot nematode soil population over control. Further sweet potato grown beds recorded 118.6% increase in healthy transplants yield over check.

Intercropping in sweet potato

Intercropping or mixed cropping is a predominant production system in small land holdings in Africa (Graham and Vance 2000), Latin America (Graham and Vance 2000) and Southern Asia (Rerkasem *et al*. 1988). It is gaining importance because it not only provides biological insurance against risks in the case of aberrant rainfall behaviour in a dry land environment (Dutta and Bandyopadhyay 2006) but also more labour employment (Nedunchezhiyan *et al*. 2008a) as well as some insect and disease control (Stinner and Blair 1990). Intercropping and crop substitution stabilize crop yields in uplands (Rao *et al*. 1982). When crops of different growth habits are put together in an intercropping system, it provides greater opportunity to secure higher yield from the same piece of land (Sarkar and Pal 2004) with minimal competition (Amede 1995).

Sweet potato is most important staple food crop in Papua New Guinea and is widely intercropped with other staple crops that mainly include taro, cassava, yams (*Dioscorea* spp.), banana, corn and peanuts (Bourke *et al*. 1994). Intercropping maize or other short term annuals (long bean (*Vigna unguiculata* subsp *sesquipedalis*), red bean, tomato (*Lycopersicon esculentum* Millspaugh) and string bean) with sweet potato is widely practiced in Java and Bogor (Watson *et al*. 1991). In Vietnam, sweet potato is grown in association with cassava and sugarcane (Chujoy and Kim 1991). Brazil, Paraguay, parts of Northern Peru and the Caribbean, sweet potato is associated in cassava, maize beans, chillies (*Capsicum annum* L.) (Prain and Fano 1991). Another cropping system seen in many environments is the home gardens in which sweet potato is grown with a wide range of intercrops. In Uganda, Rwanda, Barundi and Madagascar, sweet potato is intercropped with cassava, maize, sorghum and a variety of other crops (Ewell and Mutuura 1994). Sweet potato is also grown on the borders of the fields in association with maize, cassava, beans, banana and sorghum (Octittii and Mwanga 1990). In home gardens it is grown throughout the year usually under mixed cropping in Philippines.

Watson *et al*. (1991) reported that the intercrops (long bean, red beans, tomato, string bean) though harvested within three months, the sweet potato yields were moderately affected (25-30% reduction) in intercropping. Chujoy and Kim (1991) reported that sweet potato yielded 6-10 t ha^{-1} when grown in association with cassava and sugarcane in Vietnam. However, Nedunchezhiyan (2011) reported that when sweet potato was strip intercropped with other crops, sweet potato root yield in intercropping was higher than sole sweet potato on net sown area basis. This was mainly due to increased yield attributes per plant in border rows of sweet potato (**Table 1**) (Nedunchezhiyan *et al*. 2011b). Njoku *et al*. (2007) reported that intercropping okra (*Hibiscus esculentus* L.) as intercrop in sweet potato did not affect the sweet potato tuber yield. Further, intercropping supplements income over time and provides variety of products. In uplands, strip cropping of sweet potato (ridge and furrow) and pigeonpea (*Cajanus cajan* (L.) Millspaugh) (flat bed) (1.8 m strip each; 3:3 rows) produced higher tuber equivalent yield (13.5 t ha^{-1}), net return ($ 623.9 ha^{-1}) and benefit: cost ratio (3.24) under rainfed conditions of Orissa, India (Nedunchezhiyan *et al*. 2010a).

Sweet potato as a cover crop conserves soil moisture

Table 1 Yield components and yield of sweet potato in intercropping and sole cropping systems (pooled data of 3 years).

Cropping system	No. of roots/plant			Root length (cm)			Root diameter (cm)			Root yield/plant (g)		
	Border row	Middle row	Mean	Border row	Middle row	Mean	Border row	Middle row	Mean	Border row	Middle row	Mean
Sole cropping	2.7	2.7	2.7	11.6	11.6	11.6	8.2	8.2	8.2	167	167	167
Sweet potato + rice	2.9	2.7	2.8	12.4	11.9	12.1	8.9	8.3	8.6	222	176	199
Sweet potato + finger millet	3.2	2.8	3.0	12.9	12.0	12.4	9.1	8.3	8.7	232	180	206
Sweet potato + maize	2.5	2.7	2.6	12.1	11.9	12.0	9.4	8.4	8.9	184	168	176
Sweet potato + pigeonpea	3.3	2.9	3.1	13.4	11.9	12.6	9.4	8.4	8.9	241	185	213
LSD (*P*=0.05)	0.1	0.1	0.1	0.5	0.4	0.3	0.3	0.1	0.2	13	9	11

Source: Nedunchezhiyan *et al*. (2011b)

Table 2 Yield components and yield of rice, finger millet, maize and pigeonpea in intercropping and sole cropping systems (pooled data of 3 years).

Cropping system	Rice/Finger millet/Maize/Pigeonpea							
	Panicles/plant, cobs/plant or pods/plant				Grains/panicle, cob or pod			
	Intercrop			Sole	Intercrop			Sole
	Border	Middle row	Mean		Border	Middle row	Mean	
Rice	-	-	-	5.3	-	-	-	80.7
Finger millet	-	-	-	2.8	-	-	-	1178.0
Maize	-	-	-	1.0	-	-	-	199.0
Pigeonpea	-	-	-	76.2	-	-	-	3.8
Sweet potato + rice	5.5	5.3	5.4	-	92.8	83.4	88.1	-
Sweet potato + finger millet	2.8	2.8	2.8	-	1280.0	1188.0	1234.0	-
Sweet potato + maize	1.0	1.0	1.0	-	229.0	205.0	217.0	-
Sweet potato + pigeonpea	117.9	80.1	99.0	-	4.0	3.8	3.9	-
Cropping system	**Rice/Finger millet/Maize/Pigeonpea**							
	1000-seed weight (g)				Seed yield/plant (g)			
	Intercrop			Sole	Intercrop			Sole
	Border	Middle row	Mean		Border	Middle row	Mean	
Rice	-	-	-	20.80	-	-	-	8.9
Finger millet	-	-	-	1.91	-	-	-	6.3
Maize	-	-	-	232.00	-	-	-	46.1
Pigeonpea	-	-	-	83.20	-	-	-	24.1
Sweet potato + rice	20.80	20.80	20.80	-	10.7	9.1	9.9	-
Sweet potato + finger millet	1.91	1.91	1.91	-	6.7	6.5	6.6	-
Sweet potato + maize	234.00	232.00	233.00	-	52.6	48.2	50.4	-
Sweet potato + pigeonpea	83.50	83.30	83.40	-	37.1	27.3	32.2	-

Source: Nedunchezhiyan *et al*. (2011b)

and adds organic matter to the soil through its leaves (Njoku *et al*. 2007). Sweet potato vines grown between maize rows would act as mulch in the inter-row space thereby minimizing soil evaporation, reducing run-off or increasing infiltration (Smith and Abruna 1995). Intercropping sweet potato between maize rows is practiced not only in regions with intermittent drought but also in areas with a frequent terminal drought (Amede 2001).

Strip intercropping of sweet potato with food crops like rice, finger millet (*Eleusine coracana* Gaetrn.), maize and pigeonpea improves storage of soil moisture in soil profile. The stored moisture effectively used by the crops and produced higher yield (Nedunchezhiyan *et al*. 2010b). Nedunchezhiyan *et al*. (2011b) reported that the yield of rice, finger millet, maize and pigeonpea was found higher when strip intercropped with sweet potato compared to respective sole crops on net sown area basis. This was mainly due to higher yield attributes in border row plants (**Table 2**). Njoku *et al*. (2007) also reported that the presence of sweet potato in the planophile improves the intercrops yield.

Sweet potato is intercropped with other crop species, when soil fertility declines in PNG (Bourke and Ramakrishna 2009). In most plots sweet potato is the dominant species, even where crops such as maize, common bean, highlands pitpit (*Setaria palmifolia*), amaranthus (*Amaranthus* spp.), *Rungia klossii* and other food crops are interplanted with it. The use of chemical fertilizer or manure is uncommon although sweet potato may benefit from the fertilizer applied to the associated crops (Ocitti and Mwanga 1990). Rajasekhara Rao (2005) reported low incidence of SPW in mixed cropping systems. Similarly, a 10-fold reduction in *C. formicarius* infestation is recorded in sweet potato intercropped with rice, cowpea or colocasia as compared to monoculture of sweet potato (Pillai *et al*. 1987). Strip intercropping in sweet potato reduced the percentage of weevil damaged roots. Less percentage of weevil damaged roots were found in sweet potato + maize strip intercropping followed by sweet potato + pigeon pea strip intercropping (Nedunchezhiyan *et al*. 2010b). Suris *et al*. (1995) also reported lower percentage of SPW when sweet potato was intercropped with maize.

Sweet potato as an intercrop

Perennial crop based cropping systems involving cultivation of compatible crops in the inter spaces of the perennials in a scientific and systematic manner offer considerable scope for increasing production and productivity per unit area time and inputs by more efficient utilization of resources like space, sunlight, soil, water and labour. Sweet potato being insurance crop against natural calamities and has great flexibility in adjusting any cropping system (Nedunchezhiyan *et al*. 2008b) is grown as intercrop in plantation crops (Naskar and Nedunchezhiyan 2002).

On the West Coast of India, sweet potato is also grown as intercrop in coconut (*Cocos nucifera* L.) and areca nut (*Areca catechu* L.) gardens, both at the pre-bearing and mature phases (Nayar 1990). However, in mature stands of coconut and areca nut the productivity of sweet potato is drastically reduced for want of light. Varghese (1978) reported an average root yield of 7.1 t ha^{-1} from sweet potato raised as intercrop in one ha of coconut garden. Abraham (1974) recorded the productivity of sweet potato as 0.7 t ha^{-1} in areca nut garden. Similarly in East Coast of India, Nedunchezhiyan *et al*. (2008b) also reported relatively low sweet potato tuber yield in established coconut garden. However, it recorded net return of $ 206.1 ha^{-1} with the benefit: cost ratio of 1: 60. Intercropping sweet potato did not affect the growth and yield of coconut (Nedunchezhiyan *et al*. 2007).

In Papua New Guinea, sweet potato is cultivated from sea level to altitudes up to 2800 m. It is the dominant or co-dominant crop in various intercropping systems. Sweet potato is grown as intercrops with coffee in the New Guinea high land. In New Calidonia large rectangular beds of 1 m height are formed between coconut trees and intercropped sweet potato (Brookfield and Hart 1971).

AGRONOMIC CONSIDERATIONS

Plant population and geometry

Plant population affects crop productivity and resource use in intercropping (Ossom *et al*. 2009). Tsubo *et al*. (2003) and Zwane and Ossom (2005) reported that plant population parameters influenced the growth and yield of component crops in intercropping. This aspect requires greater attention when intercropping or relay cropping is practices. Usually there are two approaches intercropping the additive and replacement. In additive approach care is taken to adjust plant population of the intercrop to minimize the competition effects on the main crop. In replacement approach the main consideration is to have optimum plant density of both the crops to maximize the productivity and net returns. For instance in sweet potato + maize intercropping system the farmers' of Bogor (Indonesia) adopted wider spacing (50 cm × 200 cm) for maize (Watson *et al*. 1991). In rice-sweet potato relay cropping system of Taiwan the farmers leave every fourth row of rice to accommodate the sweet potato later.

Planting time and land preparation

The main crop and intercrop need not always be planted simultaneously. Planting may be staggered to increase the temporal differences which might result in higher yield advantage. But it may be seen that the earlier planted crop has little adverse effect on the later sown crop. In fodder maize-sweet potato intercropping system to reduce shading on sweet potato farmers plant maize in the slope of the ridges 30-45 days earlier than sweet potato. Further maize is harvested at the milk stage 60-75 days after planting (Watson *et al*. 1991).

The methods of land preparation also vary according to the crop combination. In rice-sweet potato relay cropping system the rice is transplanted in the puddle whereas sweet potato is planted on ridges in the place reserved for the same 30 days after planting rice (FFTC 1974). In Whagi, Baiyer and Nebilyer valleys of Western highlands Province of PNG, drains 30-50 cm deep are dug to form beds 4-5 m square. The soil from the drains is thrown on top of the beds and sweet potato is planted into this loose soil. A peanut or winged bean rotation is often used with this system (Huges *et al*. 2009).

Genotype selection

Genotypes suitable for mono cropping may not be suitable for sequential cropping or intercropping. When sequential cropping is practiced the preference is for short duration/ early bulking types of sweet potatoes. If sweet potato is relay cropped or intercropped, it is deprived of some proportion of the available solar radiation by the principle crop grown beside it. Therefore the ability to tolerate some degree of shading would be a useful trait in sweet potato varieties intended for this sort of cropping systems (Villareal and Hsu 1982). For intercropping genotypes with compact canopy may be ideal.

The variety TIS 8164 performed well under no mucuna fallow or one year mucuna fallow whereas TIS 87/0087 expressed full genetic potential when mucuna fallow was maintained for two years (Njoku *et al*. 2002).

Soil fertility management

In traditional subsistence cropping systems sweet potato receives very little manures or fertilizers. A recent study in PNG (Kirchhof *et al*. 2009) has shown that sweet potato yields decline from around 8 t ha^{-1} in gardens that came out of a 2 to 5 year fallow period to 4 t ha^{-1} in gardens that were

about to go into a fallow period. In Central America and Java studies by Moreno (1982) and Sitompul (1984) showed that in cassava/sweet potato intercropping systems competition for nutrients was one of the most important factors limiting productivity. Information on nutrient requirements of cropping systems involving sweet potato is very limited. However, the soil fertility management of cropping systems with sweet potato the following factors deserves special attention.

1. Nutrient requirement of component crops

In intercropping fertilizers should be adequately applied, so that component crops should not compete with each other. In additive series, full recommended dose of fertilizer of base crop and fertilizer proportionate to area occupied by the intercrop should be applied. In replacement series, fertilizers proportionate to the area occupied by the component crops should be applied. Further, crop combinations either in intercropping or sequence cropping such that the nutrient requirement of the component crops must differ widely. Potassium requirement of sweet potato is very high. Hence low potassium required pulses and cereals can be intercropped or relay cropped or included in the sequence cropping. Nedunchezhiyan *et al*. (2011a) reported that the sweet potato recorded higher yield when sweet potato was applied with full recommended doses of fertilizer (75-50-75 N-P_2O_5-K_2O kg ha^{-1}) in rice based sequential cropping.

2. Uptake pattern of nutrients by the crops

Component crops in intercropping should differ in peak uptake of nutrients. Hence, crops having different growth pattern and maturity period should be considered in intercropping.

3. Residual effect of nutrients applied to components in the system

High amount of potassium was contained in the soil compared to nitrate after harvesting Italian ryegrass, the succeeding crop sweet potato uses them efficiently and produced very high yield in Southern Kyushu, Japan (Machida *et al*. 2000).

4. Response to applied nutrients

Nutrients should be supplemented through fertilizers', if crops are response to the applied nutrients. Many of the occasion's crops are unable to utilize the applied nutrients and which were subjected to various kinds of losses. Especially for rainfed crops like sweet potato, nutrients should be judicially applied.

RESEARCH NEEDS AND METHODOLOGY

Technology development

Research for new technology generation is usually carried out in research stations by qualified scientists under controlled conditions. While carrying out research on cropping systems in research stations the following steps are to be involved: 1. Design of appropriate cropping pattern; 2. Screening for genotype selection; 3. Determination of optimum plant population and planting pattern; 4. Measuring competition and resource use; 5. Assessing yield stability/ biological efficiency; 6. Economic evaluation.

Technology validation and upgradation

Cropping systems are location specific and research conducted under controlled conditions in research stations by scientists will be useful to test the biological feasibility of different systems and to develop component technology to overcome production constraints created by competitive interferences and field problems. But the technical feasibility and economic viability of the cropping systems should be tested in the farmers field with participation of the farmers. The farmer should be involved in the design and testing of cropping system technology. This ensures early feedback from the farmer about inputs, management and market related constraints. In technology validation and upgradation the following phases require attention: 1. Site selection and site description; 2. Design of the cropping system; 3. Cropping pattern trials; 4. Component technology research; 5. Multilocation testing; 6. Assessment of constraints in transfer of the technology for large scale adoption.

CONCLUSION

Sweet potato because of its versatility in adjusting in any cropping systems is grown throughout tropics and sub tropics. It is mainly grown in cereal based cropping system, as because of its ability to use residual fertility and moisture more efficiently. It is also intercropped with other crops for attaining maximum productivity and profitability. However, further research is needed on agronomic aspects when sweet potato is considered in cropping systems for efficient utilization of natural resources, biotic and abiotic stress management and sustainable production.

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