

## An aquaponic system with hydroponic culture of sweetpotato and tilapia culture

### Abstract

An integrated system with hydroponic culture of sweetpotato and tilapia culture as a new combination in aquaponics was investigated. Two experiments were conducted in the present study. First experiment was conducted inside the glasshouse using plastic tanks (118 × 77 × 45 cm high) as water reservoirs to compare growth and development of two sweetpotato (*Ipomoea batatas* (L.) Lam.) varieties Beniazuma and Purple sweet lord in hydroballs, granular plastics, cut rockwool and rockwool block as supporting materials in hydroponic culture method. The diameter of hydroballs and granular plastics were in the range of 5 to 6.5 mm and 3.5 mm, respectively. The individual pieces of cut rockwool and rockwool blocks were approximately 12×10×10 mm and 86×68×200 mm high, respectively. The supporting materials were placed inside the plastic pots (100×80×220 mm high). Harvesting of the sweetpotato plants were done 3 months after planting. Greater growth and development of storage roots of sweetpotato in both the varieties were obtained in the hydroballs than the other supporting materials. In the second experiment, hydroponic cultivation of four sweetpotato varieties namely Kokei 14, Suioh, Beniazuma and Elegant summer with hydroballs as supporting material was examined with the integrated culture of tilapia fish in the pond to increase food production. Two ponds were made to conduct the experiment. The length and width of each of the ponds were 7.7 cm and 5.3 cm, respectively, and the depth of water was maintained at 0.38 cm throughout the culture period. The soil surfaces inside the ponds were covered by three layered polyethylene sheets to avoid leaching loss of water. Styrofoam boxes (42×32×25 cm high) were used to culture the sweetpotato on the water surface. Holes were made on the bottom side of the boxes to facilitate water infiltration inside the boxes and from the growing non-storage roots to the pond water to absorb water and nutrients. Nylon net containers filled with hydroballs were placed in styrofoam boxes. Sweetpotato were harvested 105 days after planting. The variety, Kokei 14, produced the greatest fresh and dry weights of storage roots, whole-plant, and percent harvest index in both the ponds with or without fish. The number and diameter of storage roots of Kokei 14 were greater than the other varieties. Tilapia fishes were cultured in one of the two ponds and the fishes were fed with artificial feed. The fishes also ate the growing non-storage roots that came through the bottom holes of the styrofoam boxes. The average length and weight of tilapia fishes 143 days after culturing in the pond with integrated hydroponic cultivation of sweetpotato increased to 10 cm and 188 g, respectively, and those were 1.8 and 6.9 times, respectively, greater than at the start of the culture. The integrated culture of sweetpotato hydroponically on the water surface and tilapia in the pond water to increase food production in a limited space is possible as well as profitable.

Keywords: *Ipomoea batatas*, tilapia fish, hydroponic cultivation, integrated culture, supporting materials

### Introduction

Due to the recent growth in the global population, concerns have arisen over the stable supply of food and water resources. Therefore, there is an urgent need to develop production technology that utilizes water resources effectively and provides a stable food supply. This study examined aquaponics, a biological production system combining hydroponics and fish farming that has been attracting attention in recent years as a resource-recycling production system.

Integrated fish and vegetable production technologies were found to be more profitable than rice production, and the adoption of the technologies has improved the micronutrient status of members of adopting households through better dietary quality in Bangladesh (Bouis, 2000). Integrated culture of fishes with vegetables resulted in significantly higher annual net cash flow than the farming of fishes and vegetables separately (Limbu, 2016). Vegetable production with integration of tilapia fishes in aquaponic systems showed good biomass production and economic return (Babatunde et al., 2019).

Aquaponics can make effective use of water and nutrients (Wongkiew et al., 2017). Sharing water between hydroponics and aquaculture systems allows plants to utilize the fertilizer components derived from fish excrement for growth. Therefore, food can be produced with less water while reusing nutrients and converting waste into high-value resources. Aquaponics is significant as a biological production system in areas with limited water and fertilizer resources. As an extreme example, an integrated culture system of crops or vegetables with fish will be an essential component of a Controlled Ecological Life Support System (CELSS) in space because it is likely to play an important role in regenerative systems for producing crops or vegetables and fish to increase food and dietary energy for a long-term human stay in space (Kitaya et al., 2003).

Sweetpotato grown hydroponically gave higher yields per plant under controlled environmental conditions by using modified nutrient film techniques (Hill et al., 1992) and in a box culture system with an air space above a nutrient solution layer (Uewada, 1990; Uewada et al., 1992) in comparison with the yield when grown conventionally under field conditions. The hydroponic technique for crop production has been mainly used where there is an absence of adequate soils, water resources, or proper climatic conditions. Previous studies on hydroponic cultivation of sweetpotato have been carried out mainly under greenhouse and growth chamber conditions.

In the box culture system developed by Uewada (1990) and Uewada et al. (1992), sweetpotato were grown in plastic boxes (inside measurements 0.4 m × 0.7 m × 0.32 m high) containing a nutrient solution on the bottom. The upper and middle portion of the sweetpotato root system developed as storage roots in the aerial spaces above the nutrient solution layer, and the lower portion of the root system developed as absorbing roots in the nutrient solution layer. The results obtained with this system suggested that the storage roots can be developed in the aerial spaces even if the absorbing roots are submerged in the solution. Though the storage roots can grow in blank aerial spaces, large-scale production using this method is not possible, and it will not be economically profitable. Large-scale production of crops at low cost, however, can hardly be done under these conditions. For large-scale production of sweetpotato through the hydroponic method, the selection of appropriate supporting materials which can provide

aerial spaces is necessary for greater growth and yield of storage roots. In the present study, hydroballs were selected as the appropriate supporting material to get greater growth and yield of sweetpotato in hydroponic methods of cultivation. After selecting the hydroballs as appropriate supporting material, the possibility of culturing sweetpotato on the water surface hydroponically using hydroballs as supporting material was examined in large-scale production with the integrated culture of tilapia fish in the pond water to increase food production.

## Materials and Methods

Selection of suitable supporting material for hydroponic cultivation of sweetpotato (Exp. 1)

The experiment was conducted inside the glasshouse using plastic tanks (118 × 77 × 45 cm high) as water reservoirs. A plastic plate table at the height of 30 cm was placed inside the water reservoir tank. The plastic rooting pots containing different supporting materials were placed on the plastic plate table. In the experiment, 4 supporting materials (Hydroballs, Granular plastics, Cutrockwool, and Rockwool blocks) and 2 sweetpotato varieties (Beniazuma and Purple sweet lord) were tested to culture in hydroponic method. The hydroballs were made with clay soils well mixed with a small proportion of sands in the range of 5 to 6.5 mm in diameter following the same preparation method of bricks but not so strong burning as for bricks preparation. The diameter of granular plastics was 3.5 mm in diameter. The individual pieces of cut rockwool were approximately 12×10×10 mm high. The rockwool blocks were approximately 86×68×200 mm high. The supporting materials were placed inside the plastic rooting pots (100×80×220 mm high). Some holes were made in the lower surface and side walls of the plastic rooting pots to ease to the entry of the nutrient solution inside the rooting pots and to grow the absorbing roots outside the rooting pots to absorb water and nutrients from the nutrition solution. Vine cutting of sweetpotato with seven nodes and five leaves was planted in supporting materials in each rooting pot. The tip of the vine cuttings was removed at planting. Two lower nodes of vine cuttings were inserted into the supporting material at planting. The nutrient solution depth was maintained at three-fourths of the rooting pot height from the lower surface for two weeks after planting. After that, the nutrition solution depth gradually decreased and kept constant one-fourth of the rooting pot height from the bottom three weeks after planting and maintained the same depth of nutrient solution throughout the growing period. The leaf number was kept constant throughout the growing period by removing the newly growing shoots. Two and a half months after planting, one to two leaves from the lower side of the vines died due to senescence. Harvesting of the sweetpotato plants was done three months after planting.

Integrated culture of sweetpotato and tilapia fish (Exp. 2)

The experiment was conducted at the experimental farm of Osaka Metropolitan University, Japan. Two ponds were made to conduct the experiment on the hydroponic method of sweetpotato cultivation. The length and breadth of each of the ponds were 7.7 cm and 5.3 cm, respectively, and the depth of water was maintained at 0.38 cm throughout the culture period. The soil surfaces inside the ponds were covered with three layered polyethylene sheets to avoid leaching loss of water from the ponds. Styrofoam boxes (42×32×25 cm high) were used to culture sweetpotato

in the pond (Fig. 1).



Fig. 1. Sweetpotato plants with boxes floating on water (A) and box with plants in nylon nets (B)

Holes were made on the lower side of the boxes to insert the water inside the boxes and coming out of the growing non-storage absorbing roots into the water to absorb nutrients from the water. Four chambers were made inside each styrofoam box. One nylon net container filled with approximately 2 kg of dry hydroballs was placed in each chamber. After pouring the hydroballs in the nylon net containers, two layered black polyethylene bags were used to cover the nylon net containers to protect the penetration of light inside the nylon net containing hydroballs. Three nodes of a rooted transplant (ca. 13 g fresh weight) of sweetpotato were inserted into the hydroballs in each nylon container at planting. Four varieties of sweetpotato, namely Kokei 14, Suioh, Beniazuma, and Elegant summer were cultured on the surface of pond water. During the growing period, fertilizers were applied twice. At the first time, fertilizers were applied inside the styrofoam boxes keeping in the perforated non-degradable small bags for 35 days after planting. One month later of the first fertilizer application, the nutrient solution was applied to the hydroballs. The insects were controlled mechanically by hand without using insecticides. Harvesting of sweetpotato was done 105 days after planting.

Two hundred tilapia fishes were cultured in one of the two ponds, and the fishes were fed with 30 g of artificial dry feed per day. The fishes also ate the growing non-storage roots that came out through the bottom holes of the styrofoam boxes and microalgae. Tilapia fishes were cultured for 143 days in the pond water. The initial average length and weight of tilapia fingerlings were 12 cm and 32 g, respectively, at the start of the culture. After harvesting of fishes, 87 fishes were sampled and measured the lengths and weights and separated into numbers according to the length and weight categories.

#### Experimental design and data analysis

The sweetpotato experiments conducted at the glasshouse for selecting the appropriate supporting materials and on the water surface for comparing the growth and yield of sweetpotato using different varieties in ponds with or without fish were laid out in a randomized block design with four replications. Fisher's Least Significance Difference method was used for comparing the growth characteristics and yield of sweetpotato using different supporting materials and two varieties of sweetpotato inside the glasshouse and on the water surface with four

varieties of sweetpotato and two ponds after an ANOVA test. Mean differences of the parameters in the treatments were compared using Fisher's Least Significance Difference Test at a 5% level of significance. The numbers of tilapia fishes were separated into different length and weight categories and have shown in the Figures. The mean length and weight of sampled tilapia fishes were also calculated.

## Results and Discussion

Exp. 1. Growth performance of sweetpotato grown hydroponically with different supporting materials. The main edible part (i.e., storage roots) of sweetpotato showed greater growth and development in hydroballs than the other supporting materials in both the varieties Beniazuma and Purple sweet lord (Table 1). On the other hand, the non-edible parts (i.e., stems, leaves, and non-storage roots) showed relatively less growth and development in hydroballs than the other supporting materials. Fresh and dry weights of storage roots in Beniazuma were approximately 2.4 times greater in hydroballs than in the cut rockwool, and in Purple sweet lord, those were approximately 5.1 times greater in hydroballs than in the granular plastics.

Table 1. Weights of storage roots, non-storage roots and characteristics of sweetpotato grown in different supporting materials in hydroponic cultivation (Exp. 1).

Varieties	Supporting materials	Weights of storage roots (g plant <sup>-1</sup> )		Weights of non- storage roots (g plant <sup>-1</sup> )		Characteristics of storage roots		
		Fresh	Dry	Fresh	Dry	Number per plant	Length (mm)	Diameter (mm)
Beniazuma	Hydroballs	14.6b	2.5a	31.2b	4.8a	4.3a	173a	14b
	Granular plastics	9.5c	1.6c	39.3a	5.3a	3.3b	133c	7.2c
	Cut rockwool	5.6e	1.2d	29.1b	5.6a	3.5b	140b	4.3d
	Rockwool block	8.8c	2.3b	33.8b	4.9a	2.8c	153b	11.8b
Purple sweet lord	Hydroballs	19.0a	2.7a	34.0b	2.1c	4.5a	148b	16.9a
	Granular plastics	4.0e	0.5e	43.4a	3.8b	2.8c	117d	8.0c
	Cut rockwool	12.2bc	1.9c	41.0a	2.9b	3.5b	77e	13.8b
	Rockwool block	7.2d	1.3d	22.7c	1.4d	2.8c	129c	11.8b
Analysis of variance†								
Varieties (V):		*	*	*	**	NS	**	**
Rooting media (M):		*	*	*	**	*	*	*
V×M:		*	*	*	**	NS	*	*

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Duncan's Multiple Range Test.

Analysis of variances was applied for 8 treatments; 2 varieties and 4 supporting materials

\* and \*\* indicate significant at 5% and 1% levels, respectively.

NS indicates non-significant

The number of storage roots was 1.5 times greater in hydroballs than in the rockwool block in both varieties. The length of storage roots in Beniazuma was 1.3 times greater in hydroballs than in the granular plastics, and that in Purple sweet lord was 1.9 times greater in hydroballs than in cut rockwool. The diameter of storage roots in Beniazuma was 3.5 times greater in hydroballs than in cut rockwool, and that in Purple sweet lord was 2.1 times greater in hydroballs than in granular plastics. The non-edible parts of sweetpotato plants showed greater growth in granular plastics, cut rockwool and rockwool blocks in both varieties in most of the cases than in the hydroballs (Table 2). Though lower and medium growth of plants were obtained in hydroballs, the storage root growth was greater in hydroballs than the other supporting materials in both varieties. Percent harvest index in Beniazuma was 2.2 times greater in hydroballs than in cut rockwool, and that in Purple sweet lord was 6.1 times greater in hydroballs than in granular plastics (Table 3). The shoot root ratio was greater in cut rockwool, rockwool blocks, and granular plastics than in the hydroballs. The reason for the greater growth and development of storage roots in hydroballs may be due to proper aeration, looseness, and providing an optimum amount of water for the normal growth and development of sweetpotato than the other materials. Hydroballs contained sufficient water for the normal growth and development of storage roots as well as whole-plant because the hydroballs were made with clay soils mixed with a small proportion of sandy soils. Hydroballs also have the capillary action to provide optimum moisture for the greater growth of the plants.

Table 2. Weights of above-ground parts, sub-ground parts and whole-plant of sweetpotato grown in different supporting materials in hydroponic cultivation (Exp. 1).

Varieties	Supporting materials	Weights of above- ground parts (g plant <sup>-1</sup> )		Weights of sub-ground parts (g plant <sup>-1</sup> )		Weights of whole-plant (g plant <sup>-1</sup> )	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
Beniazuma	Hydroballs	39.7bc	6.6b	45.8b	7.3b	85.4c	13.9b
	Granular plastics	52.8a	7.3b	48.8a	6.9a	101.6a	14.2b
	Cut rockwool	47.1ab	8.1a	34.7c	6.9a	81.7c	14.9b
	Rockwool block	55.0a	9.7a	42.6b	7.2b	97.6b	16.9a
Purple sweet lord	Hydroballs	33.7c	3.7cd	53.0a	4.8c	86.7b	8.5a
	Granular plastics	39.8bc	4.5c	47.4b	4.2c	87.2b	8.7a
	Cut rockwool	40.6bc	3.7cd	53.2a	4.9c	93.7a	8.6a
	Rockwool block	34.2c	2.8d	29.8c	2.7d	64.0c	5.6b
Analysis of variance <sup>Z</sup>							
Varieties (V):		**	**	*	**	*	**
Supporting materials (M):		*	*	*	*	*	*
V×M:		*	*	*	*	*	*

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Duncan's Multiple

Range Test.

<sup>Z</sup> Analysis of variances was applied for 8 treatments; 2 varieties and 4 supporting materials

\* and \*\* indicate significant at 5% and 1% levels, respectively.

Table 3. Weights of whole-plant, above-ground parts and sub-ground parts of sweetpotato grown in different supporting materials in hydroponic cultivation (Exp. 1).

Varieties	Supporting materials	Weights of stem (g plant <sup>-1</sup> )		Weights of leaves (g plant <sup>-1</sup> )		Harvest <sup>X</sup> index (%)	Shoot- <sup>Y</sup> root ratio
		Fresh	Dry	Fresh	Dry		
Beniazuma	Hydroballs	30.1b	4.3b	9.6c	2.4b	18.1a	0.9b
	Granular plastics	34.7ab	4.2b	18.0a	3.1a	11.4b	1.1ab
	Cut rockwool	37.2a	5.4a	9.9c	2.7b	8.3c	1.2a
	Rockwool block	38.1a	6.0a	16.9a	3.6a	13.4b	1.3a
Purple sweet lord	Hydroballs	23.7c	2.5c	10.0bc	1.2c	31.3a	0.8c
	Granular plastics	29.2b	3.1bc	10.6bc	1.4c	5.1c	1.1ab
	Cut rockwool	27.9b	2.3c	12.7b	1.4c	22.5b	0.8c
	Rockwool block	23.6c	1.9c	10.7bc	0.9d	23.3b	1.0b
Analysis of variance <sup>Z</sup>							
Varieties (V):		**	**	*	**	**	*
Supporting materials (M):		*	*	*	**	**	*
V×M:		*	*	*	**	**	*

<sup>X</sup> : (Storage roots dry weight / whole-plant dry weight) × 100

<sup>Y</sup> : Above-ground dry weight / sub-ground dry weight

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Duncan's Multiple Range Test.

<sup>Z</sup> Analysis of variances was applied for 8 treatments; 2 varieties and 4 supporting materials

\* and \*\* indicate significant at 5% and 1% levels, respectively.

Lower growth and development of storage roots in granular plastics may be due to the lack of providing sufficient

water for the plants because of the low water retention ability of granular plastics as well as low capillary action, which may restrict the growth and development of storage roots. Water-saturation conditions in the cut rockwool may restrict the growth of storage roots. Greater hardness and water saturation conditions in rockwool blocks may have a more detrimental effect on the normal growth and development of storage roots. On the other hand, in most of the cases, the relatively greater growth of non-storage roots and above-ground parts was obtained in the granular plastics, cut rockwool, and rockwool blocks than in the hydroballs. Similar results were also obtained by Islam et al. (1997) in modified hydroponic cultivation of sweetpotato in wet lowland field conditions with porous plastic tubes placed inside the soil ridges for aeration inside the ridges. The dry weight of storage roots in the aerated treatment was four times greater than in the normal soil ridges in wet soil conditions, but the dry weight of non-storage roots was greater in normal soil ridges than in the aerated ridges. From this experiment, hydroballs were selected as the appropriate material to be used in hydroponic culture of sweetpotato to obtain greater yield.

Exp. 2. Growth performance of sweetpotato grown hydroponically with the integrated culture of tilapia fish in a pond

Growth and development of the storage roots of sweetpotato in hydroponic culture were satisfactory though there were variations among the different varieties and in ponds with or without fishes (Fig 2).

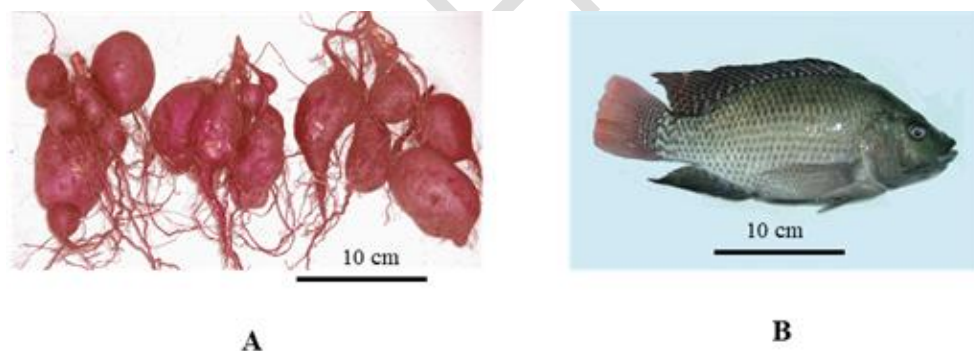


Fig. 2. Storage roots of sweetpotato (A) and tilapia fish at harvest (B)

Kokei 14 produced the greatest fresh and dry weights of storage roots in ponds, either with or without fish (Table 4). Fresh and dry weights of storage roots were 2.4 times greater in Kokei 14 than in Beniazuma in the pond with fish, and those were 3.1 times greater in Kokei 14 than Elegant summer in the pond without fish. Fresh and dry weights of non-storage roots were greater in each respective variety in the pond without fish than with fish. A greater number and diameter of storage roots were also obtained in the variety, Kokei 14, in both the ponds. The diameter was 1.4 and 1.8 times greater in the pond with fish and without fish, respectively, in Kokei 14 than in Elegant summer. Fresh and dry weights of the whole plant were 2.2 times greater in Kokei 14 than in Beniazuma in the pond with fish, and those were approximately 2.4 times greater in Kokei 14 than in Elegant summer in the pond without fish (Table 5).

Table 4. Weights of storage and non-storage roots, and characteristics of storage roots of sweetpotato grown hydroponically on the water surface with integrated culture of tilapia fish in the pond water (Exp. 2).

Ponds	Varieties	Weights of storage roots (g plant <sup>-1</sup> )		Weights of non-storage roots (g plant <sup>-1</sup> )		Characteristics of storage roots		
		Fresh	Dry	Fresh	Dry	Number	Length per plant	Diameter (mm)
With fish	Kokei 14	364.8a	102.1a	58.8c	6.4b	6.1a	113b	54.7a
	Suioh	165.9c	49.5c	57.5c	6.3b	5.6a	88c	43.7b
	Beniazuma	151.8c	41.7d	18.3d	2.6d	3.5b	113b	45.2b
	Elegant summer	223.1b	58.7c	68.2c	5.6c	6.1a	131a	37.9c
Without fish	Kokei 14	339.0a	82.9b	104.4a	9.1a	5.8a	97c	60.5a
	Suioh	244.3b	75.9b	85.4b	7.5b	5.8a	106b	48.4b
	Beniazuma	164.9c	40.0d	75.5b	8.0a	4.3b	116b	47.3b
	Elegant summer	108.5d	26.7e	63.3c	5.8c	5.3a	93c	33.2c
Analysis of variance <sup>Z</sup>								
Ponds (P):		*	*	**	**	NS	*	NS
Varieties (V):		*	*	**	**	*	*	*
P×V:		*	*	**	**	NS	*	NS

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Fisher's Least Significance Difference (LSD) test.

<sup>Z</sup>: Analysis of variances was applied for 8 treatments; 2 ponds and 4 varieties.

\* and \*\* indicate significant at 5% and 1% levels, respectively.

NS indicates non-significant.

Table 5. Weights of above-ground, sub-ground and whole-plant of sweetpotato grown hydroponically on the water surface with integrated culture of tilapia fish in the pond water (Exp. 2).

Ponds	Varieties	Weights of above-ground parts (g plant <sup>-1</sup> )		Weights of sub-ground parts (g plant <sup>-1</sup> )		Weights of whole-plant (g plant <sup>-1</sup> )	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
With fish	Kokei 14	73.4a	16.0a	423.6a	108.5a	497.0a	124.5a
	Suioh	54.4c	11.8b	223.4d	55.8c	277.8c	67.6d
	Beniazuma	54.1c	10.8b	170.1e	44.3d	224.2d	55.1d
	Elegant summer	81.4a	14.8a	291.3c	64.3c	372.7b	79.1c
Without fish	Kokei 14	53.6c	10.7b	443.4a	92.0b	497.0a	102.7b
	Suioh	67.3b	12.3b	329.7b	83.4b	397.0b	95.7b
	Beniazuma	55.7bc	10.7b	240.4d	48.0d	296.1c	58.7d
	Elegant summer	41.4d	7.7c	171.8e	32.5e	213.2d	40.2e
Analysis of variance <sup>Z</sup>							
Ponds (P):		*	*	*	*	*	*
Varieties (V):		*	*	**	**	**	**
P×V:		*	*	*	*	*	*

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Fisher's Least Significance Difference (LSD) Test.

<sup>Z</sup>: Analysis of variances was applied for 8 treatments; 2 ponds and 4 varieties.

\* and \*\* indicate significant at 5% and 1% levels, respectively.

The percent harvest index was greater in the variety, Kokei 14, in both the pond than in the other varieties (Table 6). Mortley et al. (1991) reported that the harvest index ranged from 31 to 82% among the genotypes of sweetpotato developed for hydroponic systems in greenhouses using the nutrient film technique (NFT). In the present experiment, the harvest index ranged from 64 (Elegant summer) to 82% (Kokei 14). The shoot-root ratio was greater in Beniazuma, Elegant summer, and Suioh than in Kokei 14 in ponds with or without fish. In the hydroponic cultivation method, Suioh, Beniazuma, and Elegant summer showed the poor growth and development of above-ground and sub-ground parts and, consequently, the whole plant. This may be due to the susceptibility of these varieties to water-saturation conditions. A greater shoot-root ratio was obtained in the varieties, Beniazuma, and Elegant summer. Fresh and dry weights of non-storage roots were greater in the pond without fish than in the pond with fish because the non-storage roots that came out through the bottom holes of the boxes in the pond with fish were eaten by the fish.

Table 6. Weights of stem and leaves, percent harvest index and shoot-root ratio of sweetpotato grown hydroponically on the water surface with integrated culture of tilapia fish in the pond water (Exp. 2).

Ponds	Varieties	Weights of stem (g plant <sup>-1</sup> )		Weights of leaves (g plant <sup>-1</sup> )		Number of leaves per plant	Harvest <sup>X</sup> index (%)	Shoot-root <sup>Y</sup> ratio
		Fresh	Dry	Fresh	Dry			
With fish	Kokei 14	57.6a	12.9a	15.8b	3.1b	40.1a	82.0a	0.15b
	Suioh	41.3b	8.4b	13.1bc	3.4b	30.6b	73.2b	0.21a
	Beniazuma	38.4b	7.6b	15.7b	3.2b	35.8ab	75.7b	0.24a
	Elegant summer	58.3a	10.5ab	23.1a	4.3a	34.8ab	74.2b	0.23a
Without fish	Kokei 14	40.8b	8.2b	12.8bc	2.5c	23.5c	80.7a	0.12b
	Suioh	56.2a	10.3ab	11.1c	2.0c	22.8c	79.3a	0.15b
	Beniazuma	40.6b	7.9b	15.1b	2.8b	26.5bc	68.1c	0.22a
	Elegant summer	30.7c	5.9c	10.7c	1.8c	23.5c	66.4c	0.24a
Analysis of variance <sup>Z</sup>								
Ponds (P):		*	*	*	*	**	NS	NS
Varieties (V):		*	*	*	*	*	*	*
P×V:		*	*	*	*	*	NS	NS

<sup>X</sup>: (Storage roots dry weight / whole-plant dry weight) × 100

<sup>Y</sup>: Above-ground dry weight / sub-ground dry weight

In each column, the figures with different letter(s) indicate a significant difference at the 5% level by Fisher's Least Significance Difference (LSD) Test.

<sup>Z</sup>: Analysis of variances was applied for 8 treatments; 2 ponds and 4 varieties.

\* and \*\* indicate significant at 5% and 1% levels, respectively.

NS indicates non-significant.

Average length and weight of tilapia fishes 143 days after culturing in the pond with integrated hydroponic cultivation of sweetpotato increased to 10 cm (12 cm at start and 22 cm at harvest) and 188 g, (32 g at start and 220 g at harvest), respectively, and 1.8 and 6.8 times greater, respectively, those were at the start of culture (Fig. 2). The highest number of fishes was obtained in the 20.1 to 22.0 cm length category followed by 22.1 to 24.0 cm, 18.1 to 20.0 cm, 24.1 to 26.0 cm and the lowest was in the 26.1 to 28.0 cm and 16.1 to 18.0 cm categories (Fig. 3). The highest number of fishes was obtained in the 191 to 210 g weight category followed by 211 to 230 g, 231 to 250 g, 171 to 190 g, 251 to 270 g and the lowest was in the 151 to 170 g and 271 to 290 g categories (Fig. 4).

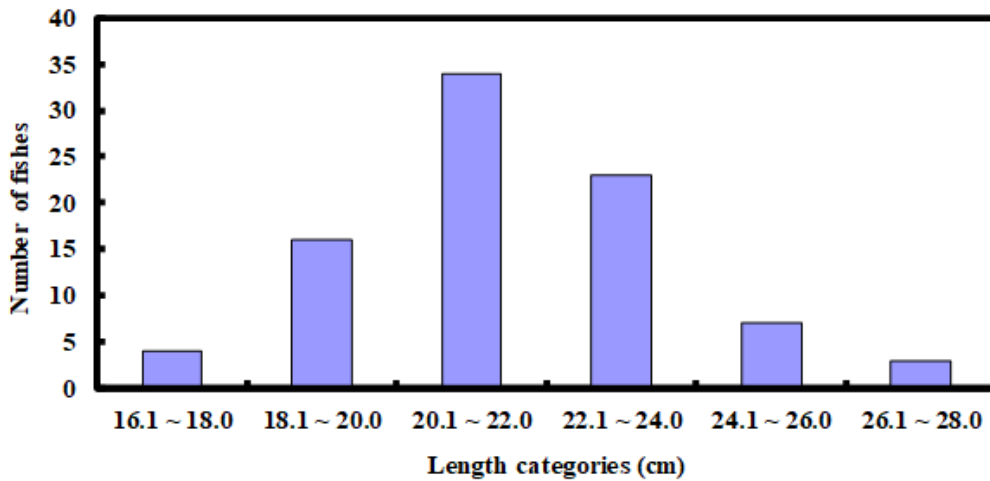


Fig. 3. Number of tilapia fish in different length categories

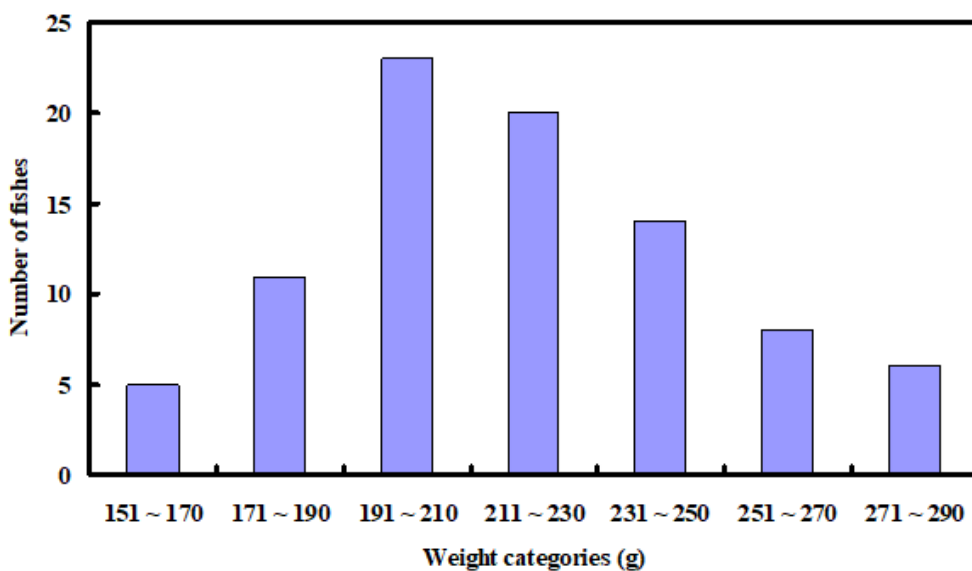


Fig. 4. Number of tilapia fish in different weight categories

Tilapia fishes can be grown in ponds with the integration of hydroponically grown any vegetable or field crops through artificial feeding, growing planktons as well as the fishes can eat the roots and other parts of the plants. The fish excretes also enrich the water with nutrients that can be absorbed by the plants. In an integrated culture system with fishes and vegetables resulted in 3 and 2.5 times greater net yield than the culture of fishes alone and farming of non-integrated vegetables, respectively (Limbu, 2016). In the present system, sweetpotato plants and fishes can be grown well symbiotically in the integrated culture system through mutual benefit in hydroponic cultivation.

## Conclusion

Sweetpotato can be cultured with the hydroponic method on water surfaces and lowland wet fields. The culture of indigenous fishes in the water can be combined with hydroponic cultivation of sweetpotato to increase food production in a limited space. The integrated culture method developed in the present study is applicable to other vegetable crops.

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