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TRADITIONAL KNOWLEDGE IN CONSERVATION AND FARMING PRACTICES OF WATER YAM (*DIOSCOREA ALATA* L.): LESSONS LEARNED FROM EAST JAVANESE COMMUNITY

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Abstract

Water yam (Dioscorea alata L.) is an underutilized crop but plays a crucial role in food security of small and marginal rural families. For centuries, local farmers have planned agricultural production while conserving natural resources by adopting traditional knowledge (TK). This study aims to documents the importance of TK on water yam diversity, conservation and farming practices from the East Javanese community, a case study in Tuban Regency, Indonesia. The data collection was using a purposive sampling through interviews and direct participatory activities. Results showed that at least seven water yam local varieties were recognized with high tuber morphological variations, namely Uwi Bangkulit, Uwi Putih, Uwi Legi, Uwi Ungu, Uwi Sego, Uwi Klelet, and Uwi Randu. The variety naming mostly reflects distinct morphology and perceptual characteristics. The farmer's reasons to cultivate variety are related to the economic value and consumable preference. Three farming systems were identified including home garden, dry land agriculture and agroforestry. The cultivation patterns are adjusted to the climatic and seasonal changes for many years, with good management practices from seed and soil preparation, planting and crop maintenance, to tuber harvest, storage and marketing. Miscellaneous uses of water yam are also documented for their sustainable livelihoods. This study can serve as a framework for decision-making at local and national level for conservation efforts and further development in cultivation management and utilization of water yam.

Keywords*: Agrobiodiversity; Conservation; Dioscorea; Ethnobotany; Tuber crop; Water yam*

Introduction

Yam (*Dioscorea* spp., Dioscoreaceae) is a monocotyledonous plant that has starchy tuberous roots with excellent nutritional and medicinal properties. The genus comprises more than 600 species, but only a few of them are cultivated and utilized [1]. In particular, *Dioscorea alata* L. generally known as water yam is one of the important species. It was first cultivated in Southeast Asia and now has become the most widely spread species throughout the tropical and subtropical regions of the world (Asia, Africa, America, and Polynesia) [2]. It is a staple food and ranked fourth as important root crops after potato, cassava, and sweet potato [3]. The tubers are nutritionally rich in carbohydrates, protein, vitamin C, essential minerals, and dietary fibers but are low fat and less of anti-nutritions compared to other species [4]. In addition, it has some medicinal bioactivities such as anti-hipertension, estrogenic, immunomodulator, anti-inflammation, and antioxidant [5].

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In Africa, water yam is the agricultural product with the highest productivity rating, and accounts for 90% of world production. It is extensively produced in the African yam belt, a region including countries such as Nigeria, Ghana, Ivory Coast, Benin, Togo, and Cameroon. [6]. Meanwhile, water yam in Asia and the Pacific is considered a minor crop in terms of harvested area and total production, but they are highly esteemed and often sold at a high price as valuable medicinal plants [7]. Particularly in Indonesia, water yam is categorized as an underutilized crop but plays a crucial role in food security of small and marginal rural families as an alternative famine food during the dry season or food scarcity periods [8]. It was reported to be found in Sumatra [9], East Java [8, 10-13], Central Java [14, 15], South Kalimantan [16], Central Sulawesi [17], Bali and Lombok [18]. It is mostly cultivated in traditional and subsistent manners, as a secondary plant and rarely cultivated on a large scale. However, in some areas of East Java such as Tuban and Malang, water yam was reported as an agricultural crop of socio-economic and cultural importance, successfully cultivated by local farmers with several agricultural systems, which needs further study [13].

Traditional Knowledge (TK) or other synonymous terms such as indigenous knowledge and local knowledge generally refer to the long-standing information, wisdom, traditions and practices of certain indigenous people or local communities which are mainly of a practical nature [19]. In recent years, documenting the TK in agriculture has received significant interest worldwide, due to its importance in developing high environmental potential and sustainable management [20]. For centuries, farmers have planned agricultural production while conserving natural resources including agricultural biodiversity by adopting the TK. Furthermore, they have developed environmentally friendly biotechnology to address issues related to agroecosystem management including climate change [21]. The valuable TK are passed down and renewed by each successive generation, ensuring the welfare of the community by providing food security, environmental conservation, and early warning systems for disaster risk management [22].

Hence, this study aims to document the importance of TK on water yam diversity, conservation and farming practices from the East Javanese community, with a case study in Tuban Regency, Indonesia. This paper presents some empirical data which highlights the community's indigenous agricultural knowledge and the changes over time in water yam conservation, farming practices and sustainable utilization. The preservation of indigenous TK and world view practices in agriculture play a significant role in modern agricultural development [19]. The results of this study hopefully will contribute to the increasingly urgent global imperative to conserve biological diversity and valuable TK in agriculture. It also can serve as a framework for decision-making at local and national level for conservation efforts and further development in cultivation management practices and utilization of water yam.

Experimental part

Study site

The study area was located in Tuban Regency, East Java Province, Indonesia. The Tuban area is located on the Northern coast of Java Island, with regional borders by the Java Sea (North), Lamongan (East), Bojonegoro (South), and Rembang of Central Java (West). Geographically, the position is at the coordinates 6.40' - 7.14' South Latitude and 111.30' - 112.35' East Longitude, with a total area approximately of 1,904.70km² and the shoreline reaches 65km. Topographically, the land areas are categorized as lowland, it ranges from 5 to 182 meters above sea level with land slopes 0-15%. The climate is considered as a dry tropical climate with air temperature between 25º-27.5º C and rainfall average around 1483mm per year [23].

The total population of Tuban in 2018 was 1,285,147 people, with 50.12% were males. Most of the population is Muslim from the East Javanese ethnic group, whose livelihood is

from farming or working in the agriculture sector while the rest are fishermen, traders and civil servants. The leading sector is in agriculture, especially food crops with paddy/rice as the main commodity followed by corn, peanuts and cassava. Most of the Tuban area is considered dry land, however various irrigation infrastructures have been developed thus can be optimized for agricultural needs [23-25].

Specifically, the study area comprised four villages at Tuban Regency including: 1. Ngampelrejo, 2. Margosuko, 3. Jati Peteng and 4. Semanding (Fig. 1). Those villages were selected based on information from local informants, especially from the water yam sellers and consumers at the local agriculture markets, as the main centers of water yam producing areas in Tuban. We carried out the field surveys at the same study area for 3 years in September 2017 (dry season), March 2018 (rainy season) and June 2019 (late rainy season, early harvest time), to capture the complete seasons data of water yam farming.

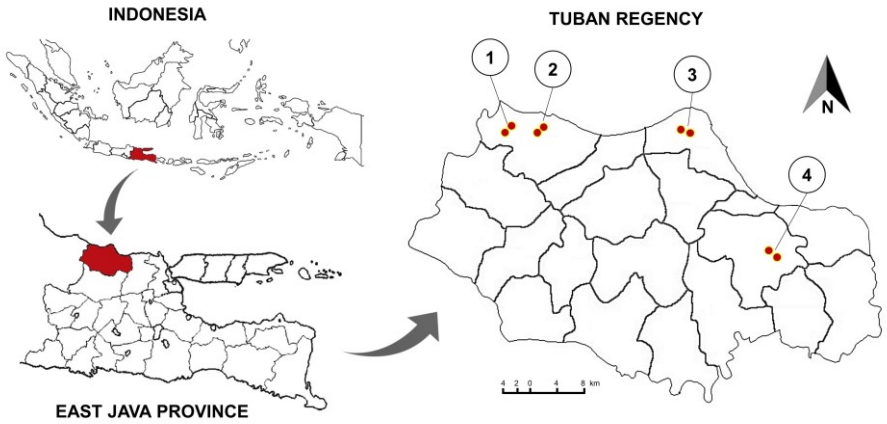

Fig. 1. Location of villages study area at Tuban Regency of East Java, Indonesia: 1. Ngampelrejo, 2. Margosuko, 3. Jati Peteng, and 4. Semanding

Methods

The data collection method was using a purposive sampling to gather valuable information from selected informants regarding their local knowledge of water yam. Snowball sampling was used to contact hard-to-find key informants such as wholesalers, resellers, landowners, and elderly farmers [26]. The interviews were performed using an open-ended, discovery-oriented and semi-structured questionnaire, as well as free-flowing talks, in order to better understand and document their TK [27]. Prior informed consent was obtained verbally before conducting each interview [28].

Information TK on water yam gathered including an inventory and their recognizable characteristics, conservation and reasons for choice to grow particular varieties, farming system practices, seasonal cultivation pattern, cultivation management from seed and soil preparation, planting and crop maintenance, to tuber harvest, storage and marketing, also miscellaneous utilization. The qualitative data gathered were then compiled and analyzed descriptively.

This study also includes direct participatory activities [27]. The selected informants assisted our surveys to water yam fields at home garden, agroforest landscapes and along the roadsides in the area. Any water yam varieties available were inventoried, briefly characterized and documented following the Descriptor of Yam (*Dioscorea* spp.) [29]. Agroecological attributes of the water yam fields were also recorded. In addition, secondary data of agro climatic conditions were obtained from Tuban official statistical reports [30] and Meteorology, Climatology and Geophysics Agency of Tuban Station [31]. Some previous study reports and

publications were also used to comprehend and enrich further data analysis and discussions. The quantitative data were analyzed in Microsoft Excel spreadsheet.

Results and discussion

Informants socio-economic profiles

In total, about 105 informants were interviewed in the four surveyed villages (mean value±SD: 26.25±2.99 per village). All of the informants were of local Javanese ethnicity. More male informants (70.48%) than females (29.52%) were represented, mainly because men were found working on farms during the day, whereas the women were at home. Most informants (66.22%) were middle-aged farmers between 36-50 y.o., followed by younger working-age farmers 20-35 y.o. (28.57%) and elderly farmers >50 y.o. (23.81%). The elder informants, both males and females, were considered as the key informants for traditional knowledge in agriculture [25, 26]. However, in this study the middle-aged farmers were more active on the farm and knowledgeable about water yam varieties, identification and cultivation in their home areas.

The TK on conservation and agriculture practices is mostly possessed by the elder farmers and passed down from generation to generation. Many modern practices of agriculture are based on traditional practices prevailing in farming communities [32]. Furthermore, the economic statuses of the informants are mostly dominated by low income farmers (income below minimum wages in Tuban <2.5 million IDR per month). It identified about 1-2 water yam wholesalers with higher income per village. Water yams are demanded by resource-poor farmers as famine foods to alleviate poverty, due to its low cultivation inputs [33].

The local name of "Uwi"

Water yam in Indonesia is recognized by several local names according to the locality. Particularly in Java, the local name "*Uwi*" is commonly used by Javanese. It is generally defined as an enlarged root or tuberous root or tubers. The term "*Uwi*" is more regionally restricted to Javanese both in Central Java and East Java, also Sumatera. Javanese ethnic group are native to Java Island, but they are predominantly located in the central to eastern part of Java. Some parts of Sumatra are also occupied by Javanese. Javanese people speak Javanese language as their mother tongue; it belongs to the Austronesian language family [34]. However, there is continuous changing in the dialect of modern Javanese from western, central to eastern Java. The term "*Uwi*" then shifted slightly into "*Huwi*" by the Sundanese people in West Java [35]. Eventually, it developed into "*Ubi*" and its derivatives in Bali and Lombok [18], Kalimantan [16] and Sulawesi [17].

Inventory and on-farm conservation of water yam varieties

At least seven recognizable water yam local varieties were cultivated in the study area, comprising Uwi Bangkulit, Uwi Putih, Uwi Legi, Uwi Ungu, Uwi Sego, Uwi Klelet, and Uwi Randu. It shows a high diversity of morphological characteristics. The most useful descriptor to differentiate among varieties is underground tuber characters especially in the shape, size, peel and flesh colour also texture [35, 36]. The variety names given by East Javanese communities mostly reflect distinct morphological characteristics such as peel colour and flesh colour, or other perceptual characteristics such as flesh taste, as well as utilization (Table 1 and Fig. 2).

The same pattern of local variety naming is applied mostly in domesticated crop plants such as in rice [37], beans [38], bananas [39] etc. Understanding the naming of varieties by farmers is important to better understand and differentiate the genetic diversity of plants cultivated in their land and its management [37]. There may be synonyms among varieties, and the same variety is often known by different names in different areas. Sometimes, the same name is used for very different varieties. The taxonomic classification of domestication plants often leads to confusion. They are mostly distinguished at infraspecific levels which are

inconsistent to Linnean names. Thus, International Code of Botanical Nomenclature (ICBN) categories of subspecies, variety and forma are often used to accommodate them [40].

Table 1. Inventory, morphology characteristics and farming scale of water yam varieties in Tuban, Indonesia

No.	Local name	English meaning	Perceptual meaning	Tuber shape	Outer peel colour	Inner peel colour	Flesh colour	Taste	Yield	Farming Scale
1	Uwi Bangkulit	Bangkulit = red peel	The tuber has red peel colour	Irregular	Brown	Red-purple	White-reddish	Less sweet	High	Self-consume
2	Uwi Putih	Putih = white	The tuber has white flesh colour	irregular	Light Brown	Light Brown	Off-white	Savory	High	Self-consume & for sale
3	Uwi Legi	Legi = sweet	The tuber has sweet taste	Oval-oblong	Brown	Light brown	White	Sweet	High	Self-consume & for sale
4	Uwi Ungu	Ungu = purple	The tuber has purple flesh colour	Irregular	Red-brown	Red-purple	Purple with white	Less sweet	Low	Self-consume
5	Uwi Sego	Sego = Rice	The tuber has become replacement of rice as staple food	Elongate-irregular	Light brown	Light brown	Off-white	Savory	High	Self-consume
6	Uwi Klelet	Klelet = abangan = reddish	The tuber has reddish peel and flesh colour	Irregular	Red-brown	Red-purple	White with purple	Savory	Low	Self-consume
7	Uwi Randu	Randu = white silk-cotton or kapok	The flesh in off-white colour like silk-cotton	Elongate	Light Brown	Light brown	Off-white to yellowish	Savory	Medium	Self-consume

Fig. 2. Morphological appearance of some tuber and flesh of water yam varieties in Tuban, East Java, Indonesia: 1. Uwi Bangkulit, 2. Uwi Putih, 3. Uwi Legi, 4. Uwi Ungu, 5. Uwi Sego, 6. Uwi Klelet, and 7. Uwi Randu

The survey results showed that five water yam varieties were named after their distinct morphological characteristics. Uwi Bangkulit was named after its red peel colour; "*bangkulit*" is an abbreviation for "*abang kulite*" (Javanese) which means red peel colour (Fig. 2-1). Uwi Putih has white flesh colour (Fig. 2-2), while Uwi Ungu has a flesh purple colour (Fig. 2-4). Uwi Klelet was named after its reddish flesh colour (Fig. 2-6). The word "*klelet*" is synonym to "*abangan*" in Javanese which means reddish. Likewise, Uwi Randu was possibly named after its off-white flesh colour similar to white silk-cotton/kapok ("*randu*" is the vernacular name of *Ceiba pentandra*). Furthermore, two water yam varieties were named after their perceptual

characteristics. Uwi Legi was named after its sweet taste ("*legi*" = sweet). It has oval to oblong tuber shape and is considered to have the sweetest taste among other varieties (Table 1, Fig. 2-3). Whilst Uwi Sego was named after its utilization as replacement of rice for staple food ("*sego*" = rice).

In terms of the number of varieties cultivated by farmers, seven water yam varieties were found in Tuban while a previous study reported only 5 varieties [12]. Meanwhile in other regencies of East Java, more varieties of water yam were found. Ten varieties were found in Malang [12], 13 varieties in Nganjuk [41] and 17 varieties in Pasuruan [11]. The cultivation of plant species, particularly crop plants by the local community is part of the conservation strategy. They build strategies for on-farm conservation of plant genetic resources at their land for sustainable living [42]. The more variety of water yam that is planted on farms and utilized for their livelihood, the more it is conserved.

However, the farmer's reasons for choosing a particular cultivar are related to the economic value and consumable preference. Farmers tend to cultivate the water yam varieties which have high value to be sold in the market and preferred to be consumed. Most of the farmers in Tuban cultivate Uwi Legi and Uwi Putih because they are tastier (sweet to savory), high yield, and salable in the markets (Table 1). Uwi Ungu is considered as the least desirable for cultivation because it tastes less sweet. Due to the threat posed by commercially valuable variety preferences which may cause the loss of less popular local water yam varieties, therefore increasing the urgency of conservation efforts both on-farm/in-situ and ex-situ, such as in genebanks [43] and botanical gardens [36].

Farming system practices

Water yam is a tuberous crop adaptable commodity in dry land and low fertility soil often cultivated in rural areas [2, 3]. Due to the different economic statuses of each farmer, there are three types of farming systems used to cultivate water yam in Tuban. The first water yam farming system is the home garden. Home gardens are important units to improve food security especially in developing countries. Water yam is considered a species component mostly found in home gardens [44]. In this study, water yam farmings at home garden scale are often found in Ngampelrejo and Semanding villages. At home garden, farmers may cultivate their water yam in their own-land front yards and backyards also at roadsides as hedge plants without any husbandry management (Fig. 3A and B). It is mostly cultivated for an alternative source of food for self-consumption during the dry season (famine food). Farmers have cultivated several water yam varieties in their home garden that support conservation efforts.

The second water yam farming system is in dry land field intercropped with annual crop. In Margosuko village, farmers mostly cultivated water yam in dry land fields at commercial scale both as the landowners or land leaseholders. The main annual crops are cultivated such as corn, chilies, ground nuts, green beans, cassava, taro, etc. (Fig. 3C, D and E). Water yam plants grown with vines creeping up thus need stakes to support the plants. Intercropping is a viable alternative to reduce the high cost of staking in water yam, also effective for integrated weed management [45, 46]. On a larger scale of water yam farming, the tubers yield mostly for commercial sale in the markets. The tubers are harvested at the last after all annual commodities are harvested, thus leaving an additional income for farmers. Farmers are mostly cultivated only a commercial variety i.e. Uwi Legi or Uwi Putih.

The third water yam farming system is agroforestry which combines trees and agricultural crops, including water yam. Farmers are sharing revenue with the village government or state forest enterprise. They cultivate water yam as an understory layer of perennial trees, mainly teak tree (Fig. 3.F). In this study, water yam cultivation in an agroforestry system was found in Jatipeteng village, where the area is forest. Water yam is tolerant to low light intensity under the tree shades. However, agroforestry practice by applying pruning and managing planting density are needed for optimum growth and yield [47]. Farmers

at agroforestry system scale may cultivate several water yams varieties, for both self-consumptions also to secure their income by selling part of the tuber yields in the market.

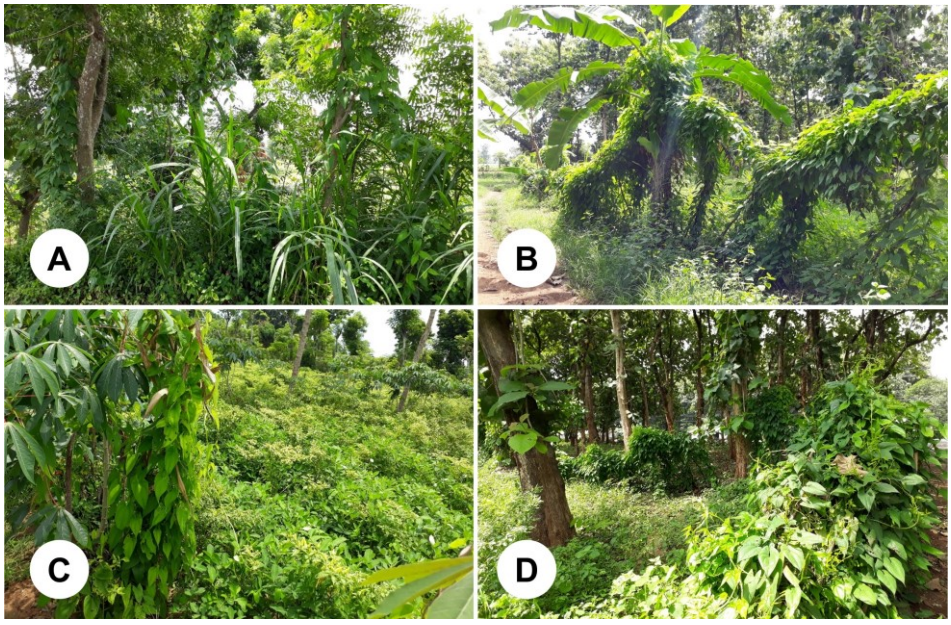

Fig. 3. Water yam farming systems in Tuban, Indonesia: A. Backyard homegarden; B. Hedge plants at roadsides; C. Dry land field intercropped with corn, cassava, chilies and ground nuts; D. Understory of teak agroforestry

Seasonal cultivation pattern

The growth cycle of water yam is generally divided into four phases [48]. The first phase is the dormant tuber. The second phase is the growth of the primary shoots and roots, followed by rapid development of vegetative and tubers as the third phase. The last phase is flowering (generative), tuber maturity, roots and shoots senescence, and the loss of tuber dry matter after the maximum is reached (Fig. 4A). The time required for development per phase is different for each variety. In addition, it is also influenced by environmental factors such as planting location, altitude, and local climate. The late-maturing varieties are characterized by long growth period and high yield, widely distributed in the lowland's areas. Meanwhile, early maturing varieties exhibit a relatively short growth period, mostly distributed in high-altitude areas [49]. Water yam growth depends on variability of soil conditions and climate factors for sprouting, vegetative development, tuberization and productivity [50].

The three years' study on the farmer's farm in Tuban showed that they already have a seasonal cropping pattern in cultivating water yam, as the result of empirical experience that has been passed down from generation to generation. The cultivation pattern was found to be in accordance with the climatic and seasonal changes in Tuban for years (Fig. 4B). Farmers are adjusting their cropping patterns to the arrival of the rainy season. Although water yams are relatively drought tolerant, they need adequate moisture during their growth period [51]. In addition, the farmers have been practicing good cultivation of water yam management from upstream to downstream.

Based on the rainfall data 2017-2019, it can be seen that the rainy season in Tuban starts from November to April (early rains in October), and the dry season starts from May to October (Fig. 4B). Farmers start to do soil preparation in September while the tuber is a dormant phase (Phase 1). Planting season is conducted in October (beginning of rainy season) as early as

possible before the heavy rains come, the best timing for planting is in November and the last planting is in December. Late planting may cause seed tubers to rot. During the planting season, the tuber seeds are already at shooting and rooting phase (Phase 2). Furthermore, vegetative growth and tuberization occurred until April (Phase 3), followed by the generative phase, tuber maturation, and senescence (Phase 4). The tuber yields are ready to be harvested early in June with the best time for harvesting in July, and at the latest in August because the tubers are starting to enter the dormant phase again (Fig. 4A and B).

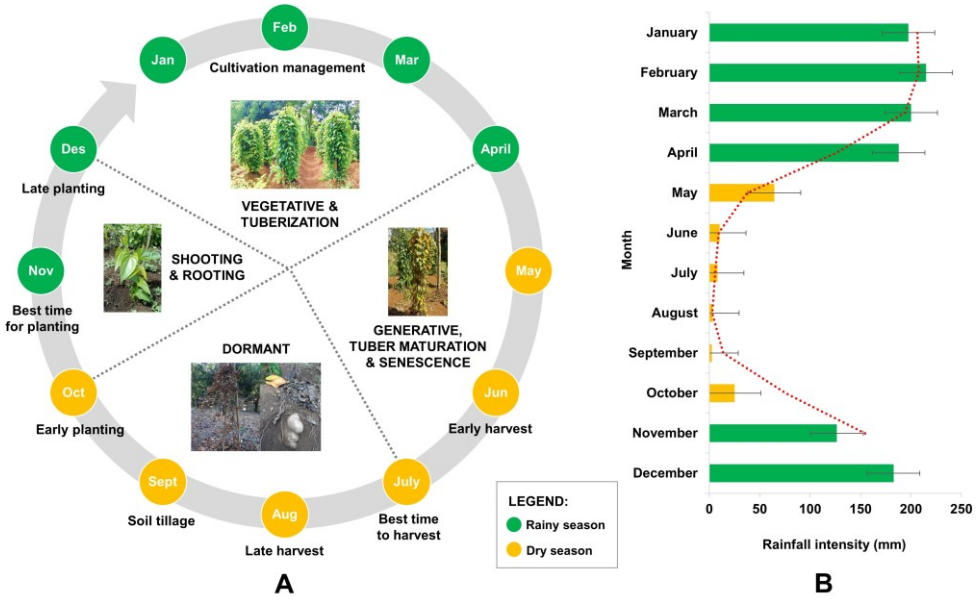

Fig. 4. Seasonal cultivation pattern of water yam in Tuban, East Java, Indonesia: A. Growth cycle, and B. Average monthly rainfall intensity in Tuban 2017-2019

Planting materials/seed system

Water yam can be propagated vegetatively using underground tubers and aerial tubers. Most farmers in the studied area depend on their own planting materials saved from the previous cropping season in the form of underground tubers. At home garden scale, some farmers leave some of the underground tubers in the soil to be regrown for the next cycle, mostly multiple years without replacement. However, some farmers also purchase planting materials from the local markets. The seeds of underground tubers are often planted whole (small size tubers) or cut into minisetts. In West Africa, planting small whole underground tubers is considered more profitable and produced higher yield than minisetts [52].

For the minisett technique, the water yam underground tubers are cut into minisetts of approximately 50-300g and left the cut surfaces to dry for a while and then planted (Fig. 5A). Some farmers applied the minisett cuts with wood ashes then left in shade for a day to prevent it from rotting. The water yam minisett technique facilitates rapid and high volume of seed production and it is economically viable [53]. More experienced farmers are using the tuber peels which have buds, which are cut into pieces of approximately 3-4cm, for a more economical reason (leftover peels). Meanwhile, the aerial tubers can be planted directly without being cut, due to their small size (Fig. 5B). However, the harvest yields from aerial tuber seeds

will be lower than those using underground tubers. An increase in seed size in some varieties of water yam would enhance their sprouting and growth potentials [54].

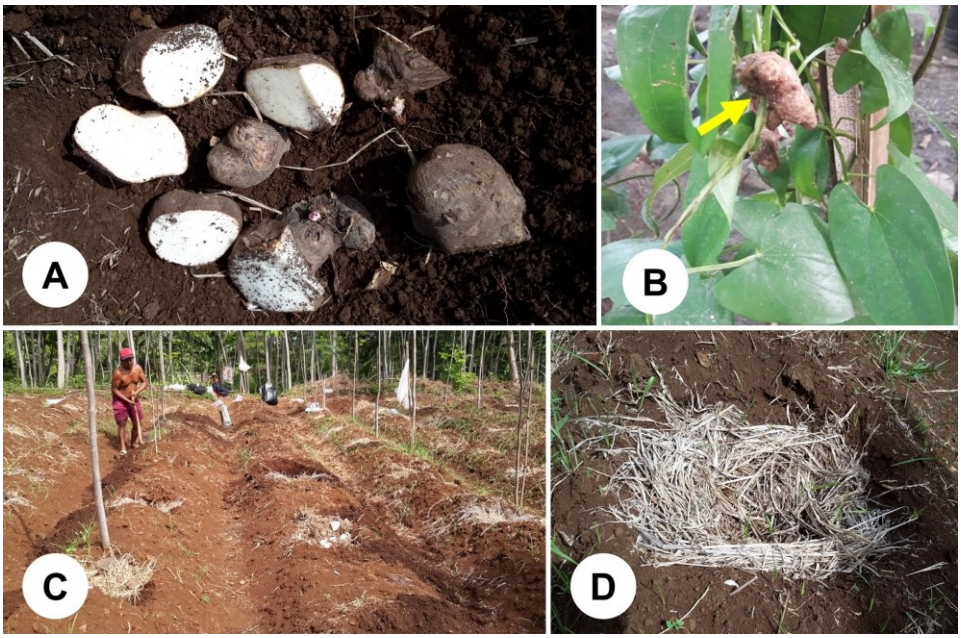

Fig. 5. Cultivation management practices: A. Minisett of underground tubers; B. Aerial tubers; C. Soil and planting preparation; D. Planting hole with manure and rice straw litter

Soil preparation and planting

Farmers in Tuban begin to prepare the soil for the next planting season in September to October (Fig. 5A). The soil needs to be prepared at least 1-2 weeks prior to planting. Soil preparation is mostly done manually at home garden or with a tractor machine on a dry land field scale. The land needs to be deep plough, harrow, and ridge or form mounds with hoes (Fig. 5C). The soil at planting time should be loose and well-worked. Water yam plants require deep, loose, textured loamy soil that is rich in organic matter [55]. The soil is then fertilized using manure (cow, goat, or chicken dung) from their own cattles. The water yam tuber seeds are then set shallow planting about 10cm deep in soil, 1 seed per hole with peel position at the bottom, and mulched with rice straws or whatever leaf litter available (Fig. 5D). The mulch around the planted sets protects them from excessive heat and desiccation, especially in areas with hot temperatures and dry weather [56].

The planting spacing of water yams follows the main commodities (annual crop) planned to be planted. Water yam is a perennial crop, so the seed is sown the first before the main annual commodity, but is the last to be harvested. As discussed before, the main annual crops cultivated by farmers in Tuban include corn, chilies, ground nuts, green beans, cassava, taro, etc. (Fig. 3C, D and E). The general planting spacing of water yam by farmers in Tuban is 2.0 x 1.0m between row and stands, and 1.0 x 1.0m for narrow spacing. However, the planting spacing of water yam also depends on the seed set size [56], the narrower spacing is used for smaller seed sets to adjust the expected yields.

Cultivation management

During the first 2-4 months after planting water yam needs sufficient water for vegetative development. Farmers in Tuban mostly depend on rains and use irrigation as needed

to water the crops. Along with the rainy season, the weeds also grow rapidly, so weed control is important. The control weeds can be conducted using manual hoeing, hand pulling, and herbicides. Furthermore, due to the impact of rain splashes and the weeding process, the mounds tend to diminish thus requiring remounds (add more soil) to avoid exposure of the growing tubers. Pests and diseases control are conducted, if necessary, along with the main commodity controls using manual eradication also chemicals (insecticides and fungicides).

The common diseases mostly found in water yam such as anthracnose and leaf virus-like symptoms. Anthracnose caused by the bacterium *Colletotrichum gloeosporioides*, shows symptoms of leaf necrosis and dead shoots, thereby reducing the photosynthetic efficiency of plants with significant yield losses [57]. Meanwhile, virus-like symptoms mostly observed are typical mosaic chlorotic pattern and leaf distortion, plant stunting and brown spots in the tubers; which are possibly caused by Potyvirus, Badnavirus and Cucumovirus [57]. Whilst the common pests identified include grasshoppers, white flies, leaf feeder larvae, stem and tuber feeder larvae, etc. Water yams can be attacked by several insects such as a leaf-feeding beetle *Crioceris livida* and Asian sawfly larvae *Ansioarthra coerulea*, also stem and root boring of *Leucopholis coneophora* larvae etc. [58].

Water yams are climbers hence their vines need stakes for better leaves and vegetative development. In the home garden scale, the water yam plants are using whatever available and nearest plants as stakes to grow (Fig. 3A and B). Several tree plant species used as stakes including local fruit trees such as citrus, mangoes, guavas, bananas, etc.; nut trees such as *Parkia speciosa* (petai/stink bean), *Leucaena leucocephala* (lamtoro), *Cynometra cauliflora* (nam-nam), *Anacardium occidentale* (cashew), etc.; and shade trees such as *Lannea coromandelica* (jaranan), *Gliricidia sepium* (gamal), *Paraserianthes falcataria* (sengon), *Ceiba pentandra* (randu/kapok) etc.

In the dry land field, water yam plants are allowed to creep on the ground and to the body plant of the main commodity, but the direction of the vines will be guided and trained if necessary, so that not too much interfere with the growth of the main commodity (Fig. 4C, D and E). However, some farmers also provide stakes with bamboo sticks or tree branches of 1-3m high. They stake the plant individually or in groups of two or three, depending on the requirements and resources. Meanwhile, in the agroforestry system, farmers are using the main perennial trees, mainly teak trees as stake (Fig. 4F and G). Plants that are not provided with stakes will produce less tuber yield than those with stakes, leaf spot disease incidence and severity, also weed biomass have strong and positive association with non-staking plants [45, 59].

Tuber harvest and post-harvest

In general, the water yam tubers can be harvested 7 to 8 months after planting. It can be harvested any time after large-scale leaf yellowing (senescence of the shoot) occurs in the field. In Tuban, the tubers are ready to be harvested early in June with the best time for harvesting in July, and at the latest in August (Fig. 3A). The tubers are harvested by digging around the tuber to loosen it from the soil and lift it up carefully to prevent bruising. The tubers are left on field for 2-5 days to let the peel dry and to cure the injured tubers for further storage. By exposing the tubers at a warm temperature range of 29-35ºC and 90-95% relative humidity; the peel will thicken and new tissue forms under the surface of injured areas in the tuber [56]. After harvesting, the dry land is left fallow for several weeks, then it is prepared again for the next planting season (Fig. 6A).

Furthermore, the farmers are sorting out the tubers and grading them according to size and health status. Only healthy tubers which are free from rot, cuts, insects, scrapes, larvae, and bruises can be stored. Most post-harvest damage to the tubers occurs during storage. Tubers with cut surfaces are more susceptible to insect pests which may cause serious yield losses in

stored tubers [58]. The freshly harvested tubers are then transported to the storage place. Farmers are temporarily storing the water yam tubers on a raised platform under the tree shades on field (Fig. 6B) then transferred to the barn with good ventilation (Fig. 6C). The water yam tubers are then stacked and covered with a canvas tarpaulin for further use or for trade (Fig. 6D).

The water yam tubers in the storage can be eaten and marketed during the 5 months or longer following harvest. Some of the harvested tubers will be set aside to be used as planting seeds for the next season [60]. The tuber's damage reaches 10 to 50% after 5 months of storage. Whilst the tuber weight loss in 4.5 months was 29.5 to 39.2% in 6 months of storage [58]. Some tubers may produce sprouts during storage, but it can be detached to avoid loss of tuber quality for trading [56].

Fig. 6. Water yam tuber harvest and storage: A. Dry land field after harvest; B. Temporary storage on field; C. Traditional barn for storing tubers; D. Stacks of tubers covered with tarpaulin in the barn

Markets of water yam tuber

Home garden scale farmers in Tuban mostly consume a great part of their water yam tuber production for themselves, and a small part is sold as additional income. Meanwhile, larger-scale farmers at dry land fields mostly sell the tuber yields commercially to the local markets via wholesalers or retailers. In Semanding area there are many local stalls on both right and left side of the road (main road of Tuban to Gresik and Surabaya) which sell typical and popular Tuban agricultural products such as water yams, pumpkins, palmyra palms, wine palms etc. (Fig. 7). The potential target buyers are domestic tourists. The water yam price at farmer's level is quite good around Rp 2,500-3,000 per kilo, and the selling price to consumers can reach Rp 4,000-10,000 per kilo. In Nigeria, the profitability and efficiency of the water yam marketing system can be improved by lowering the production and marketing cost [61]. Further studies on profitability analysis and marketing efficiency of water yam in Tuban Regency is suggested.

Furthermore, the wholesalers and retailers are able to play the price with the payment system that can be directly paid or debt-bondage. In debt-bondage system, the wholesalers can

make payment to farmers at any time when they have cash or after the tubers are sold out in the market. Indeed, the practice of the debt bondage system is very detrimental to farmers [62]. However, some of them don't have any option since they have to continue to secure the land for the next planting season, rather than the yields being unsold. Due to the longer storage time of water yam tubers (up to 6 months after harvest), some farmers dare to wait longer to sell their yields waiting for better prices but bear the risk of the tubers' damage.

Fig. 7. A local stall of agriculture products in Tuban, East Java, Indonesia: including water yam (Photo credit: IDN Times/ Imron)

Miscellaneous uses of water yam

Like in many other areas of the world, people in Tuban mostly consume the water yam tuber to be served as a substitute to staple food (rice), as famine food due to the limitations of food resources during the dry season. The cooking process is very simple by boiling, steaming, roasting and frying the fresh tubers then serving it with grated coconut and sugar or salt for taste. Due to the high carbohydrates and fiber content [4], it remains people's stomach full for a long time and may overcome flatulence [8, 14]. The tuber also can be fried, to substitute potato as french-fries, however it has a browning problem which can be overcome by pre-treatments using calcium chloride ($CaCl_2$) immersion and blanching [63].

Some inputs related to post-harvest processing of water yam tubers into various processed products that provide additional economic value are suggested to be given to the people of Tuban. Water yam tubers are very potential as functional foods due to their high essential nutrient contents. Some health benefits of water yam tubers, including as a substitute for rice for diabetes patients, to reduce the risk of breast cancer and cardiovascular disease, and used as a therapeutic drug in patients with osteoporosis and maintain intestinal health [5, 14, 18]. More advanced processing techniques are now available by making it into flour to substitute or complement wheat flour [64]. It has low gluten content so it is considered healthier for gluten-sensitive patients such as children with special needs (autism) [14]. Furthermore, it can be developed into confectionery products such as cookies and cakes [65], noodles, chips [65], crackers and biscuits [66, 67] etc.

Some varieties of water yam with purple flesh such as Uwi Ungu (Fig. 2-4) are used by people in Tuban for anemia remedies to produce hemoglobin due to its high anthocyanins [68]. Water yam tuber is also recommended to be eaten by pregnant women to strengthen the womb in early pregnancy. The phytoestrogens and progesterone-like properties in water yams can help

regulate the hormone balance [69]. In addition, people also utilized the water yam leaves and tuber peels for cattle feeders. Water yam leaves contain phenolic compounds promising as antioxidants [70]. No part of the water yam plant is wasted, everything is used for sustainable livelihoods.

Conclusions

There were seven water yam local varieties recognized and cultivated by farmers in Tuban of East Java, namely Uwi Bangkulit, Uwi Putih, Uwi Legi, Uwi Ungu, Uwi Sego, Uwi Klelet, and Uwi Randu. Their morphological characteristics are greatly varying with variety naming mostly reflecting the distinct morphology and perceptual characteristics. The farmer's reasons to cultivate particular varieties are related to the economic value and consumable preference. Therefore, increasing the urgency of conservation efforts both on-farm/in-situ and ex-situ of water yam local varieties.

Three farming systems of water yam were identified including home garden, dry land field and agroforest. The cultivation patterns are adjusted to the climatic and seasonal changes for many years, with good management from seed and soil preparation, planting and crop maintenance, to tuber harvest, storage and marketing. Miscellaneous uses of water yam are also documented for their sustainable livelihoods. Some inputs related to post-harvest processing of water yam tubers into various processed products that provide additional economic value are suggested to be given to the farmers of Tuban.

In conclusion, this study can serve as a framework for decision-making at local and national level for conservation efforts and further development in cultivation management and utilization of water yam.

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