Optimization of EC Values of Nutrient Solution for Tomato Fruits Quality in Hydroponics System Using Artificial Neural Network and Genetic Algorithms

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Abstract. Total soluble solids (TSS) and fruit fresh weight are two indicators to show the quality of tomato fruits. To gain high values of TSS and fruit fresh weight, it is important to consider the concentration of nutrient solution, which is commonly represented by Electrical Conductivity (EC) value. Generally, the increasing of EC value not only increases the number of TSS, but also decreases fruit fresh weight. Therefore, it is important to optimize the EC value for both indicators of quality of tomato fruits. The objective of this research is to optimize the EC value of nutrient solution on each generative stage using Artificial Neural Network (ANN) and Genetic Algorithms (GA). ANN was used to identify the relationship between different EC value treatments with TSS value and fruit fresh weight. GA was applied to determine the optimal EC value in generative growth, which is divided into three stages. Results showed that the optimal EC values in the flowering stage, the fruiting stage and the harvesting stage were 1.4 mS/cm, 10.2 mS/cm and 9.7 mS/cm, respectively.

Keywords: *artificial neural network; genetic algorithm; hydroponics; tomato fruits quality.*

1 Introduction

Tomato fruit quality can be determined by the following parameters: soluble solid, fresh weight, fruit size, acidity, dry matter, stiffness and flavor. Soluble solids content and fruit fresh weight are the most important indicators for determining tomato fruits quality. Soluble solid content indicates the total solid in fresh tomato fruit soluble in water. It is commonly represented by total soluble solids (TSS) and measured using a refractometer on weight basis (% brix). Fruit fresh weight is usually affected by its water content. The higher the weight of fresh tomato, the higher the water content is. TSS value and fruit fresh weight are factors related to each other. An increase value in one factor is always associated with a decrease in the other, *vise-verse*. Both parameters are affected by the concentration of nutrient solution which is commonly represented by electrical conductivity (EC).

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Previous studies showed that increasing the concentration of nutrient solution could improve tomato fruit quality by the increase in the number of TSS [1-4]. Unfortunately, as described above, the fruit fresh weight would be decreased [5]. However, excessively high EC value of nutrient solution was associated with poor plant growth. When it was too low, plant growth was stunted from lack of fertilizer [6]. Therefore, it is important to determine the optimum EC value in order to produce tomato fruit with high TSS value and high fruit fresh weight. Accordingly, tomato fruit can be produced with high quality and economic value as desired.

This experiment was conducted with the objective to optimize the EC value in tomato crop cultivation. It was important to identify the relationships between different treatments of EC values and both TSS value as well as fruit fresh weight. Since it was difficult to explain those relationships in mathematical models due to the complexity of the physical and physiological processes involved, another approach was used. Artificial Neural Network (ANN) program is usually suitable for use in dealing with complex systems, such as cultivation system, than that of traditional mathematical methods [7]. ANN has the capability to identify an unknown complex dynamic system [8]. The benefits of using ANN program treatments are due to first its massively parallel distributed structure, and second, its ability to learn and therefore generalize [9]. In addition to the ANN program, Genetic Algorithms (GA) as a powerful tool for use in an optimization process was also used. GA is a combinatorial optimization technique capable of dealing with a complex objective function and simulates the biological evolutionary process based on crossover and mutation in genetics [10].

2 Materials and Method

2.1 Experimental Set Up

The experiment was conducted in a hydroponics system inside a greenhouse located in Agricultural and Forestry Research Center, University of Tsukuba. The study was focused to gain high TSS value and fruit fresh weight of tomato fruits. Therefore, the optimization process was conducted only in the generative growth phase.

The generative growth was divided into three stages; (1) flowering, (2) fruiting, (3) harvesting. In all stages, the treatments were consisted of two different EC values and two different planting densities (Figure 1). Therefore, there were four patterns of treatments in this experiment. Morimoto et al., [11] found that three or more data sets were necessary for identification using ANN. The EC value treatments consisted of low EC level (range 1,2-2,4 mS/cm) and high EC level (range 8,0-10,2 mS/cm). The planting densities consisted of 25 cm and 10 cm plant spacing, respectively.

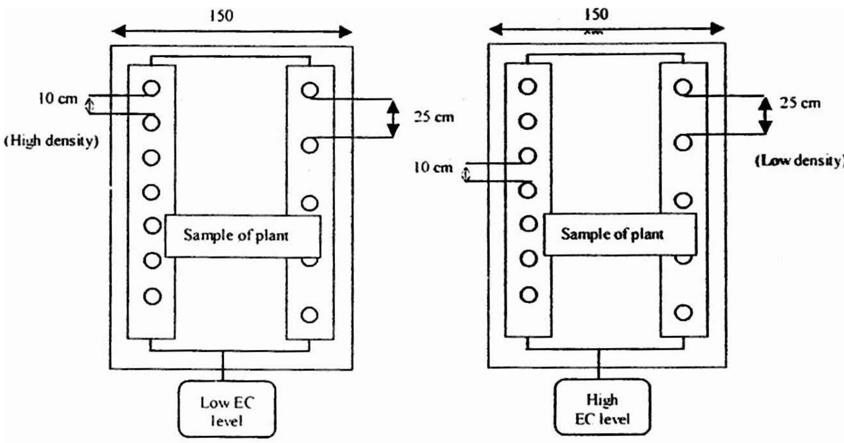

Figure 1 Schematic diagram of experiment.

2.2 Materials

Tomato (*Lycopersicum esculentum*, Mill) cultivar 'Money Maker' seeds were sown in trays with moist vermiculite in a greenhouse. When the cotyledons were fully open, the seedlings were transplanted into rockwool cubes (125 cm^3, Nittobo Co., Ltd., Japan) and grown in deep flow technique (DFT) system with Otsuka-A nutrient solution (Otsuka Chemical Co., Ltd., Osaka, Japan). In this stage, the nutrient solution was adjusted to an EC of 1.2 mS/cm and pH of 6.5-7.0. After 1 month, the seedlings were transplanted to nutrient film technique (NFT) hydroponics system. Otsuka-B nutrient solution was used in the NFT system in greenhouse. It was supplied to tomato plants in all treatments. When the first flower was opened on the first truss of each plant, pollination was promoted by a vibrator and spraying of 2-methyl-4-chlorophenoxyacetic acid (4-CPA). And then the plants were pinched above so that each plant only had one truss.

2.3 Development of Artificial Neural Network (ANN) model

ANN was used to predict the number of TSS and fruit fresh weight. In this study, the ANN model consisted of three layers: input layer, hidden layer and output layer. Some studies [11-14] showed that a three-layer neural network with one hidden layer have gained successful results. Light intensity, plant spacing, EC value in flowering stage (EC_1), EC value in fruiting stage (EC_2) and EC value in harvesting stage (EC_3) were inputted, while TSS value and fruit fresh weight were used as the value of the output layer (Figure 2).

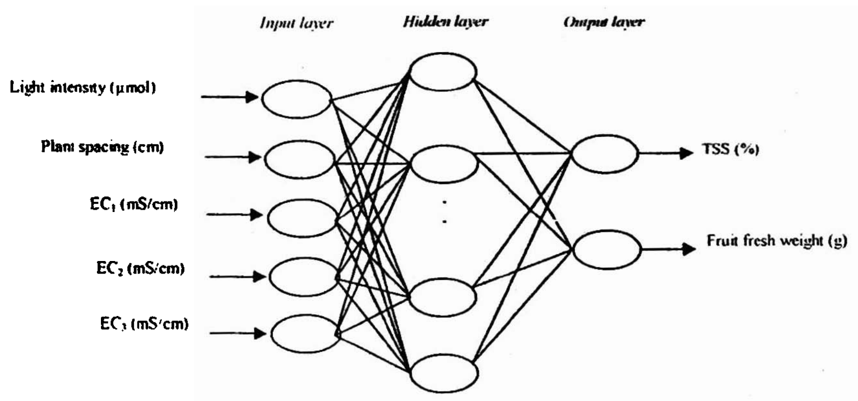

Figure 2 Structure of ANN model.

Back-propagation was used as the learning method, which is composed of two procedures: feed-forward and back-propagation weight trainings. A sigmoid function was selected as the activation function for both hidden layer and output layer. This function has a lengthy history in neural network applications [15], which is given by:

$$f(net) = \frac{1}{1 + e^{-net}} \quad (1)$$

where,

$$net = \sum_{i=0}^{n} x_i w_i \quad (2)$$

x_i, w_i, n are the inputs, weights and number of inputs, respectively.

The data samples were divided into two data sets, a training data set and a testing data set. A training data set was used for training the neural network, and a testing data set was used for evaluating the accuracy of the identified model. This type of model validation was called "cross-validation" [16]. The total a training data set was 65% of all data. The training process resulted weight values of the ANN model for the relationship between input and output parameters. All variables were normalized between 0 and 1, using fixed minimum and maximum values both in training and testing processes.

2.4 Development of Genetic Algorithms (GA) model

GA was used to determine the optimal EC value in flowering, fruiting and harvesting stages. The optimization process was done separately with the ANN model development. The weight values from ANN training were used as input for GA model to predict TSS and fruit fresh weight. Also, EC values (EC_1, EC_2, and EC_3) were used as input for GA model. The EC values were determined through searching method in GA model.

The objective function was given by the sum of the average value of TSS and fruit fresh weight on each stage (Equation 3). The problem of this summation was the different units of TSS value and fruit fresh weight. To avoid the problem, both parameters were normalized between 0.2 and 0.8.

$$F(EC_1, EC_2, EC_3) = \frac{1}{m}\left(\sum_{j=1}^{n}\sum_{i=1}^{m}\frac{TSS_{ij}}{m} + \sum_{j=1}^{n}\sum_{i=1}^{m}\frac{W_{ij}}{m}\right) \quad (3)$$

Maximize $F(EC_1, EC_2, EC_3)$

Subject to $1{,}4 \le EC_1 \le 9{,}6$; $2{,}2 \le EC_2 \le 10{,}2$; $2{,}1 \le EC_3 \le 9{,}7$ mS/cm

where

$F(EC_1, EC_2, EC_3)$: function of nutrient concentration, dimensionless.
TSS : Total soluble solid (%)
W : Fruit fresh weight (g)
m : number of plants
n : number of treatments

In order to employ *GA*, individual, fitness and *GA* operators were defined as follows:

1. Definition of the individual:
   In the *GA* optimization, an individual represented a candidate for the optimal solution. In this problem, the optimal *EC* value in flowering, fruiting and harvesting stages were determined. Therefore, the three optimal values of nutrient concentration, EC_1, EC_2, EC_3 represented an individual and each EC representative was coded as six-bit binary string. As an illustration, an individual was given as follow:

   Individual = EC_1, EC_2, EC_3
   = 011000, 101001, 001010 (binary string)
   = 4.52, 7.40, 3.30 (decimal values)

   A set of individual was called a population. They evolved toward better solution. *GA* worked with a population involving many individuals.

2. Fitness function:
   Fitness function was an indicator to show the quality of an individual. All of individuals in population were evaluated in terms of their performances by this function. The higher fitness functions of an individual, the better the ability to survive. In this problem, i.e., maximizing problem, fitness function was given as same as objective function (Equation 3).

3. *GA* operators
   The main operators were crossover and mutation. Crossover combined features from two individuals based on crossover rate (Pc). It operated by swapping corresponding component in the binary strings representing an individual. Here, one-point crossover was used in each parameter of EC. Mutation inverted one or more bits binary string (also called gene) in each individual based on mutation rate from 0 to 1 or 1 to 0.

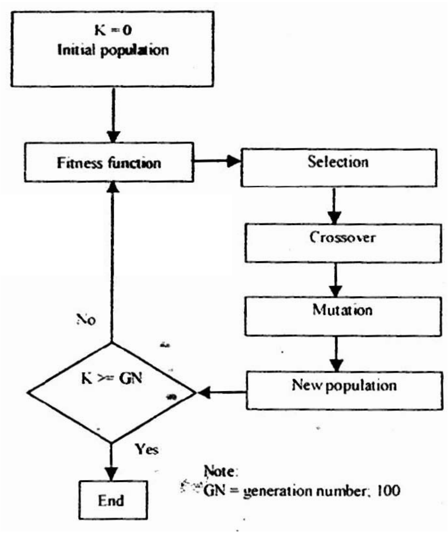

Figure 3 Flowchart of optimization process using GA.

Procedures of optimization using GA can be seen in Figure 3 and could be further explained as follows:

a) An initial population consisting of ten individuals was generated at random.
b) The fitness values of all individuals were calculated using Equation 3.

c) The performance of each individual was evaluated using the elitism strategy, i.e., 60% of all individuals with highest performance was selected and retained for next generation.
d) Crossover and mutation operations were applied to the selected individuals.
e) The new population was created.
f) Steps (b) to (d) were repeated until the required generation number achieved. An optimal value was given as an individual with highest fitness.

3 Results and Discussion

3.1 Identification Process by using ANN

The training process was carried out using the following ANN parameters: learning rate = 0.6, momentum value = 0.6 with total iteration of 1000 and seven nodes of hidden layer. Figure 4 shows the identification results in the response of TSS value and fruit fresh weight to the EC values, plant spacing and light intensity. The data used in the test was independent from the training data.

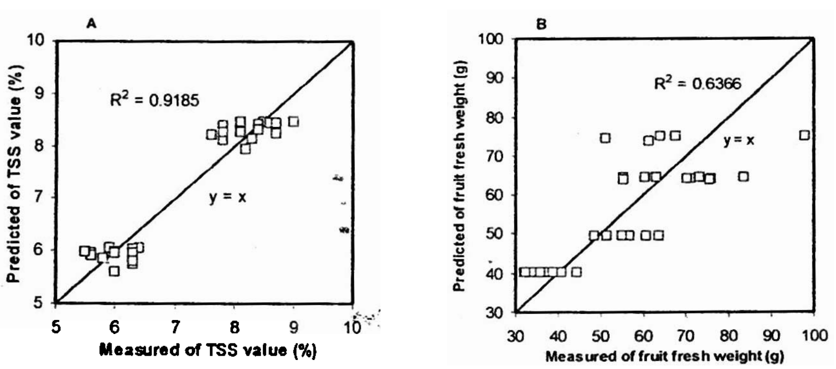

Figure 4 Comparison between measured data and predicted data by ANN models; A: TSS value: B: fruit fresh weight.

It can be seen in Figure 4 that the coefficients of determination (R^2) values for TSS value and fruit fresh weight are 0.9185 and 0.6366, respectively. Overall, it was found that the predicted data were closely related to measured data. This result means that a reliable computational model could be obtained for predicting TSS value and fruit fresh weight.

3.2 Optimization Process by using GA

As explained in the previous section, GA was used to determine the optimal EC value in flowering (EC_1), fruiting (EC_2) and harvesting (EC_3) stages. GA searched the optimal EC value by interval $1.4 \leq EC_1 \leq 9.6$; $2{,}2 \leq EC_2 \leq 10.2$; $2.1 \leq EC_3 \leq 9.7$ mS/cm. GA operators (crossover and mutation rate) are important factor for the algorithm to perform the optimization satisfactorily. The crossover rate (Pc) was selected to be 0.6, while mutation rate (Pm) was selected to be 0.05, respectively. By those values, expectedly, both the diversity of individuals and a global optimum can be reached.

Figure 5 shows the evolution curves during the search for an optimal value of the fitness. The fitness value increased sharply from the first to 12^{th} generation and reached the maximum value at 22^{nd} generation. From 12^{th} to 22^{nd} generation, the fitness value increased gradually from 1.0563 to 1.0604. After 22^{nd} generation, the fitness value reached its constant value (1.0604).

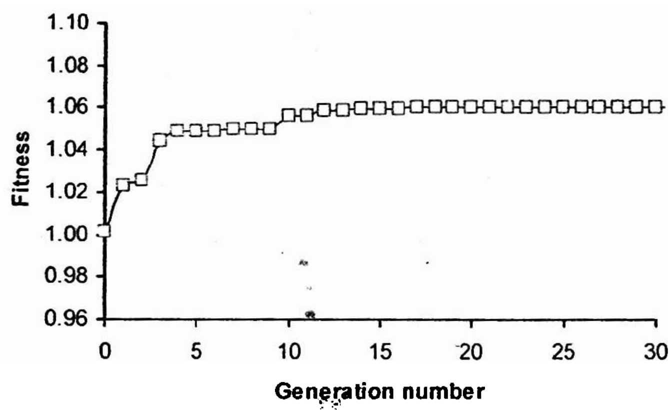

Figure 5 Evolution curves in searching for an optimal value of fitness function.

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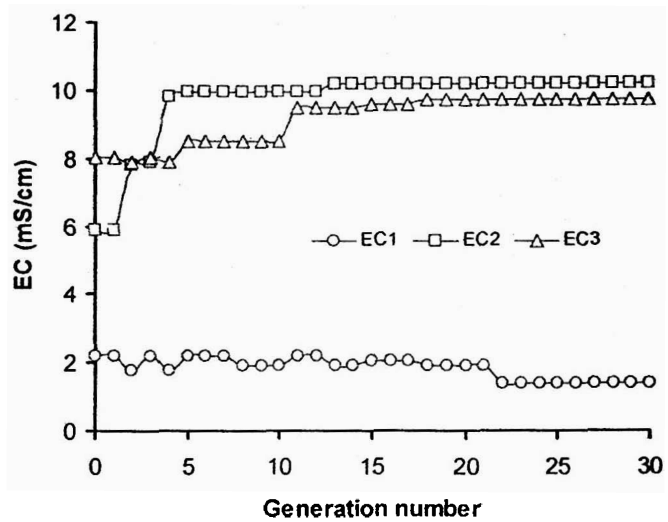

Figure 6 Evaluation curves in searching the optimal EC values on each generative growth stage.

Figure 6 shows the evolution curves during the search for the optimal EC values on each generative stage. GA optimizer recommended maintaining a markedly lower level (1.4 mS/cm) at flowering stage (EC_1), and a slightly high level at both fruiting and harvesting stages. The optimal EC values were 10.2 and 9.7 mS/cm at the fruiting and harvesting stage, respectively. In hydroponics system, it is known that the concentration of nutrient solution is one of the most important control factors for adjusting the balance between the vegetative and generative growth [17]. In the vegetative growth, as explained previously, plants focus on the development of root, stem and leaf. Therefore, maximum water uptake by root is needed. However, the low EC value is essential for the plants. The flowering stage is the first stage after vegetative stage. In this stage, the low EC value could be effective in suppressing the excessive vegetative growth. On the other hand, the high EC value in the fruiting and harvesting stages appears to be useful in accelerating generative growth. By this reason, however, the result of GA optimization clearly maximized fitness.

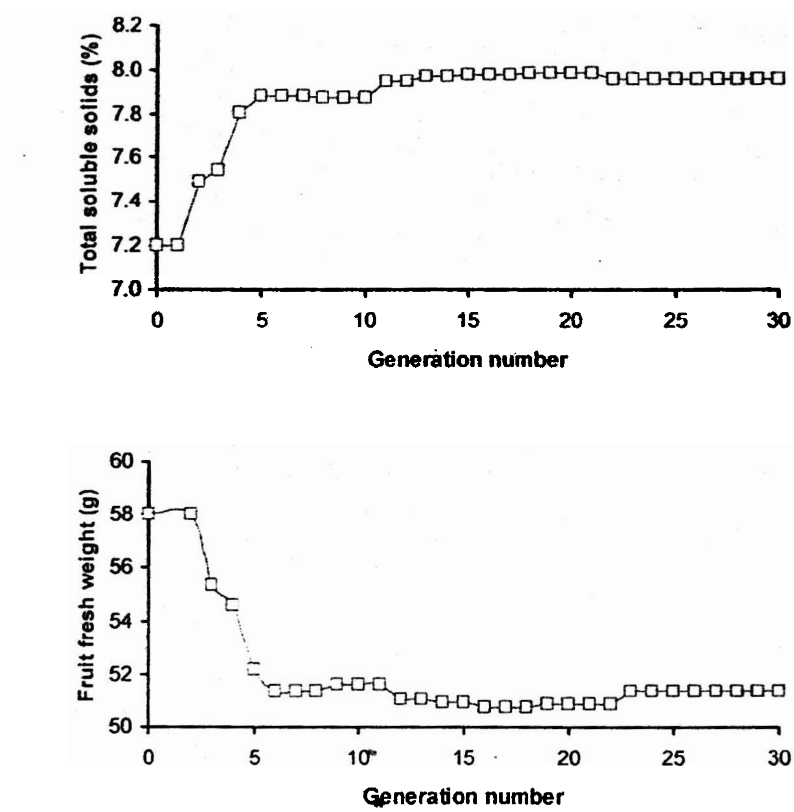

Figure 7 The estimated TSS value and fruit fresh weight to the optimal EC value.

Figure 7 shows the estimated TSS value and fruit fresh weight results calculated through the simulation using ANN model. The upper figure is the estimated TSS value of tomato fruit. The lower figure is the estimated fruit fresh weight of tomato fruit. By the optimal EC value, it was estimated that the results of TSS value and fruit fresh weight were 7.9% and 51.34 g, respectively. These results indicated good quality of tomato fruit suitable to be produced.

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4 Conclusion

A computer program for optimization of EC values of nutrient solution on hydroponics system was developed using Artificial Neural Network (ANN) and Genetic Algorithms (GA). ANN was used to identify the relationship between differences EC value treatments with TSS value and fruit fresh weight. GA was applied to determine the optimal EC value. The ANN model consisted of three layers with seven nodes of hidden layers. The results indicated that the predicted data were closely related to measured data. GA model successfully searched the optimal EC values in flowering, fruiting and harvesting stages that were for 1.4 mS/cm, 10.2 mS/cm and 9.7 mS/cm, respectively.

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Education of Agricultural Technology for Improving Food Security of Kinship Groups in Jayawijaya Regency, Irian Jaya, Indonesia

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1. Introduction

In remote rural areas of Jayawijaya Regency, Irian Jaya, Indonesia, food security problems are crucial because of died toll occurred in 1997 during prolonged dry season. Similar disaster should be avoided eventhough the same unfortunate season occurred. Education of agricultural technology has been performed based on local needs to improve food security of kinship groups in the regency. The primary value of cooperation among the members in a kinship group should be a significant force in formation of an agricultural cooperative. Empowerment efforts has been done to integrate education of agricultural technology with the primary value. This paper describes these efforts as a model of education of agricultural technology in early stage of development of agricultural cooperative.

2. Jayawijaya Regency

Geographically, Jayawijaya Regency is located in 3°20' to 5°12' south latitude and 137°19' to 141° east longitude. It is located in the central highlands of Irian Jaya Island. The altitude of the regency is in the range of 1400 to 2200 m above sea level. Administratively, Jayawijaya Regency is consisted of 28 districts, which are divided into 571 villages and 6 urban villages. Total area of the regency is 52916 square km, with total population of 465800 it accounts for the density of 8.8 per square km. Average annual population growth has been 3.2 %.

In the regency, peoples belong to Dhani and Lani tribes. The typical culture of them is highlanders. They are not willing to leave the hill where they live because the bodies of their ancestors had been buried in the hill. This causes very hard difficulty in providing health, education, or any other service for them. Agriculture has close links to people's perceptions of society. Land is not owned individually, nor is it always clear which group of people has a claim. Land is controlled by the patrilineage, which grants use rights to its members. The overall right to grant the use rights rest with the lineage chief. However, the decision to open new garden land requires deliberation of all members of a particular kinship group who have acquired use rights through common descent or marriage affiliation. The garden site is divided among the cultivators according to the number of wives of each male shareholder. The borders of each plot are indicated by trees and stones. Particularly, swine established the exchange of women between kinship groups through marriage arrangements.

The regency is affected by humid tropical climate with high temperature and high relative humidity. The average temperature has been reported as 19.3 °C, while the maximum and minimum figures have been reported as 25.6 and 14.5 °C, respectively. The average relative humidity has been 86 %. The average monthly precipitation has been reported as 125 to 165 mm, with the average rainy day of 16 per month.

Sweet potato is the all-pervading crop. There are more than 60 cultivars of *Ipomoea* in the regency. For baby food, sweet and soft cultivars with a colored flesh are preferred. The cultivars fed to swine are big and fibrous. Its are for humans during food shortages only (Schneider *et. al.,* 1993). Other crops appear mostly in mixed cultivation with sweet potato, which is present in most fields. Traditionally, the main source of carbohydrate for daily menu of the peoples in Jayawijaya Regency is sweet potato. As can be seen in Table 1, about 82 % of the agricultural land in Jayawijaya Regency are covered with sweet potatoes.

Table 1. Cultivation area, harvest area, productivity, and production of crops in Jayawijaya Regency, 1998.

	Cultivation area (ha)	Harvest area (ha)	Productivity (ton/ha)	Total Prod. (ton)
Sweet potatoes	50 866	48 831	8.06	393 624.52
Wet land paddy	351	340	3.23	1 098.00
Dry land paddy	51	49	1.60	78.30
Corn	753	730	1.21	886.29
Cassava	361	347	8.37	2 902.25
Peanut	560	538	1.08	587.77
Soybean	535	519	1.04	542.00
Vegetables	8 081	7 758	7.09	54 987.79
Fruit	586	637	11.40	72 60.34

Source : Agency of Food Crops and Horticulture, Jayawijaya Regency, 1999

There are two basic types of cultivation systems can be distinguished according to their ecological setting. The techniques that have been developed for each of them are the valley-floor cultivation and the slope cultivation. In the Baliem Valley the drainage of the otherwise swampy or muddy soil is highly developed. After the clearing and burning of the secondary vegetation, the soil is tilled. The peoples raise small beds by deeply dug drains. Whole sections or compounds of 4 to 10 hectares are drained in this way and divided by a system of main ditches. Apart from the control of water level, the system allows to control soil moisture. This restores the soil fertility by using mud and green manure from the ditches. Slope cultivation is done by planting on beds with or without tillage on medium to very steep and/or stony soil. Drains run across contour lines. Therefore, erosion rates are high and the fertility of the land drops very fast.

Wamena, the capital town of the regency can only be reached from Jayapura, the capital city of the province by aircraft. Land transportation from Wamena to the neighboring districts is very limited. Transportation from almost all the districts to Wamena is by small aircraft. Some villages in these areas can only be reached from local airstrip by foot in three to four days (Table 2).

Table 2. Estimated time to reach typical villages from the location of airstrip in the District of Anggruk and Ninia, Jayawijaya Regency

From District Airstrip	To Village	Estimated time (hr) to reach by foot
Anggruk	Ponteknima	12
Anggruk	Nipsa	36
Anggruk	Nalca	84
Ninia	Holuwon	6
Kurima	Sumo	48

3. Disaster in Remote Rural Highlands

In remote rural of Jayawijaya in the central highlands of Irian Jaya, food security is a severe problem. The severe problem of food security is caused by longstanding very poor accessibility. In these remote rural highlands, the productivity of sweet potato in slope cultivation is low. On the other hand, the peoples have no habit to storage sweet potato. They harvest only an amount of sweet potatoes to be consumed within a day after the harvest. They transplant almost everyday and harvest the sweet potatoes also almost everyday. Such a traditional cultivation system of sweet potatoes is critical when a prolonged dry season as well as a serious morning frost occurr.

In 1997, the dry season struck Kurima, Tiom, Ninia, Anggruk, Mapenduma, and Kenyam Districts for about six months, longer than the usual three months a year in normal condition. As a result, the sweet potato plants were exposed under prolonged water stress before finally dried. On the other hand, the health status of the people was not good enough. Then, a died toll account for more than 100 peoples occurred. Table 3 shows the list of villages that had been exposed under the prolonged dry season in 1997. It was very difficult to bring food for the people who live in such remote highlands. Some emergency efforts were conducted to send fresh sweet potatoes, dried cassavas, and instant noodles from outside of the regency even from Java Island. However, all of these products were not suitable for them. Fresh sweet potatoes were damaged while dried cassavas and instant noodles were not matched to their taste. In addition, fulfill them with these foods for a long period of time may weaken their self-reliance on food.

Table 3. List of villages that had been exposed under the prolonged dry season in 1997.

No	District	No	Village	Population	Agric. land (ha)	Seriously damaged crop (ha)
1	Kurima	1	Soba	3.713	237	59
		2	Seima	2.172	136	34
		3	Ibiroma	1.064	68	17
		4	Tangma	3.285	210	105
		5	Juarima	1.566	100	25
		6	Obolma	3.039	195	48
		7	Pasema	3.701	237	213
		8	Ukha	1.309	84	20
		9	Userem	1.813	116	29
		10	Tolikapura	7.936	508	126
		11	Samenage	3.586	230	206
		12	Hihundes	728	47	11
		13	Lokon	2.964	190	47
		14	Wanem	690	44	39
		15	Anjelma	1.819	116	58
		16	Paima	700	45	6
		17	Yogosem	495	32	4
		18	Sumo	1.241	79	11
		19	Amuma	3.973	254	38
		20	Memnowok	2.632	168	25
		21	Mogi	2.301	160	24
	Sub total			*50.727*	*3.256*	*1.145*
2	Tiom	1	Balingga	3.040	195	28
		2	Kuyawage I	2.581	165	148
		3	Kuyawage II	1.784	114	102
		4	Oyi	846	54	40
		5	Nobo	1.355	87	43
		6	Gubo	1.013	65	32
	Sub total			*10.619*	*680*	*393*
3	Ninia	1	Ninia	4.237	271	244
		2	Korupun	6.693	428	385
		3	Holuwon	3.134	201	180
		4	Yabi	2.650	170	152
		5	Kabianggama	2.662	170	153
		6	Langda	1.225	78	70
		7	Bomela	2.553	144	129
		8	Wanim	1.380	88	79
		9	Suntamon	1.526	98	87
	Sub total			*26.060*	*1.648*	*1.479*
4	Anggruk	1	Yaholikma	1.160	74	11
		2	Hereki	958	61	9
		3	Mimbaham	1.407	90	13
		4	Hereapini	2.465	158	23
		5	Palentum	1.273	81	12
		6	Ubahak	3.138	201	30
		7	Saruk	1.531	98	14
		8	Walma	1.480	95	14
		9	Solinggul	1.044	67	10
		10	Siwikma	2.825	181	27
		11	Piliam	1.402	90	13
		12	Pontenpelek	1.096	70	10
		13	Pontenikma	7.099	454	68
		14	Kosarek	1.253	80	12
		15	Nahomas	2.182	140	20
		16	Sosomikma	653	42	6
		17	Pini	764	49	7
		18	Konda	898	57	8
		19	Endoman	2.103	135	20
		20	Nipsan	2.896	185	27
		21	Lelambo	1.234	79	11
		22	Tibul	662	42	6
		23	Sobundalek	7.546	483	72
		24	Nalca	1.514	97	14
	Sub total			*48.583*	*3.109*	*457*
5	Mapenduma	1	Jigi I	1.287	82	74
		2	Jigi II	1.079	69	62
		3	Mapenduma	2.996	192	143
		4	Mugi	2.997	192	172
	Sub total			*8.359*	*535*	*451*
6	Kenyam	1	Kenyam I	2.471	158	23
		2	Kenyam II	2.954	189	28
		3	Ndugwa	1.417	91	13
	Sub total			*6.842*	*438*	*64*
TOTAL				*151.190*	*9.666*	*3.989*

The most serious frost struck Kuyawage District in 1979 or 1982, in 1989, and in 1992. Kuyawage is located at 2700 m above sea level where the fragile balance of crop can be readily observed. For the period before 1979, no reliable information could be obtained. It appears that there were 3 or 4 frosts in the last 15 years.

4. Food Security Improvement

To prevent the same disaster that occurred in 1997 in Jayawijaya Regency, Bogor Agricultural University proposed to the Government of Indonesia an improvement of food security as a part of the government measure to overcome the food crisis. It was mainly consisted of the establishment of Emergency Food Station (EFS) based on local resources (Fig. 1). In 1998, the proposal was accepted. The EFS then was installed in Baliem Valley of Jayawijaya Regency in central highlands of Irian Jaya, during the fiscal year of 1998/1999. The activities of the EFS were the improvement of cultivation method, the improvement of post-harvest handling, the development of small-scale food industry, and the improvement of distribution system.

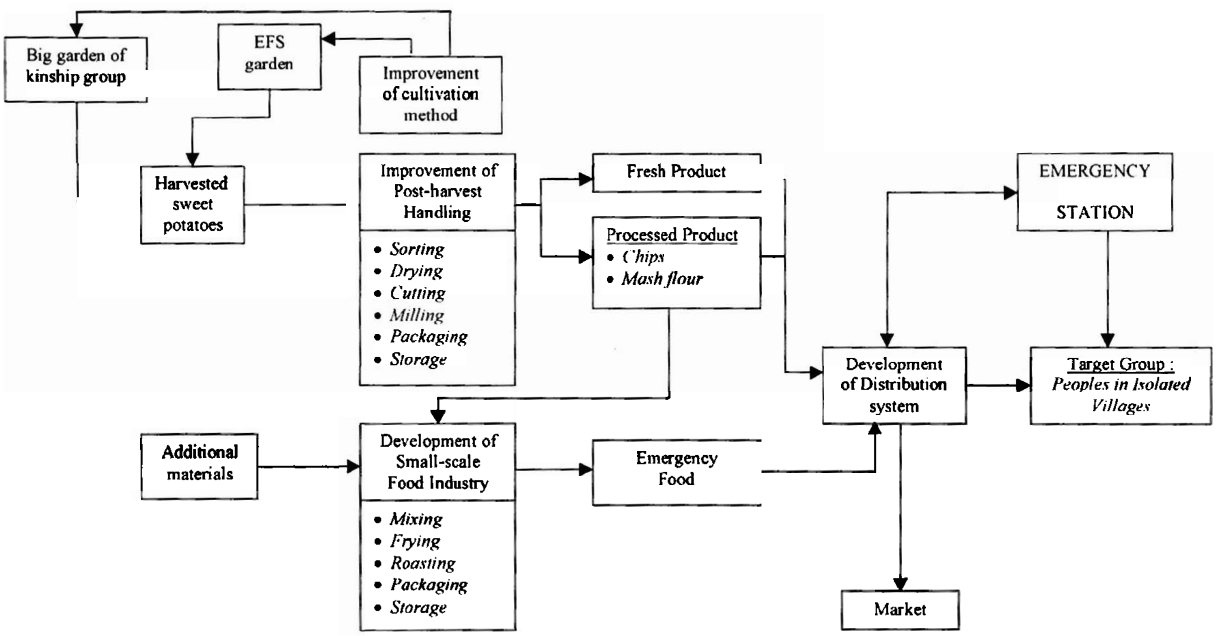

Fig. 1. Overall view of establishment of the Emergency Food Station (EFS)

4.1. Improvement of cultivation method

Average productivity of sweet potatoes in Jayawijaya Regency was reported at 8.06 ton/ha, while the productivity in local experimental farm was reported at 14.4 ton/ha. The regency can only be reached from the capital of province by aircraft. Therefore, agricultural production should consider to minimally using external inputs. The agricultural development strategy should be based on LEISA (Low External Input Sustainable Agriculture).

Traditional cultivation method should not be changed drastically. A gradual improvement of cultivation method may be important. It has been done to improve the fertility of soil by using compost. The method to produce compost had been introduced. The farmers had been trained to make compost from leafs, swine disposals, and limestone in the amount sufficient for their own land. It needs a lot of compost to improve the fertility of soil. The soil is predicted to need the application rate of 5 ton compost/ha. Therefore, to improve the fertility of the soil in 90 ha cultivation area under EFS supervision 450 ton of compost is needed. Fertilizers have not been introduced in this program, because it may cause the local farmers to be dependent to external input. Any introduction of external output should be carefully done because, at present, the regency can only be reached from another town/city by aircraft. A land transportation system to Jayapura has been initiated but it is not functional yet. Careless intervention might bring the regency into continuous dependency.

On the other hand, there are some idle land covered with grass. An increase in power input should be given to extend the cultivation area. In the idle land, the grass should be cut and the soil should be tilled. Because of lack in local human work force, agricultural hand-tractors had been introduced. The hand tractors have been used in limited level, especially to extend the cultivation area, which was almost impossible to be achieved by only human work force in short time. In order to achieve a proper use of hand-tractors, a training program for operators had been conducted. In addition, a workshop for maintenance and small repair had been installed.

4.2. Improvement of post-harvest handling

The most critical chain in sweet potato production in the regency is the post-harvest handling. The peoples harvest sweet potatoes whenever they need in the amount for that day or the following day. In other words, they *store* sweet potatoes inside the soil in their land. This tend to be a dangerous situation during a prolonged dry season. Therefore, an improvement of post-harvest handling had been done. It included cleaning, sorting, cutting, drying, milling/grinding, packaging, and storage (Fig. 2). The main objective of these activities was to increase the quality of product to be stored in a longer period of time.

In order to overcome a dangerous situation during prolonged dry season, emergency foods had been introduced. The emergency food should meet the following characteristics: (1) acceptable to the local peoples, (2) can be stored for a long period, (3) made from local agricultural product, (4) easy to produce and distribute, (5) low production cost, (6) rich in nutrient content. Sweet potato chips, sweet potato flour, and mashed sweet potato had been introduced as emergency foods. It should be cooked before serving. For emergency situation, ready to consume food may be suitable. Therefore, sweet potato cookies, sweet potato in jar, roasted sweet potato had been introduced. EFS had been equipped with machineries for post-harvest handling: slicer, screw mill, mixer, molder, oven, fryer set, etc. Greenhouse-effect solar drier had also been installed at the EFS.

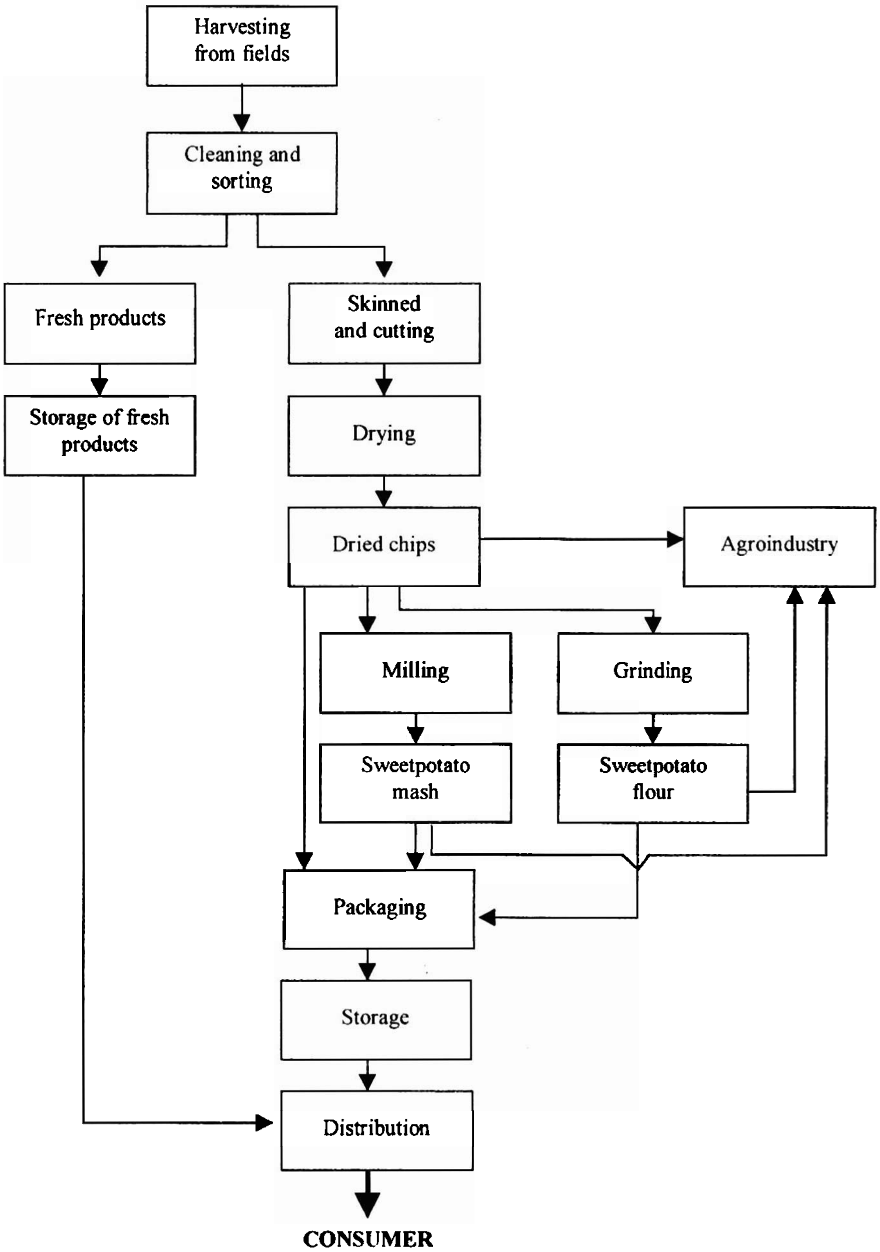

Fig. 2. Schematic diagram of sweet potatoes handling in the EFS

4.3. Development of small-scale food industry

The EFS has been developed as a small-scale food industry. The sweet potato processing line included mixing, roasting, frying, packaging, and storage (Fig. 2). The main objective of these activities was to produce ready to consume foods from sweet potato. The EFS should operate during emergency situation as well as in normal condition. Therefore, it should produce not only emergency food, but also food for sale. In normal condition, the EFS should also be a small-scale food industry. It is important to manage the EFS as a food industry in order to be a self-sufficient unit and to socialize the products. In addition, efforts have been made to introduce products from the EFS to consumers in Jayapura. An approach to strengthen pull factors has been performed to develop the food industry.

4.4. Development of distribution system

Beside the EFS, emergency food storage had been built in remote villages to form a complete distribution system. It is also proposed to open airstrips in some villages. In pre-emergency situation, emergency food may be transported from the EFS and stored in the storage. In addition, an early warning system is proposed to overcome food crisis in the regency as well as the province.

5. Education of Agricultural Technology

5.1. Education of Agricultural Technology in EFS

A training facility had also been built in the EFS to facilitate training program for farmers from the neighboring villages. The education of appropriate agricultural technology includes: (1) improvement of cultivation method, (2) improvement of post-harvest handling, (3) production of emergency food. Appropriate agricultural technology may be used to support rural development in order to achieve self-reliance on food. The technology plays an important role in food production by improving quality and quantity of products through increasing the intensity of cropping, minimizing the plant disease, reducing the harvest loss, and increasing efficiency. However, implementation of agricultural technology in Jayawijaya Regency should consider the cultural background of the people.

5.2. Technological and Cultural Perspectives

There are no limits to the number of perspectives that may exist in social intervention through introduction of agricultural technology. However in Jayawijaya Regency, two perspectives: the technological and the cultural account for the major concern.

Underlying the technological perspective is the image of production. Therefore, this is conceived as a relatively mechanistic process. Social relationships are based on technological necessity. The concern is economic and the primary value is efficiency. Underlying the cultural perspective is the image of community. Social relationships are traditional. Integrity of the culture is a primary value (House and Mathison, 1983).

The technological perspective assumes that there is considerable consensus in both interests and values. It is assumed that everyone shares a common interest in advancing interventions and that everyone operated from a common frame of values. For the case in Jayawijaya Regency, because of wars among tribes in the past, the cultural perspective assumes a more fragmented society, more valu consensus within groups. Land is not owned individually, nor is it always clear which group of people has a claim. There are many cases of protracted negotiations between the local government officers and the lineage chief, which are clear evidence for the determining role of kinship groups in land use and land allocation. The land for EFS is one of the example cases. The separate groups do not share a value system or a common way of resolving conflicts. A common agreement is problematic since the different groups may not understand each other. The only problem is to find how best to achieve a solution that ensures welfare for the community. Education of agricultural technology should consider local values in selecting the technological packages.

5.3. Partnership in Education of Agricultural Technology for Kinship Group

Parallel organizations play an important role to maintain the actors in agribusiness in a healthy relationship. Therefore, margin distribution among actors should be reasonable. Parallel organizations should not interfere these relationships, but it is important for them to develop incentive-disincentive system to realize the healthy relationship. Local non-government organization (church organization, social workers, etc.) should be included in the partnership. The schematic diagram of the developed partnership is presented in Fig. 3.

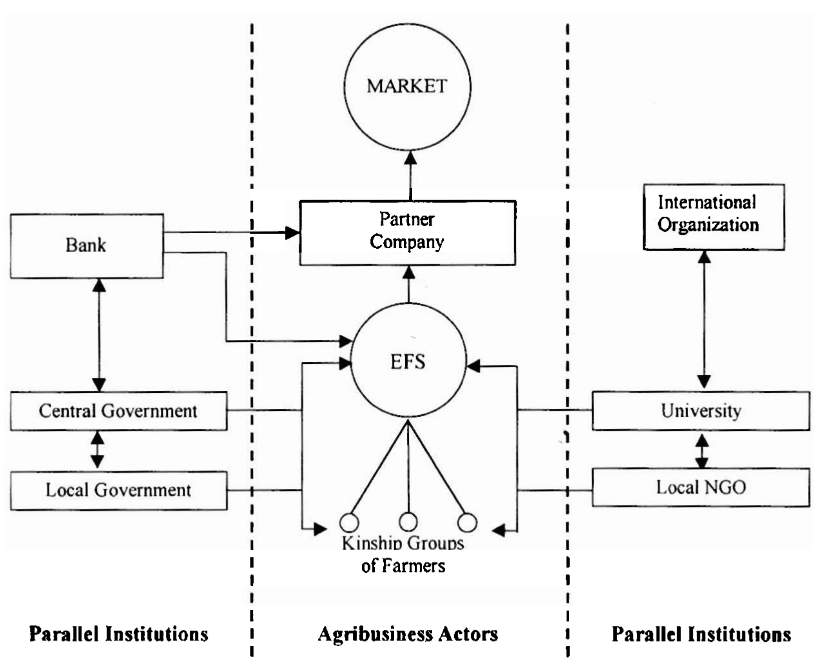

Fig. 3. Schematic diagram of the developed partnership

6. Concluding Remarks

The EFS installment and initial operation were running well. However, because of the prolonged difficulties in government revenue, there was no budget for the EFS in the next fiscal year

(1999/2000). Efforts have been made by Bogor Agricultural University not only to maintain the EFS in operation but also to prepare human resource to operate it in the future. The university is giving scholarship to two local officials in the Agency of Food Crops and Horticulture, Jayawijaya Regency to be the student in the university. A communication with Sustainable Agriculture Development Project (SADP), funded by the Asian Development Bank (ADB) had been initiated. Fortunately, there is Disaster Mitigation Component (DMC) activity as a part of the SADP designed to develop remote rural highlands, which is inline with our initial concept. In 2000 fiscal year, the university is assigned by the SADP to conduct baseline survey for the DMC locations. A comprehensive cooperation should be done among institutions having similar program for the kinship group.

The education of agricultural technology has been successfully initiated the food security improvement among kinship groups in the remote rural highlands of Jayawijaya Regency through the installment of Emergency Food Station (EFS) based on local resources. An incentive system should be develop for kinship groups to maintain their primary value in cooperation. Involvement of university and local NGO to learn more detail about the local values leads to give a significant contribution to maintain the sustainable operation of the EFS.

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