14. Present status and future research in sweetpotato in Indonesia

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Abstract

In Indonesia, sweetpotato is considered an important food crop. However, its total harvested area and productivity indicate that development of the crop is relatively stagnant or declining. Research priority given to sweetpotato is lower than rice and other food crops. In Indonesia, government research institutions and universities carry out research on sweetpotato, but the Research Institute for Legume and Tuber crops (RILET) in Malang, East Java, is the only research institute that formally holds the mandate for sweetpotato research. In this paper, researches on crop improvement, crop management, pest and disease management, post harvest and socio-economic aspects, are reviewed and used as the basic knowledge to formulate future directions for sweetpotato research in Indonesia.

The future researches identified in this study include breeding for specific uses or specific traits, development of effective and efficient production technology, development of postharvest technology, and marketing studies.

Introduction

Among the tuber crops grown in Indonesia, sweetpotato is the second most important after cassava. Sweetpotato roots are mostly used as food while the surplus is used as feed and raw materials for industries. Despite its importance as a food crop however, the harvested areas of sweetpotato declined in the last decade, i.e., from about 208,700 hectares in 1990 to 184,200 hectares in 2000. During the same period, the yield stagnated at 9.4 t/ha to 9.5 t/ha., very much lower compared to its yield potential of up to 30-40 t/ha.

Sweetpotato has high carbohydrate content and could be a staple food substitute. To generate a better and more efficient production technology for sweetpotato, research priority should thus be given to sweetpotato. This will help boost sweetpotato development in Indonesia. However, the Indonesian government still puts higher priority on rice research. Even among the secondary food crops, research priority given to sweetpotato is lower compared to the legumes such as soybean and peanut.

This paper reviews the status of research on sweetpotato and possible future research directions that may be taken to optimize the contribution that sweetpotato can make as a food crop.

Sweetpotato Research Programs and Activities

Research programs and institutions involved

Government institutions and universities carry out research on sweetpotato in Indonesia. The Central Research Institute for Food Crops (CRIFC), Bogor, as one of the coordinating research institutes under the Agency of Agricultural Research and Development (AARD) holds the formal mandate for doing research and development for food crops including sweetpotato. Prior to a reorganization of AARD in 1995, all six research institutes of the CRIFC, namely Bogor Research Institute for Food crops (BORIF), Sukamandi Research Institute for Food crops (SURIF), Malang Research Institute for Food crops (MARIF), Sukarami Research Institute for Food crops (SARIF), Banjarbaru Research Institute for Food crops (SARIF), and Maros Research Institute for Food crops (MORIF) incorporated sweetpotato in their research programs. However, in the reorganization of the AARD in 1995, the research institutes under the CRIFC were organized according to a commodities-based approach. Research on sweetpotato was mandated to the Research Institute for Legumes and Tuber Crops (RILET), a new name for what was previously MARIF. Therefore, RILET is the only government research institute with a specific mandate to perform research and development on sweetpotato and other tuber crops. Research on applications of (RIFCB) biotechnology to sweetpotato are performed by the Research Institute for Food Crops Biotechnology (also under CRIFC). Basic biological research involving sweetpotato may be carried out by the Biological Institute of the Indonesia National Institute for Science (LIPI). Universities that have research programs on sweetpotato include Bogor Agricultural University (IPB), University of Gajah Mada in Yogyakarta; University of Brawijaya in Malang, and University of Cendrawasih in Manokwari.

Since the establishment of a regional office of the International Potato Center for East, Southeast Asia and the Pacific (CIP-ESEAP) in Bogor in 1990, a number of research activities on sweetpotato have been developed and carried out by CIP-ESEAP in collaboration with the national agricultural research system.

National coordinated research program on sweetpotato

In 1992, CRIFC established the national coordinated programs on cassava and sweetpotato, which aimed to support the national development program by making effective and efficient use of human, physical, and financial resources. Researches were directed to the most critical constraints in sweetpotato production (Table 1), which served as an operational guidance for planning, organizing, and coordination of research activities on sweetpotato (Dimyati and Manwan, 1992).

Research Accomplishments

Development of high yielding varities adapted to specific conditions and uses

Germplasm collection

Over 1155 sweetpotato accessions have been collected and conserved ex-situ at RILET and Research Institute for Agricultural Biotechnology and Genetic Resources (RIABGR)[1]. Most of these were provided by CIP-ESEAP. These accessions include eight improved varieties, 916 native cultivars, 32 introduction and 199 breeding lines (Yusuf et al., 1999). Recently, in collaboration with National Institute of Agricultural Science (NIAS), Japan, another 141, 22, 51, and 82 sweetpotato land races were also collected from Bali, Sumbawa,

[1] Formerly, the Research Institute for Food Crops Biotechnology (RIFCB).

Lombok and Sumba, respectively. In-situ conservation of sweetpotato land races by farmers was also carried out and studied in Irian Jaya (Prain, Schneider and Widyastuti, 2000).

CIP-ESEAP began working on sweetpotato conservation in 1990. A total of 1554 accession were collected from all over the Indonesian archipelago (Java, Sumatera, Sulawesi, Nusa Tenggara, and Irian Jaya). However, some were duplicates while the others died, bringing the number of accessions currently maintained by CIP-ESEAP to 1051 (Mok and Schmidiche, 1999; Tjintokohadi and Setiawan, 2001). This germplasm was duplicated at RILET and RIABGR. (Research Institute for Agricultural Biotechnology and Genetic Resources), a new name for RIFCB[1].

Efforts to conserve the sweetpotato germplasm in the form of *in-vitro* culture have already been started. Sunarlim et al. (1999) reported that by using base MS medium and mannitol, sweetpotato culture could be conserved for 6 to 10 months without any subculture.

Germplasm characterization and evaluation

At RILET, most of the germplasm collection have been characterized, recorded and catalogued. Characterizations following the procedure of Huaman (1992) involve morphological characters, yield potential and quality. Some of the germplasm have been evaluated for their tolerance to biotic and abiotic stress (Rahayuningsih et al., 1999). Sweetpotato germplasm conserved by CIP-ESEAP has been characterized and some evaluated for dry matter content, resistance to scab disease, and flowering ability (Tjintokohadi et al., 1999). The information regarding the germplasm collection including collection, characterization, and evaluation has been made available in CD format (Prain and Hermann, 2000).

Research on resistance screening for weevil or scab disease have been carried out in line with the breeding program (Supriyatin and Rahayuningsih, 1994; Rahayuningsih et al., 1995; Rahayuningsih and Supriyatin, 1997; Martanto et al., 1997). Length of rootstalk did not correlate with weevil resistance. Yusuf (2000) reported that dry matter; total sugar and protein content were positively correlated with the degree of root damage. Carotene content negatively correlated with the degree of root damage.

Hardaningsih and Rahayuningsih (1995) identified 42 of 78 clones to be high yielding, having sweet taste and high dry matter content, and resistant to scab disease. Yusuf (1999) indicated that Binoras Op-2, AS 94001-8 clones and Cangkuang have the following characteristics: high yield, high dry matter and high flour content.

Population and crop improvement

At RILET, the sweetpotato breeding program has focused on the development of sweetpotato varieties that have high productivity, high dry matter content, tolerance to abiotic stress (drought and shading), and resistance to pests and diseases (weevil pest and scab disease) (BALITKABI, 2000). Done in collaboration with other research institutes, the breeding program of CIP-ESEAP has been mainly directed towards increasing dry matter yield and to a certain extent, for specific purposes such as early maturation and high vitamin A content (Mok et al., 1997; Tjintokohadi and Setiawan, 2001). Research on low temperature as well as low radiation have not been initiated.

Since sweetpotato roots are mostly used for human consumption, criteria used for breeding and selection are also based on parameters related to food preferences such as taste, texture, water and fiber content. For industrial uses, selection is based on canopy structure, root size and morphology, and dry matter (for flour and starch content). Since 1992, eight improved varieties (Cangkuang, Muaratakus, Sewu, Sari, Boko, Sukuh, Jago and Kidal) have been released by MARIF/RILET. Varieties SUKUH (clone AB94001-8) and JAGO (clone B0053-9) were bred in a collaborative effort between RILET and CIP-ESEAP.

Improvement of crop production system

Improvement of crop management

In Indonesia, sweetpotato is grown in very diverse environments and agroecological zones. It can be grown from altitudes of 10 m until up to 2500 m asl such as in Irian Jaya. For high productivity, the crop requires soil of light texture, good drainage and sufficient moisture during the vegetative growth period. Research on different methods of land preparation indicated that in sandy soil, land preparation did not affect growth as well as root yield (Widodo, 1986).

Plant spacing may vary in planting sweetpotato but the common practice is a distance of 100 cm x 25 cm or 40,000 plants/ha. Widodo (1992) reported that on young volcanic soil, sweetpotato population could be increased to 66,666 plants/ha (plant spacing 100 cm x 15 cm) with resulting

yield 15% higher than normal population. Further increasing the plant population to 100,000 plants/ha did not increase the root yield but significantly increased the vine fresh weight.

In growing sweetpotato, most farmers usually do not apply any fertilizer or just put a small amount of urea or organic manure. This may be the reason why yield obtained by farmers is still lower than the potential yield. Basuki and Guritno (1990) reported that Phosphorus (P) fertilizer is not needed for sweetpotato planted on wetland after rice which has been fertilized with P. Nitrogen (N) and Potassium (K) fertilizer at the rate of 45 kg/ha N + 60 kg/ha KCL was found adequate for increasing sweetpotato tuber yield. In young volcanic soil, P is not required and fertilizer rate of 100 kg/ha Urea + 100 kg/ha KCL is recommended in order to obtain a yield of around 25 t (Widodo, 1990). In the central production area of sweetpotato in East Java, application of this fertilizer rate increased the sweetpotato yield significantly (Guritno et al., 1996). Application of ZA fertilizer at the rate of 10 kg S/ha`increased tuber yield up to 2 t/ha (Tangkuman et al., 1997).

Isgiyanto and Widodo (1999) reported that on Regosol and young volcanic soil, fertilization with 200 kg/ha Urea + 100 kg/ha SP36, or 100 kg/ha Urea + 10 t/ha of organic manure is needed to increase sweetpotato yield. Raharjo et al. (1989) showed that application of 2 t/ha rice straw as mulching increased sweetpotato root yield up to 50%, and improved NPK absorption. Application of 60 kgha P_2O_5 combined with 2 t/ha of mulch yielded about 32 t/ha of roots.

Farmers often lift and turn over the vines once every two weeks during the bulking period. Widodo (1986) reported that without turning over the vines, plant development was better and yield was higher than when the vines are turned over and when frames are used for vine growth. However, this result contradicts the findings of Artha and Suastika (1992) which showed that canopy modification increased root yield up to 45%.

The time of harvest proved to be an important factor that determines root quality. Harvesting time varies according to the sweetpotato variety planted and environmental conditions. Marzempi (1991) reported that based on its yield, starch and fiber content, the optimum harvesting time was around 120-130 days for cultivar Prambanan and 123-133 days for TIS 5125-4. The period between planting and harvesting time for sweetpotato grown at higher altitude (lower temperature) is longer than those grown in the lowlands.

Innovative training approaches are used in teaching farmers new crop production techniques. In 1997 CIP-ESEAP and the Indonesian National IPM Program, initiated farmer field schools (FFS) on Integrated Crop Management (ICM) in sweetpotato in West, Central and East Java (Van de Fliert and Braun, 1999). Farmer field schools were shown to be instrumental in increasing sweetpotato profitability for farmers (Van de Fliert et al., 2001).

Improvement of water management

Sweetpotato requires adequate water. During the wet season, irrigation is infrequently applied since rainfall usually provides adequate moisture. More attention is instead directed towards adequate ridge drainage. On the other hand, during the dry season, the unavailability of irrigation water is a limiting factor to yield. Responses of sweetpotato varieties to limited water supply vary. Clone MLG 12659-op93-2, MIS 110-94-1 and MIS 146-94-1 are considered tolerant to drought conditions (Rahayuningsih, 1999). Sutrisno et al. (1999) also reported that clone 12588-1, 12650-2, 12650-3, 12614-1 and 12659-4 are adapted for the uplands of Malang. The yield of these clones is 185% to 289% higher than the local cultivar. Wiryawan et al. (1983) showed that under excessive soil water content, canopy production is very high resulting in overlapping of the leaves and inefficient photosynthetic process.

Rain distribution in each region determines the proper planting time of sweetpotato. Wargiono (1989) showed that in Lampung, sweetpotato planted in February-April produce higher root yield compared to a crop planted in May-September.

Improvement of cropping system

In upland conditions, sweetpotato is grown as monoculture or intercropped with other crops. Response of sweetpotato to cropping system varies. Genjahrante and CN123-2 are tolerant for intercropped condition (Djatiwaluyo, 2000).

Research on intercropping showed that mungbean intercropped with sweetpotato did not significantly affect the sweetpotato yield. But when sweetpotato was intercropped with peanut, cowpea or maize, sweetpotato root yield was brought down by 11-17% (Widodo, 1991; Widodo and Hartojo, 1993; Widodo et al., 1997). However, loss from yield reduction was offset by the yield of peanut planted as a companion crop. Economic analysis indicated that sweetpotato intercropped with peanut is the most profitable due to the highest marginal rate of return of 919% (Widodo, 1991).

Improvement in pest and disease management

At least 16 species of insects are known to cause varying degrees of damage to sweetpotato in Java. However, except for the sweetpotato weevil (*Cylas formicarius*) and the convolvulus hawk moth (*Herse convolvuli* L.), most of the pests caused only minor damage (Franssen, 1986).

Research has therefore focused on sweetpotato weevil. Bionomics of sweetpotato weevil has also been studied. Waluyo and Mok (1994) reported that heaviest damage from sweetpotato weevil (up to 70%) was observed during extremely dry periods, while in the rainy season, damage was only up to 20%. Rahayuningsih and Supriyatin (1997) also noted that incidence of weevil in the uplands was higher compared to the lowlands. Moreover Trustinah et al. (1993) reported that drought stress during the tuber formation stage is associated with weevil infestation. Intensity of weevil damage increased from 26% during normal conditions to 49% in drought condition. Delay in harvest also causes heavier damage.

Researches on control measures of sweetpotato weevil have been conducted. Nonci et al. (1994) showed that application of insecticide Furadan 3G at planting time and 60 days after planting (DAP) reduced weevil infestation and root damage. Supriyatin (2000) reported that extract from neem leaves (*Azadirahta indica*) effectively reduced weevil damage. Entomophagus fungi *Metarhizium* and *Beauviria bassiana* are also reported to be effective in controlling sweetpotato weevil. Supriyatin (1999) and Braun and Van de Fliert (1999) reported that the use of sex pheromones of virgin female could attract and trap the adult male insect and eventually reduce insect population. However, when the insect population in the field is high, the use of sex pheromone trap is no longer effective. Combination of sex pheromone and dipping of planting materials into insecticides were effective in reducing root damage.

Integrated pest management of sweetpotato weevil involves field sanitation of damaged crops (including wild *Ipomoea)*, cultural practices (use of healthy planting materials, hilling up, watering, mulching, crop rotation and mix cropping), resistant varieties, use of sex pheromone and spraying with insecticide (Waluyo and Prasaja, 1996; Supriyatin, 2001).

At least seven fungal diseases are known to infect sweetpotato (Sumartini et al., 1994; Hardaningsih and Sumartini, 1999). Among them, scab disease (*Sphaceloma batatas*) is considered as the most important disease and often causes serious yield losses of sweetpotato in Irian Jaya as well as other central production areas in Java (Amir, 1988; Paiki, 1998). Methodologies for fungal isolation, sporulation, and laboratory and field screening have been developed (Amir, 1988; Anggiani and Amir, 1988.). Studies on fungal strains were also carried out. Amir et al. (1994) reported the presence of three fungal strains in sweetpotato central production areas of Central and West Java. Using a different differential host, Syamsidi et al. (1999) found at least nine strains of *S. batatas* from sweetpotato central production areas in Central Java, East Java and Bali. Clones Muara Takus, Cangkuang, MIS 104-1 and MIS 146-1 are considered having horizontal resistance to most of the fungal strains (Syamsidi et al., 2000).

Research on chemical control for scab disease has been carried out, and some fungicides were reported to be effective in reducing the disease intensity. Farmers could not however apply fungicides due to lack of money for the purpose and their belief that spending for fungicides is not worth the value of sweetpotato.

Research on diseases caused by viruses infecting sweetpotato is very limited. Saleh et al. (1977) reported the presence of little leaf witches' broom associated with mycoplasm-like organism. Little-leaf is considered the second important disease of sweetpotato at Manokwari, Irian Jaya after scab (Paiki, 1998). Field screening using natural infection showed that among 226 sweetpotato clones evaluated at Manokwari, 60 are resistant to sweetpotato little-leaf (Rusmadi et al., 1998). Recently, Machmud and Rusmadi (1998) used NCM-ELISA to detect the presence of two viruses - sweetpotato feathery mottle virus (SPFMV) and sweetpotato chlorotic stunt virus (SPCSV) - in sweetpotato in West Java and East Java. An intensive survey in Java and Irian Jaya using NCM-ELISA showed that at least seven different viruses infected sweetpotato, namely sweetpotato feathery mottle virus (SPFMV), sweetpotato mild mottle virus (SPMMV), sweetpotato latent virus (SPLV), sweetpotato chlorotic fleks virus (SPCFV), sweetpotato chlorotic stunt virus (SPCSV), virus c-6 and virus c-8 (Machmud and Rusmadi, 1998; Paiki and Erari, 2001). Among these, SPFMV was considered the most dominant virus.

Improvement in production and distribution of planting materials

Sweetpotato is propagated using vegetative parts such as tuber and vine. Vine cutting is the main planting material in sweetpotato production. To obtain good planting materials, vine cuttings that originated from selected tubers are obtained from the nursery. The selected tubers are sprouted before transplanting in the nursery. After 2-3 months, the young vines can be harvested and transplanted for multiplication purposes.

In preparing vine cuttings, farmers usually do not use a standard measure to determine the length of cutting. Wargiono et al. (1994) showed that vine cuttings of 3-4 nodes are not significantly different than cuttings of 20 cm length in terms of roots produced as well as number of vine cuttings obtained.

Pests and diseases might infect vine cuttings obtained from the previous crops, therefore dipping of cutting materials into fungicide and insecticide before planting is recommended.

Farmers usually store the vine cuttings for 12 to 24 hours before they are planted to allow them to wilt slightly and become more pliable and easier to set into the soil. Research indicated that time and storage methods of planting materials significantly affected the growth and yield of sweetpotato. Sugito et al. (1991) showed that delayed planting of vine cuttings for 3 days does not affect the root yield. However, longer delay of planting date (6 to 10 days) reduced the viability of the planting materials, crop biomass and yield (Sugito et al., 1991; Djazuli, 1996). Storage of vine cuttings under shady condition is better than in the refrigerator, humidity chamber, or water/sand container.

Post harvest handling and processing

Sweetpotato root tuber is watery and the roots deteriorate rapidly after harvest. Researches on postharvest handling, processing into a semi-finished (intermediate) product with longer storage life, and increasing the storage life of fresh roots are therefore necessary.

Setiawati et al. (1994) reported that storage of sweetpotato fresh roots in a room (with ordinary room temperature and air humidity) for one month caused 15% root damage. However, root damage is lower if the roots are covered with humid rice straw mulch, although the roots tend to sprout.

Researches on processing of sweetpotato into various intermediate products (flour and starch) as well as end products have been carried out. Aside from processing into flour and starch,

which lengthen the storability, sweetpotato may be dried in the form of cube-chips (Setyono and Thahir, 1994) or granule as an alternative intermediate product of sweetpotato (Utomo et al., 1994).

To support the development of home industry for sweetpotato flour, a number of simple and small-scale equipment for chip preparation as well as for flour production have been developed (Sutrisno and Ananto, 1999). Household level processing of sweetpotato flour was shown to feasible during the dry season in East Java, though profitability was sensitive to the price of wheat flour (Peters and Wheatley, 1997).

Study on the effect of steaming and NaOH concentration on flour quality indicated that the best flour in terms of chemical and sensory quality was produced by a combined treatment of steaming for 30 minutes plus NaOH at 0.5 ml although the product had a rather unattractive color (Kumalaningsih, 1997).

Color of sweetpotato flour is influenced by its flesh color. In general, sweetpotato with a white or yellowish white flesh color is preferred over that with orange flesh color. Soaking of the sliced tubers in water for 20 hours or in 0.5-1 percent natrium bisulfit resulted in a light white flour color (Hari et al., 1994; Sastrodipuro et al., 1994). Using Ca (OH) 2 improves the texture of chip and increases flour yield, whereas the use of Na-bisulfit improves flour color (Kumalaningsih, 1997). Studies on the effect of storage temperature of tubers on the physical and chemical properties of sweetpotato flour indicated that the effect varies as much as the chemical composition among the varieties (Kumalaningsih, 1997).

Flour and starch content of sweetpotato depended on the variety as well as age during harvest. Harvesting of 120 days was considered optimal to obtain a high starch as well as flour yield. Starch content was considerably reduced when harvesting was delayed at 150 DAP. Sugar content fell significantly when harvest was done beyond 90 days, but the amylase content was not greatly affected by the time of harvest (Antarlina et al., 1990). The protein content of sweetpotato flour can be increased by adding protein of legumes or maize to form a composite flour (Antarlina, 1994; Utomo and Antarlina, 1997; Antarlina and Utomo, 2000).

Sitophilus sp. and *Aspergillus* sp. are serious pest and fungal infecting sweetpotato flour. Sweetpotato flour may be stored for six months using sealed plastic bags and jars to keep its quality (Antarlina and Bedjo, 1997).

Research also indicated that sweetpotato flour could be used for making various food products such as cookies, cakes, bread, ketchup, noodles, and vermicelli (Antarlina, 1993; Widowati et al., 1994; Antarlina, 1996; Utomo and Antarlina, 1997, Suismono et al., 1997; Kumalaningsih, 1997). Sweetpotato flour could substitute 20 to 100 percent of wheat flour depending on the product being manufactured.

A study on bioconversion of carbohydrates from starch to fructose shows that it is higher in Borobudur variety than in Daya and Prambanan (Sastrodipuro, 1986).

Studies on socio-economics of sweetpotato

In Indonesia, sweetpotato is mostly used for consumption, directly either as supplement or as staple food, and indirectly through food industry products. Certain amount is also used as raw materials by the feed and chemical industry. Unfortunately, studies on the market differentiation as well as market size of each industry product have not been carried out yet.

There are two distinct types of farmers involved in sweetpotato production, namely subsistence farmers who grow sweetpotato for their own needs and as feed for their livestock (such as in Nusa Tenggara and Irian Jaya) and commercial farmers who usually sell most of their products and keep only a small portion for their own consumption (in Java and other major islands) (Dimyati and Manwan, 1992). Sweetpotato is also an important component of household gardens in Java and is used to make a number of traditional snack foods, such as chips and *Kremes* (Watson et al., 1991).

In Java, the sweetpotato marketing chain involve farmers as producers, village traders, collectors, processor and retailers. The collectors play the most important role among various traders in channeling the product from producers to consumers. In most cases, farmers usually receive 50-60 percent of the consumer's price depending on the distance between production and consumer centers (Dimyati and Manwan, 1992). Herianto (1997) reported that the big traders received the highest marketing margin (52.6%), collectors received 7.8 percent and harvesting contractors received only 3.2 percent while the farmers had no power to exert significant influence on the matter of price.

Marketing and price risk is considered an important constraint in growing sweetpotato. Sarasutha et al. (1995) indicated that the decline in sweetpotato harvested area and productivity in South Sulawesi was mainly due to price fluctuation.. A study on factors affecting farmers' decision making in sweetpotato cultivation showed that it was influenced by internal factors such as farmers' experiences, age, number of family, and external factor especially farmer-marketing agent relationship (Heriyanto, 1994). When grown in the dry season after rice, Watson et al. (1991) and Peters and Wheatley (1997) found that sweetpotato was relatively profitable in Java compared with competing crops such as soybean and peanut. Farmers, however, noted high marketing and price risk for sweetpotato. Most farmers in Java sold their sweetpotato to farmers using the *tebesan* system, in which the standing crop was sold before harvest and harvesting was the responsibility of the trader (Heriyanto, 1994).

Sweetpotato is considered a potential source of raw materials for processing into intermediate products (flour, starch) and end products (food, feed and chemical product). Sweetpotato flour can substitute or replace wheat flour depending on the final food product. It was estimated that sweetpotato flour can substitute up to 1.255 thousand tons of wheat flour required to process into bakery products (bread, cake, cokies), noodles, and vermicelli equivalent to US $271.1 million (Heriyanto and Winarto, 1998). However, no reliable estimates of current utilization of sweetpotato in Indonesia by processing industries exist. Damardjati et al. (1990) estimated about 2000 t/yr of sweetpotato are used by processing factories in Java, while Gunawan, Wheatley and Irfansyah (1995) estimated as much as 500,000 t/yr may be used for processing. Gunawan, Wheatley and Irfansyah (1995) derived their estimate by taking the difference between the quantity of sweetpotato food availability in national food balance sheets from the quantity of sweetpotato consumption reported in national household consumption surveys However, this approach is likely to overestimate the quantity available for processing (Woolfe, 1992). Thus, there is a lack of reliable estimates of sweetpotato utilization for Indonesia.

Research on constraints to technology adoption

To accelerate transfer of technology (new improved varieties, cultural practices, pest/disease management, postharvest technology) developed by research institutes, on-farm researches have been conducted in some sweetpotato production areas in East Java and Irian Jaya (Widodo and Rozi, 1990; Basuki and Guritno, 1990; Tubun and Karafir, 1990; Widodo, 1997).

In general, improved technology such as improved varieties, fertilizers, and proper methods of application have significantly increased root yield and farmers' income. However, farmers often decide not to adopt the technologies for several reasons such as capital limitation, unavailability of production factors, unstable, and low price of sweetpotato roots.

Planting of local varieties which have good taste but are low in productivity is believed as one of factors that led to the low and declining sweetpotato yield (Basuki and Guritno, 1990; Widodo, 1997). Farmers prefer these local varieties mainly for their good taste and marketability.

Unstable and sharp price fluctuations of sweetpotato during harvest time is believed to be the main reason for the decline in harvested areas and sweetpotato productivity in South Sulawesi (Sarasutha et al., 1995).

Future Research Directions

Further or continued research is needed in the following areas:

Germplasm and breeding program:

- Characterization of sweetpotato germplasm for specific uses such as high dry matter, carotene, protein, vitamin B & C or anthocyan content.
- Characterization of sweetpotato germplams for specific traits such as tolerance to abiotic stress (drought, acid soil, shading, cold temperature, low radiation) and biotic stress (weevil, scab, viruses).
- Breeding for development of sweetpotato varieties for specific uses and specific traits.

Crop management program:

- Development of effective and efficient production technology
- Identification and assessment of yield losses from diseases caused by virus
- Development of a better and efficient IPM for weevil, scab and virus

Postharvest program:

- Development of postharvest technology for securing and raising quality for consumption and industrial uses.
- Development of a technology for advance use and waste processing

Socio-economic program:

- Assessment of market size and market differentiation and development.
- Constraints to technology adoption

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Table 1. Constraints and factors influencing sweetpotato production in Indonesia

Constraint	Importance	Main and specific researchable issues
Yield potential	***	Development of high-yielding varieties adapted to different conditions
Improved varieties	*****	Local condition and uses
Quality	****	- Collection and introduction of germplasm
Drought	**	- Germplasm evaluation
Low temperature	*	- Population improvement
Low radiation	*	- Selection for food, feed and industrial uses
Plant morphology		
Planting materials	*****	Improvement in production and distribution of planting materials - Improvement of storage conditions of planting materials - Pre-treatment of planting materials - Technology for producing improved planting materials - Availability and demand of propagative materials - Policies and social economic aspect of production and distribution of propagative materials Improvement of crop management
Pests Hawk moth	**	- Economic threshold of losses due to pest and diseases - Integrated control of pest
Weevil	***	
Others	**	
Diseases Scab	**	- Integrated control of diseases
Viruses	*	
Harvesting time	****	- Determination of best harvesting time
Water management	***	- Water management
Post harvest		
Processing	***	Improvement of post-harvest handling and processing - Post harvest processing - Post harvest post and micoorganism - Advance processing - Waste utilization
Storage	*****	Handling and storage of fresh product
Marketing	***	Assessment of market size and market differentiation and development
Prices	***	- Farmers' and consumers' preferences - Factors affecting price
New uses	**	- New ways of utilization - Improvement of existing product
Cropping system	***	Improvement of cropping system
Year round production	***	- Characterization of cropping/farming system components - Refinement of existing cropping system

Adoption new Technology	****	- Year round production Constrains to technology adoption - Reason for non-adoption of improved technology - Identification of actual farmers need - Evaluation of improved technology

Notes: ***** = highest importance, * = lowest importance