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A critical review of the role of taro Colocasia esculenta L. (Schott) to food security: A comparative analysis of Kenya and Pacific Island taro germplasm.

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ABSTRACT

The many threats to global food security in Sub Sahara Africa include poverty, unsustainable cultivation practices and climate change. Increasing poverty and decreasing food security have been exacerbated by continued low food crop productivity by smallholder farmers, constrained by several factors. Taro (Colocasia esculenta L. (Schott.) is a amongst the category of plant species that farmers and researchers have neglected or underutilized crops considered as orphan crops yet they can have the potentials to ameliorate malnutrition and food paucity in developing nations. In Kenya, taro production has suffered low crop productivity leading to under-exploitation in terms of popularity of the crop, food security, nutritional aspects and economical contribution to the country earnings. In terms of food production, it does not translate into improved yields for sustained food security and as a result of this; its agricultural production is extremely low. The agronomic potential and importance of taro remains unknown because it has remained as underutilized crop in the country due to little attention attached to the crop. As a result, it has led to dangerous levels of reduced economic livelihoods and loss of its genetic diversity. This paper review interest in neglected taro food crop stems from a variety of factors that could lead to an increased understanding of the adaptation potential of taro to enhance development of efficient and sustainable taro cultivation practices. The review could be a major breakthrough in understanding various biotechnological approaches towards integrating the taro crop into mainstream research for crop improvement and intervention programs.

Key words: *Taro as a food crop; Under-exploitation; Commercial production; Agronomic potential; Low crop productivity; Undesirable impacts; Economic livelihoods; Genetic diversity; Smallholders farmers.*

Abbreviations

AFLP- Amplified Fragment Length Polymorphism; AP- PCR – Arbitrarily primed Polymerase Chain Reaction; DArTs- Diversity Arrays Technology; DNA- De oxy- ribonucleic acid; FAO- Food and Agriculture Organisation; MAS- Marker Assisted Selection; PCR- Polymerase Chain Reaction; RAPDs- Random Amplified Polymorphic DNA; RFLP- Random Fragment Length Polymorphism; SSRs- simple sequence repeats (SSRs); ICUC-International Center for Underutilized Crops.

Introduction

There is rampant food insecurity in the developing in Sub-Saharan African nations. Farmers and researchers have neglected many underutilized crops; taro (arrowroot) (Colocasia esculenta L. (Schott.). This has had undesirable impacts on food sustainability and food security of developing nations towards the demands of ever increasing world population. The world production of taro is estimated at 11.8 million tons per annum (Vishnu et al, 2012) produced from about 2 million hectares with average yield of 6t/ha (Singh et al, 2012). Most of the global production comes from developing countries characterized by small holder production systems relying on minimum external resource input (Singh et al, 2012). FAO (2008) published global data on the taro production indicating that West Africa (Nigeria, Cameroon, Ghana and Ivory Coast) is by far the largest taro producing region. Taro is one of the few fresh commodities for which Pacific Islands countries have been able to achieve significant levels of exports, with 10,000-12,000 tons exported annually yet African countries like Kenya have not given much attention to the underutilized crop. It is not clear why these countries have focused so much on a few crops like maize, beans and potatoes and neglected the orphans' crops like taro? This is despite the fact that, taro is an ancient important staple food crop grown throughout many Pacific Island countries, parts of Africa, Southeast Asia, Madagascar and the Caribbean for its fleshy corms and nutritious leaves crop (Lebot and Aradhya, 1991; Opara, 2001; Oke, 1990). Taro is vegetative propagated root crop species belonging to the monocotyledonous family Araceae. It is the fourteenth most consumed vegetable worldwide (Lebot and Aradhya, 1991). In addition to contributing to sustained food security in the domestic market, it also brings in export earnings (Revill et al., 2005 and Palapala et. al., 2009). As such taro has the potential to ameliorate household food hunger and malnutrition for people who live below the poverty line as rural farmers. The crop has variously been referred to as an "orphan crop or underexploited or underutilized" and the terms are ever used interchangeably to describe its economic viability to sustain food security and rural income for small scale farmers. In conjunction to the terms being referred to, this paper gives a deeper insight of this crop in terms of its popularity, food security, nutritional aspects and economical contribution to the country earnings.

Popularity and the origin of the crop

Pacific-Island countries have invested so much in research and development of taro crop that has led to commercial large scale production and domestic foreign exchange earner. This may be attributed to the huge economic returns they receive from foreign export earnings. Sub-Saharan African countries like Kenya who have given very little attention to this particular crop. Taro commonly known as arrowroots, and locally known as "Nduma" is a well- balanced food highly nutritious and compares favorably with other foods rich in carbohydrates, proteins vitamins and minerals (Jirarat et al., 2006; Vishnu et al, 2012). Its corms, cormels, leaves, stalks and inflorescence are utilized for human consumption. Most Kenyan communities have traditionally continued to rely on staple foods like, potatoes, sorghum, millet, beans, maize and cassava yet very little consideration has been given to this crop. Most local farmers have not realized the significance of growing taro, particularly in African which are food deficient. In contrast, taro is an important staple food crop grown throughout many Pacific Island countries, parts of Africa, Asia and the Caribbean for its fleshy corms and nutritious leaves (Dako, 1981; Dura and Uma, 2003). The exact centre of origin of taro is thought to be South Central Asia, probably in India or the Malay Peninsula (Purseglove, 1972). Others have also reported that, it originated from North Eastern India and Asia (Kuruvilla and Singh, 1981; Hanson and Imamuddin, 1983; Ivancic, 1992) and gradually spread worldwide by settlers. It later spread to China, Egypt and the rest of Africa. The greatest intensity of its cultivation, and its highest percentage contribution to the diet, occurs in the Pacific Islands. Using isozyme analysis, Lebot and Aradhya (1991), reported the existence of two gene pools for cultivated taro; one in Asia and the other in Pacific. This indicates that taro was domesticated in Asia as well as in the Pacific; therefore, it can be considered as a native plant of the Pacific. This may explain why the Pacific Island countries have better huge commercial production and marketing strategies that promote conservation of taro genetic resources through sustainable use compared to the Kenyan taro agricultural practices.

Why taro production is low in Kenya?

There are many pertinent questions regarding taro agronomical potential from Kenya perspective in comparison to the Pacific Asian countries. In Kenya, increasing poverty levels and decreasing food security are bottleneck problems that have been exacerbated by continued low food productivity amongst smallholder farmers. The Kenyan farmers have not diversified their agricultural systems in order to improve their livelihoods especially poor rural farmers. About eighty five per cent (85%) of the subsistence farmers rely on maize production adopting non formal seed system which is commercially non-viable. The farmers rely on indigenous landraces because they cannot afford to plant hybrid maize produced by seed companies. The agricultural diversification by growing a variety of crops including underutilized crops is the alternative way to address food security and alleviating poverty amongst rural folks.

Pacific Island taro exports have the potential to more than double if the product can be made more competitive in terms of price and quality (McGregor et al., 2011). Increased taro exports would result in significant benefits for large numbers of low-income rural people. The Fijian, Samoan, Tongan and Vanuatu taro industries offer the greatest potential, in terms of exports. FAO (1999) reported that the bulk of the taro production were in Africa, with Asia producing about half as much as Africa, and Oceania about one tenth as much. The major producers in Asia were China, Japan, Philippines and Thailand; while in Oceania, production was dominated by Papua New Guinea, Samoa, Solomon Islands, Tonga and Fiji. Table 1 shows taro production in Africa and the contribution of West Africa nations to the global taro production while table 3 shows the comparison in production amongst world countries.

In Kenya, the production of taro is extremely low compared to even the neighboring countries like Uganda, Rwanda and Burundi which are exporters of taro. Taro production suffers low productivity, probably due to low quality planting materials and low level of value-addition and processing (Wanyama and Mardell, 2006). Breeders face the difficult choice of selecting the right parents in the absence of an accurate assessment of their genetic constitution (Quero et al, 2004). In Kenya, increasing poverty levels and food insecurity are major concerns as a result of ever increasing population. In Pacific Island countries taro is under greater intense cultivation, and it has the highest percentage contribution to the diet. There are several factors that account for the African continent's food crisis because of their inability to adequately feed its growing population. One of these factors is the genetic erosion of resources of indigenous African crops including taro. Moreover, in Kenya, farmers also lack the ability to rapidly adapt taro varieties to ever changing climate and the increasing biotic and abiotic plant stresses that limit maximum crop production. There is an urgent need to preserve the remaining indigenous germplasm of native food crops for future crop development and posterity.

In Kenya, taro crop is used as a traditional food by many communities where as a delicacy. It is a highly nutritious plant that plays a crucial role in people's diets. Taro contains carbohydrates, proteins, very good essential mineral elements like potassium, calcium, phosphorous, vitamins and dietary fibres (Onwueme, 1978; Lambert, 1982; Hanson and Imamuddin, 1983; Bradbury and Holloway, 1988; Opara, 2001; Lee, 1999). There is need for increased research in local taro production, diseases and pests. Although taro crop is more expensive than other root crops in Kenya, its agronomical potential production is still low hence contributing to Kenya being considered a food insecure country in the world. No research work has been done on taro in Kenya and as such no modern varieties have been developed. Furthermore, there is limited information concerning the diversity of species or varieties, agronomy, production and contribution to food sustainability and security.

Distribution and production trends of taro

The world production of taro is estimated at 11.8 million tons per annum (Vishnu et al, 2012). Taro is produced globally from about 2 million hectares with average yield of 6t/ha (Singh et al, 2012). Most of the global production comes from developing countries characterized by small holder production systems relying on minimum external resource input (Singh et al, 2012). Taro crop could be well adapted to different agro-ecological zones of Sub-Saharan Africa nations but its productions system is skewed majorly to West Africa compared to East Africa. In Africa, high production of global taro production about seventy four per cent (74%) comes from west and central African countries (FAO report, 2012) as shown in Table 1. The Food and Agriculture Organization (FAO) database report on production of major crops uses the label taro to represent the total production of all Colocasia and Xanthosoma spp. But there is no report indicating even East Africa regions including Kenya by FAO reports. This attest to the fact there is no concerted efforts by all stakeholders to improve taro production system in east Africa per se. Twalana et.al 2009 also reported that the events of production and consumption of taro in East Africa is neither known nor the variety of taro being grown. This is partly because even research and development, their production system is regarded as an informal production activity, managed outside convectional market and economic channels. Yet, in the region, the taro crop could contribute substantially to food and income security of many households. Onyeka et.al 2014 also reported that the cocoyam production system is partly regarded as an informal activity by both researchers and policy makers. This could possibly attribute to its under-exploitation and understood crop despite its nutritional value and its potential as a food and cash crop. Although the crop is contributing substantially to the food and income security of many households in West and Central Africa, there is a lack of well documented and consolidated information on its cultivation, consumption and importance to livelihoods in this region.

In Kenya, taro production system is extremely low in comparison to other root and tuber crops like cassava, sweet potato and yams. This could be possibly of hindering factors such as lack of planting materials, improved taro varieties, pest and diseases, limited research activities and information research on taro germplasm varieties compared to Pacific-Islands communities. In some parts of Kenya provinces like Western, Rift valley and Nyanza, taro is grown by small scale farmers near the streams/ river banks since most of rural folks are lacking modern irrigation facilities for an upland taro cultivation. This is because of poor marketing strategies by major agricultural stakeholders and policy markers. This is over reliance on major cash crops such as maize, beans and sugarcane production. This is a major hindrance to diversification of food crops in the country to meet the demands of ever growing populations.

This explained the fact the taro farmers have very limited information concerning high yielding varieties from different parts of the country due to uncoordinated and limited taro research. This assertion is also true because of decreased taro production in Kenya as a result of poor selection of quality planting materials and taro variety /cultivating with low suckering and stolon ability for both upland and lowland taro production in Kenya. This emphasizes the need of embracing or introducing the concept of taro client oriented breeding approaches that encourages effective and efficient taro production system. This brings closer the research based knowledge information to the rural farmers on efficient and proper utilization of taro crop like any other dominated cash crops in the mainstream farming

Table 1. Cocoyam Production In Africa And The Contribution By West Africa Nations

Year	Area harvested (Ha) West Africa	Area harvested (Ha) Africa	Production (tonnes) Africa	Production (tonnes) West Africa
2003	87.46	64.55	77.39	59.31
2004	87.51	64.15	78.24	60.18
2005	87.72	64.28	79.29	60.28
2006	88.23	65.35	80.30	61.61
2007	88.03	65.06	78.60	58.94
Mean	87.79	64.68	78.76	60.06
2008	87.14	67.49	79.25	59.72
2009	85.68	60.44	73.09	48.94
2010	85.85	60.35	72.72	47.38
2011	85.72	58.56	74.52	48.97
2012	85.86	59.37	73.84	48.91
Mean	86.05	61.24	74.68	50.78

Source: Fao Reports (2012).

Table 1. Cocoyam Production In East Africa Region In (2005-2006)

Country		Quantity Harvested in Bags (%). (One bag is 150 Kilograms)					
	Bags	1-3	4-6	7-8	10-12	13-15	16+
Uganda		32.2	24.4	23.3	7.8	5.6	6.7
Tanzania		-	30.8	7.5	2.5	-	-
Kenya		38.9	25.5	16.5	6.8	4.9	5.5

Source: Talwana Et Al., 2009.

Table 2. Top 20 World Producers Of Taro, Ranked By Production (2008)

Rank	Country	Production Value (USD 1,000)	Production (tones)
1	Nigeria	554,968	5, 387,000
2	Ghana	173,931	1,688,000
3	China	160,558	1,638, 592
4	Cameroon	98,899	1,200, 000
5	Papua New Guinea	29,360	285, 000
6	Madagascar	17, 307	240, 000
7	Japan	15,513	179,700
8	Egypt	13,698	151, 971
9	Rwanda	11,394	110,607
10	Philippines	10,400	115,956
11	Central African Republic	10, 302	100,000
12	Thailand	8,087	78,500
13	Côte d'Ivoire	7,717	93,639
14	Fiji	7,624	74,009
15	Democratic Republic of the Congo	6,825	66,250
16	Burundi	5,988	58,125
17	Gabon	5,279	56,000
18	Solomon Islands	4,532	44,000
19	Liberia	3,090	30,000
20	Guinea	2,892	31,200

Source: Http://Faostat.Fao.Org/

Nutrition and economic aspect of taro

Why taro crop is of great value to the livelihoods of millions of poor rural farmers in Sub-Sahara Africa countries? Have researchers and farmers elucidated the contributions towards enhancing nutritional qualities, food sustainability, cultural and aesthetic values and income generation? Taro locally known as "Nduma" (Kiswahili) is an indigenous African crop that has been cultivated in Africa for centuries. It is a highly nutritious plant that plays a crucial role in people's diets. The crop is now cultivated in the continent from the Sahara to South Africa and Madagascar.

Taro corm is an excellent source of carbohydrate, the majority being starch of which 17-28% is amylase, and the remainder is amylopectin (Oke, 1990). Taro is especially useful to people allergic to cereals and can be consumed by children who are sensitive to milk, and as such taro flour is used in infant food formulae and canned baby foods (Lee, 1999). It contains greater amounts of vitamin B-complex than whole milk (Lee, 1999). Taro corm is low in fat and protein; however, the protein content of taro corm is slightly higher than that of yam, cassava or sweet potato. The protein is rich in some essential amino acids, but is low in isoleucine, tryptophan and methionine (Onwueme, 1978). Proximate composition of the taro corm on a fresh weight basis include; Moisture 63-85%, Carbohydrate (mostly starch) 13-29%, Protein 1.4-3.0%, Fat 0.16-0.36%, Crude Fibre 0.60-1.18%, Ash 0.60-1.3%, Vitamin C 7-9 mg/100 g, Thiamine 0.18 mg/100 g, Riboflavin 0.04 mg/100 g, Niacin 0.9

mg/100g (Onwueme, 1994). In Pacific Island countries such as Fiji and parts of Africa, taro is a staple food crop (Lebot and Aradhya, 1991; Opara, 2001).

Taro is one of the few major staple foods where both the leaf and underground parts are important in the human diet (Lee, 1999). Opara (2001) reported that taro leaf is an excellent source of carotene, potassium, calcium, phosphorous, iron, riboflavin, thiamine, niacin, vitamin A, vitamin C and dietary fibre.

Taro has a considerable economic importance as a fresh crop in many large islands in the Pacific region such as Samoa, Fiji as a cash crop and foreign exchange earner (Hanson and Imamuddin, 1983). Taro can be exported; its production not only provides cash to the farmers but is also a valuable foreign exchange to the country. These Pacific islands countries have been able to earn substantial revenue from the taro export trade, mainly to Australia and New Zealand. Many other countries would like to participate in taro exportation, but they are deterred by quarantine regulations against one or other of the taro diseases and pests.

Social cultural aspects of taro

Socio-cultural attachment to taro has meant that taro itself has become a totem of cultural identification. People of Pacific Island origin continue to consume taro wherever they may live in the world, not so much because there are no substitute food items, but mainly as a means of maintaining links with their culture. This cultural attachment to taro has spawned a lucrative taro export market to ethnic Pacific Islanders living in Australia, New Zealand and western North America (FAO, 1999). Various parts of the taro plant are used in traditional medical practice. Taro corms and leaves are used in traditional medicine, evidence of the long association of the people with the plant (Pancho, 1984).

Pests and diseases of taro

Taro productivity is largely affected due to pests and disease problems, which are becoming a limiting factor for taro production (Ivancic, 1992). Numerous viral diseases are known to attack taro species. They are most serious viral pathogens with some infections resulting in severe yield reductions and even plant death. The most common world-wide is the Dasheen mosaic virus (DsMV). Taro Dasheen mosaic virus is caused by a stylet-borne, flexuous, rod-shaped virus that is spread by aphids. It is characterized by chlorotic and feathery mosaic patterns on the leaf, distortion of leaves, and stunted plant growth. The disease is not lethal, but yield is depressed. Taro bacilliform virus (TaBV) is a virus transmitted by the plant hopper, Colocasia bobone disease virus (CBDV) is a cytorhabdovirus (Yang et al., 2003)**.** Other taro diseases include the taro soft rot, which is caused by several species of Pythium, which is soil borne and attacks the roots and corm. Sclerotium rot is caused by Sclerotium rolfsii, which causes stunting of the plant, rotting of the corm and formation of numerous spherical sclerotia in the corm. Cladosporium leafspot is caused by Cladosporium colocasiae where brown spots appear on the older leaves. Amongst the pests, taro beetle belonging to the genus Papuana is of great concern.

Molecular Techniques Application

There are bottleneck issues regarding the taro germplasm production in Kenya in comparison to Asian Pacific Island countries. In the Sub-Sahara African regions, taro germplasm production and germplasm delivery mechanisms are informal and have not been properly developed to address the needs of resource-poor farmers. There has been no intervention strategy to select the better high yielding cultivars used by smallholder farmers which are resistant to climate conditions in the region. Research on germplasm varieties is needed to ensure the appropriateness and sustainability contributing to food security, health care and good education.

Genotypes characterization of taro germplasm accessions under different ecological zones for comparative assessment of its genotype performances for crop improvement and the selection of desirable genotypes for breeding plays a vital role. The characterization of germplasm banks will play an important role in the sustainable conservation and increased use of crop genetic resources of Taro (Trujillo et al, 2002). The evaluation of genetic diversity could greatly assist in the selection decisions in taro breeding (Hu et al., 2008). Researchers have also showed that significant correlations exist between yield and several vegetative traits. This reinforces the suitability of agronomic characters in selecting genotypes (Garcia et al., 2006; Dwevedi and Sen 1999). The improved taro germplasm accessions can enhance food security and opportunities for income generation (Verma and Cho, 2004).

Moreover, taro cultivation in Kenya is mainly practiced by small scale farmers that grow a few popular varieties mainly propagated vegetatively leading to the fixation of a few plants of a particular genetic base and potentially, loss of some valuable genetic resources (Lebot and Aradhya, 1991). Genetic diversity assessment between individuals within a species or between different species or populations is very important in every crop improvement program for selection of genetically diverse parental lines to obtain superior recombinants (Kithinji, 2011). This information is highly vital in formulating breeding programs aimed at improving the quality of productions of taro in Kenya. Marker assisted selection (MAS) involves the use of specific molecular markers to select for a particular trait or genotype. Marker Assisted Selection has several advantages which makes it convenient for use in this research. The use of molecular markers can save a lot of time in the breeding process. They may aid in discovering more information about the function of the gene of interest and facilitate its' use in genetic diversity assessment and quality control (Kithinji, 2011).

The Global Plan Action of FAO (1996a) findings have advocated the importance of germplasm collections for underutilized species and several international organizations such as Biodiversity International and International Center for Underutilized Crops (ICUC) have already started the promotion process of conserving germplasm collection of underutilized crop species. The use of molecular genetics tools such as tissue culture and micro propagation; DNA genotyping and sequencing for genetic diversity assessment, genomics, proteomics and marker-assisted selection markers will play a crucial role in developing strategies of commercial exploitation of taro crop species in Sub-Saharan African countries.

Polymerase Chain Reaction (PCR) - Based Technique

PCR is a molecular biology technique where a sample of DNA (the "template") is mixed with DNA polymerase and short targeted priming sequences ("primers"), cycling through various temperatures leads to the production of a copy of the part of the template DNA sequence between the two primers. Reiterating the cycle many times allows the new copies to serve as templates in the next round, resulting in an exponential increase in copy number of the target sequence. This technique was invented by Kary Mullis in 1983 and it has resulted to the development of various types of PCR-based techniques.

There are major advantages of Polymerase Chain Reaction techniques compared to hybridization-based methods which include: A small quantity of DNA is required, there is the elimination of radioisotopes in most techniques, DNA sequences can be amplified from preserved tissues using PCR techniques, which allow accessibility of methodology for small laboratories in terms of equipment, facilities, and cost, there is no prior sequence knowledge required for many applications, such as AP-PCR, RAPD, DAF, and AFLP, PCR techniques can reveal high polymorphism levels that enable the generation of many genetic markers within a short time and PCR techniques have the ability to screen many genes simultaneously, either for direct collection of data or as a feasibility study, prior to nucleotide sequencing efforts (Wolfe and Liston, 1998). Depending on the primers used for amplification, the PCR – based techniques can be arbitrary or semi-arbitrary primed - PCR techniques, which are developed without prior sequence information (e.g. RAPDs, AFLP) or site-targeted PCR techniques, that are developed from known DNA sequences (e.g., EST, CAPS, SCAR, STS). They are vital technique that can show similarity patterns of genetic distances particularly for crops within inbred lines (Archak et al., 2003).

Simple Sequence Repeats (SSRs) Marker Technique

They are also called simple sequence repeats (SSRs), these are tandemly arranged blocks of short nucleotide sequences, usually 1-10 nucleotides. Studies with simple sequence repeats (SSR) and amplified fragment length polymorphism (AFLP) markers have confirmed the existence of these two distinct gene pools (Noyer et al., 2003; Kreike et al., 2004). The number of repeat units in the block can vary noticeably between individuals within a species. This variation can be targeted by PCR, by placing the primers either side of the block. This leads to highly reproducible, co-dominant, easily analyzed and polymorphic markers (Powell et al., 1996; Hedrick, 2001). Together these characteristics make the microsatellites loci one of the best genetic markers for mapping purposes (Oliveira, et al., 2010). The SSRs represent one of the most widely used markers in marker assisted breeding. Microsatellites or single sequence repeats are DNA regions with composed of small motifs of 1 to 6 nucleotides repeated in tandem, which are present and widespread in both eukaryotic and prokaryotic genomes (Toth et al., 2000). Microsatellites were developed from both coding and noncoding regions of the plant genome (Scotti et al., 2000). There are several resources that can be used to search for SSR; Public databases, expressed sequence tags (ESTs) databases (Scotti et al., 2000; Broughton et al., 2003), DNA libraries such as genomic, genomic- enriched for SSR.

Conclusion

From this paper review, there are many suggestions put forward to focus on taro crop research and improvement to meets the needs of ever increasing rapid human population in addressing global food security issues. First, there is need to develop databank information on number of accessions to be conserved locally to protect the genetic diversity of the species. There should be sufficient information on the ecological distribution of the taro and safeguarding its indigenous local knowledge. Secondly, there is need to develop taro crop innovation systems to be strengthened and made more participatory to improve adaptability, productivity, adoption rates and enhance food and nutrition security of small scale and low resources farmers especially client oriented breeding. This result will generate innovations to enhance crop adaptability to the consequences of climate change, crop diversification and productivity constraints. Thirdly, the government should develop the basic policy framework on agronomic agricultural practices for underutilized crops like taro to ensure commercial production of this particular crop for food sustainability to address poverty, malnutrition and income generation to rural farmers

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