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COMPLETE REPORT

PROGRAM IN SCIENCE AND TECHNOLOGY COOPERATION

COLLECTION AND UTILIZATION OF TAMARIND GERMPLASM

PROPOSAL NO.5.243

GRANT NO. 936-5542-G-00-6026-00

SUBMITTED BY

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Project Profile

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PREFACE

The project of Collection and Utilization of Tamarind Germplasm was granted by USAID under the Program on Science and Technology Cooperation from 1986-1989.

Tamarind is a specy of plant in Family Leguminosae which is greatly under-exploited and it is extensively utilized in Asia and Africa but unknown elsewhere.

Fortunately, it was realized by USAID concerning it high potential of utilization. Hence, the research and development of tamarind has been carried out in order to enhance its economic potential as a cash crop in the future.

In this project, large number of superior accessions of both sweet and sour types of tamarind have been collected from all over Thailand and neighboring countries.

Sweet tamarind plantation in Thailand has been established and developed into commercial scale more than 25 years, so it is evident that tamarind has been adapted and distributed in this part of the world for a long time.

Besides the collection of tamarind germplasm, the Rhizobium investigation is an interesting part of the project.

We are grateful to USAID for kindly supporting this research project which made this investigation possible.

We are also highly indebted to Professor Dr. Knud E. Clausen, Research Geneticist, North Central Forest Experiment Station, U.S.D.A for his help and special assistance in preparing the full project proposal.

Our grateful thanks are due to the former Director and present Director, Science and Technology Division, Office of Technical Resources, USAID, Thailand, Professor Dr. Ernest Briskey Mr. R.F. Barnes and Mr, Win McKeithen for their administrative supports during the course of the investigation.

We are grateful to Dr. Jaroon Kumnuanta and Dr. G.L. Hiebert, Science and Technology Division, Office of Technical Resources, USAID, Thailand, for providing guidance, keen interest, helpful suggestions and constant encouragement during the course of the investigation.

Lastly, we are grateful to Faculty of Agriculture and Khon Kaen University for providing neccessary facilities which made this investigation possible

Dr. Sumrit Feungchan
Principal Investigator

PART 1 COLLECTION AND UTILIZATION

1. INTRODUCTIONS

Tamarind (*Tamarindus indica* L.) is indigenous to the dry savannas of tropical Africa but was introduced to Asia in the ancient time by Arab traders. It was readily accepted by the people in this region due to its pleasant acidic tasting fruit, particularly in India (Bueso, 1980).

The specy also reached the new world long time ago, nd now generally grows in most tropical countries. Throughout most of the tropics, the tree grows untended along road sides, in backyards or on wasteland. However, plantations do exist in India which harvested over 250,000 tons of fruit pulp annually (NAS, 1979), and in Mexico where 37,000 tons of pulp were harvested in 1979 from 4,443 ha. of plantations in six states (Hernandez-Unzon and Lakshminarayana, 1982 A).

It has been widely grown in Thailand from sea level up to 2,000 metres. Most people consider it to be "native" to the kingdom and the pulp has been used by the Thai in their daily lives e.g. for culinary, beverage and medicinal purposes. Most of the production come from untended trees and wild types eventhough a few small scale sweet tamarind orchards have been established recently.

Great genetic diversity has been observed in tamarind types in Thailand. Owing to the recent rural and agricultural development resulting in "genetic erosion" at an alarming rate for various crops in the country including tamarind. The number of good germplasms has been decreased drastically. So that the germplasm collection af tamarind should be urgently carried out and systematically screened for further evaluation.

2. OBJECTIVES

The specific objectives of this Project are to :

1) comprehensively collect *Tamarindus indica* L. germplasms from tamarind trees of known variability in quantity and quality of fruit (both sweet and sour types) and quantity of biomass (size of tree and quantity of leaves) ;

2) evaluate the comprehensive collection of tamarind for genetic variability in rate and extent of growth and production of food and biomass, under comparable condition (accomplished by grafting on rootstocks) ;
3) clone the fast growing, early producing, sweet and sour tamarind types to propagate superior cultivars that yield large amounts of high quality fruit pulp and important sources of biomass for food, fuel or soil conditioning uses ;
4) select and develop dwarf rootstock to be used for grafting and exploiting the selected cultivar, through improved yield per hectare and better cultural management (production and harvesting) ;
5) develop efficient means for culturing the improved rootstock ; and
6) Develop the technology of tamarind production and establish demonstration plots and suitable cultural practices for tamarind plantation

3. MATERIALS AND METHODS

3.1 Germplasm Collection

Most of the tamarind types, both sour and sweet, are grown untended in different parts of Thailand, therefore, it will be necessary to collect germplasm by various means. Gerneral germplasm collection can be made through collaboration with provincial agricultural extention officers, and also by randomized selection from different locations. Apart from the collection in Thailand, germplasm of both sour and sweet tamarind types were collected from abroad such as India and other countries, through the Internatonal Board for Plant Genetic Resources-Sourtheast Asia Regional Committee, FAO Regional Office, Bangkok, Thailand.

After collection of germplasms for a period of 6-12 months, it was anticipated that the enormous amounts of gerplasm collected were ready for experimentation. The germplasms collected were in the form of seed, and scions of individual trees needed for grafting purposes. For germplasms collected from other overseas cooperators, the characteristics of the germplasm as either seed or grafted materials, had accompanied the germplasm being sent, using data sheets described by the International Tropical Fruit Descriptors (1979) with some slight modifications.

3.1.1 Study of pod specimens

Collection of pod specimens of sour tamarind had been done. Pod specimens were studied in various catejories based on International Tropical Fruit Descriptors (1979).

The obtained data had been analysed for grouping the frequencies of the pulp weight, percentage of pulp weight, and number of pods per kilogram in order to formulate the criterion for primary accession screening.

3.1.2 Collection of grafted plants from accessions

A total of 51 accessions of sour tamarind have been selected based on the Real Value of pulp from the different parts of the country. The accessions were carefully examined and only 42 accessions remained for further investigation. All these accessions were propagated by mean of side approached grafting for further evaluation.

3.2 Testing of germplasms

3.2.1 Biomass study

All tamarind seedling specimens for biomass accession selection derived from seeds collected in various parts of the country. By assumption that each specimen might be different in its genotype.

To study the growth of plant both in containers and in the field on each experiment, Completely Randomized Block Design was employed which consisted of 6 replications, 90 treatments, and each treatment composed of 4 plants totally 2160 plants.

For spacing, the field experiment was 2x2 meters where as those using the container were placed closely. The data collection had been recorded every three months on growth of canopy for field experiment. For container experiment, only height of the plants were observed.

The field experiment with Completely Randomized Block Design consisted of 6 replications, 90 treatments, each treatment composed of 4 plants totally 2160 plants at spacing 2 x 2 meters.

The data collection of the field experiment had been done as mentioned above as the container experiment as well. The data were used as the primary criteria for biomass accessions selection. After biomass accession obtained, the stomatal counting (the technique based on Majumder et al., 1972), angle of branches and growth rate were investigated.

3.2.2 Fruit study

3.2.2.1 To observe the accession mother plant at the original site.

To study the performance of the mother plant in pod yield for the preliminary evaluation of accession related to the Real Value of Pulp, tree habits, girth size and shape of canopy, age of plant etc. by using IBPGR Descriptors for Tropical Fruits.

3.2.2.2 To test the accession grafted plants in the field

The grafted accession plants had grown in the testing plot with the Completely Randomized Block Design consisted of 6 replications with 4 plants for each treatment, 44 and 23 treatments for sour and sweet types, respectively. The data had been recorded on growth of grafted plants.

3.2.2.3 To analyse the chemical composition of pulp of sour and sweet types accession.

The chemical analysis of shell, pulp and seed of accessions had been carried out based on the method of AOAC.

3.3 Rootstock study

3.3.1 The search for dwarf rootstock

To search for phenotypic expression of the untended dwarf rootstocks. Fortunately we found one potential dwarf rootstock which will be studied on the morphological characteristics such as the conopy size, internode length and leaf area etc. Eventually, the dwarf characteristic will be continned.

3.3.2 The search for rootstock plants other than tamarind rootstock

To collect and test the other closely related species to tamarind for rootstock studies including those leguminous plants that form nodules.

3.3.3 Chemical treatment for the production of dwarf rootstock

To control canopy size for induction of dwarf tamarind rootstock by using a certain inhibiting substances namely SADH, CCC, MH, and Paclobutarzol. The seeds were treated by prolonged soaking method in solution for 6 hours at various concentrations viz. 1000, 2000, 3000, 4000, and 5000 ppm. The number of 25 seeds were soaked in the different concentrations and required 4 replications. The treated seeds were sown in the containers and growth rate, canopy size, number of stomata etc. were investigated at seedling stage. The experimant had been started on January 1988

3.4 Cultural Practices and Demonstration Plots

3.4.1 Cultural practices

3.4.1.1 To study the effect of plant regulators on fruit setting.

Preliminary study on the effect of different plant regulators and concentrations for the fruit fruit setting of sweet tamarind as following :

4 - CPA	conc.	5,	10,	15 and	20 ppm.
GA_3	conc.	5,	10,	15 and	20 ppm.
NAA	conc.	50,	100,	150 and	200 ppm.
SADH	conc.	500,	1000,	1500 and	2000 ppm.

Each chemical concentration applied to the 5 plants at flowering stage and the number of fruit setting were recorded

3.4.1.2 To study the effect of plant regulators on widening the crotch angles of tamarind.

To control the angles in branching by using the chemical substances with TIBA and BA at various concentrations viz. 25, 50, 75 and 100 ppm, the chemical treated seedling were grown in the experimental plot for observation and data collection on girth, height, diameter, length and number of lateral branches.

3.4.1.3 To study the effect of spacing on growth.

To study the effect of the different space in order to find out the basic data on branching of plant for asexual propagation purpose.

Completely Randomized Block Design had been used with 3 replications and 3 treatments at spacing of 2x1, 2x1.5 and 2x2 meters.

3.4.1.4 To study the young leaf production for human consumption.

By foliar application with defoliant namely Thiourea, Urea, Potassium nitrate, Ethephon and 2,4-D at the rate of different concentrations eg. 50, 100, 150, 200 and 250 ppm.

Completely Randomized Block design with 5 replications, 6 treatments and 20 plants per treatment had been used.

3.4.1.5 To study the change of pulp colour in storage.

The pulp colour was gradually changed from the brown one to black when stored in the room temperature. From this effect, the pulp quality was inferior and its price was reduced. Hence, the experiment had been tried to overcome this problem by using the several means as follow :-

1. Powdered salt : 5, 10, 15, 20, 25 and 30 % (by weight)
2. Steam : 15, 20 and 30 minutes.
3. Sodium metabisulphite 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ppm.
4. Sun dry : 3 days
5. Hot air incubation : 40, 45, 50, 55, 60, 65 and 70 C for 24 hours.
6. Cold storage : 5 and 0 C.

The spectrophotometer was used to determine the changing in colour of tamarind pulp at the initial and final observation on the storage.

3.4.2 Demonstration Plots

The experiment includes two sites of demonstration plots, one in the Khon Kaen University campus and the other in the private orchard. The grafted plant of sweet tamarind type had been planted in the demonstration plot with the spacing of 6 x 6 meters.

4. RESULTS/ DISCUSSION / TABLES :

4.1 Germplasm Collection

4.1.1 Study of pod specimens

Fig. 1,2,3 and 4 had shown that the frequencies of number of pods per kilogram, pulp weight, percentage of pulp weight. The real value of pulp (R.V.*) was used as the criteria in selecting the accessions (see table 1)

From table 1, the real value of pulp is used as the main criterion in specimen ranking. Based on the level of real value of pulp from 10-21, the 23 specimens were selected as accessions for further investigation. The level of real value of pulp of 10 is considered to be the minimum value for this selection with the following reasons : 1) the frequencies from real value of pulp of 10 and upward has shown constant curve, 2) the other criteria such as number or pods per kilogram, pulp weight and percentage of pulp weight have shown in the same trend of good correlation (Fig 1,2 and 3)

R.v.* = Pulp weight x % Pulp weight/100.

Table 1 Physical characters of sour tamarind pod used as primary criteria for accession selection from 689 specimens in 1986

Code	Ave. Wt. of pod (gm)	No. of pod/kg.	Pulp Wt. (gm)	% Pulp Wt.	Real value* of pulp	Rank
86-2-13-001	77.83	12.85	40.80	52.4250	21.3894	1
86-2-13-019	83.18	12.02	36.70	44.1210	16.1924	2
86-2-13-018	78.86	12.68	35.51	45.0360	15.9941	3
86-2-08-095	32.92	30.38	22.31	67.7700	15.1195	4
86-2-13-020	58.03	17.23	29.21	50.3461	14.7061	5
86-2-08-038	22.92	43.63	18.20	79.4070	14.4521	6
86-2-13-015	57.98	17.25	28.13	48.5240	13.6513	7
86-2-13-008	50.59	19.77	26.17	51.7360	13.5398	8
86-2-13-002	53.33	18.75	26.70	50.0700	13.3687	9
86-2-13-009	61.73	16.20	27.03	43.7900	11.8378	10
86-2-08-077	41.69	23.99	22.19	53.2200	11.8095	11
86-2-13-017	53.40	18.73	24.93	46.6760	11.6340	12
86-2-13-011	54.84	18.23	25.20	45.9520	11.5799	13
86-2-08-028	50.78	19.69	24.18	47.6120	11.5120	14
86-2-13-004	51.19	19.54	24.21	47.2940	11.4499	15
86-2-08-008	51.73	19.33	29.28	46.9310	11.3925	16
86-2-08-047	45.40	22.03	22.68	49.9560	11.3300	17
86-2-13-005	38.72	25.83	20.73	53.5380	11.0984	18
86-2-08-178	47.15	21.21	22.40	47.5080	10.6418	19
86-2-08-083	43.71	22.88	21.38	48.9090	10.4558	20
86-2-08-183	38.42	26.03	19.96	51.9520	10.3686	21
86-2-08-016	47.54	21.03	21.93	46.1290	10.1161	22
86-2-13-014	73.68	13.57	27.20	36.9190	10.0420	23

R.V.* = % Pulp Wt. x Pulp Wt./100

Fig.1 Study of pod specimens

(689 specimens from 9 provinces in the Northeast, 1986)

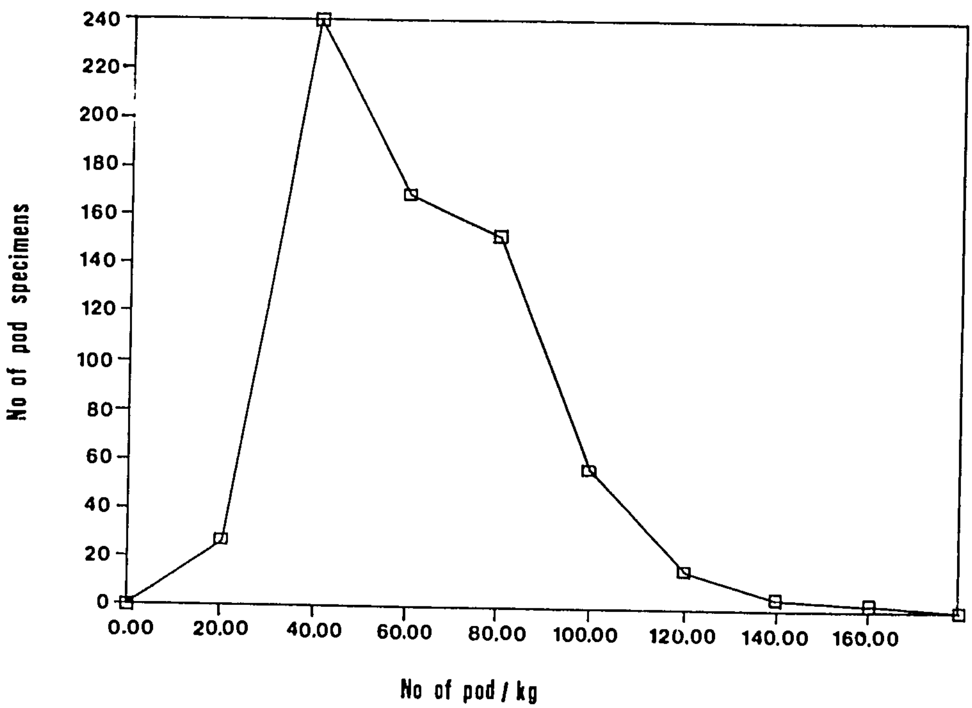


Fig.2 Study of pod specimens
(689 specimens from 9 provinces in the Northeast, 1986)

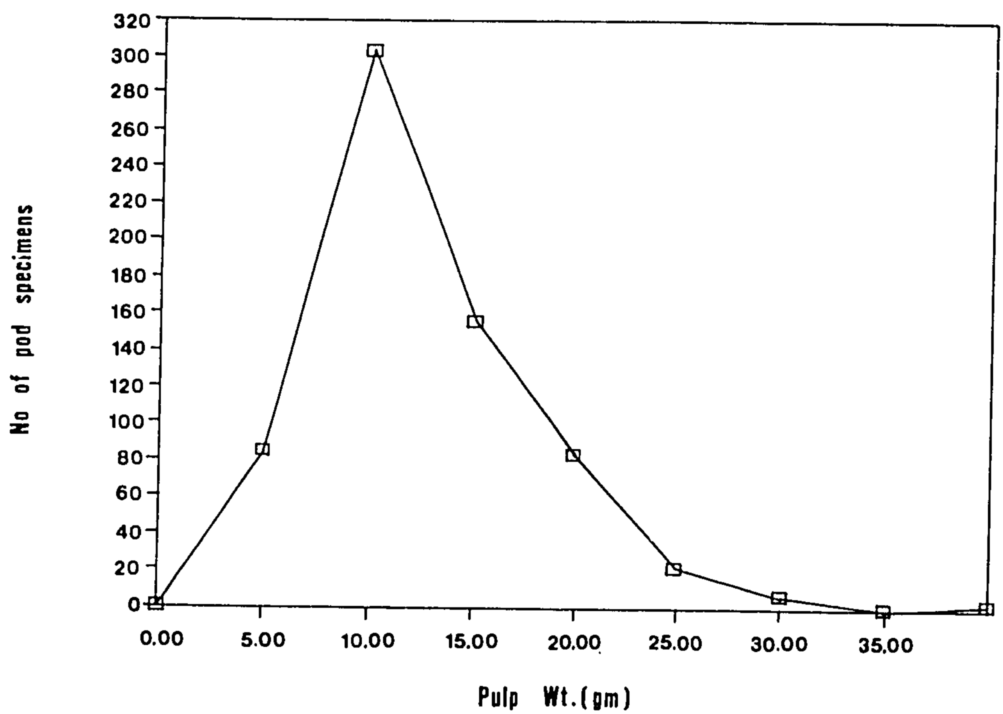


Fig.3 Study of pod specimens

(689 specimens from 9 provinces in the Northeast, 1986)

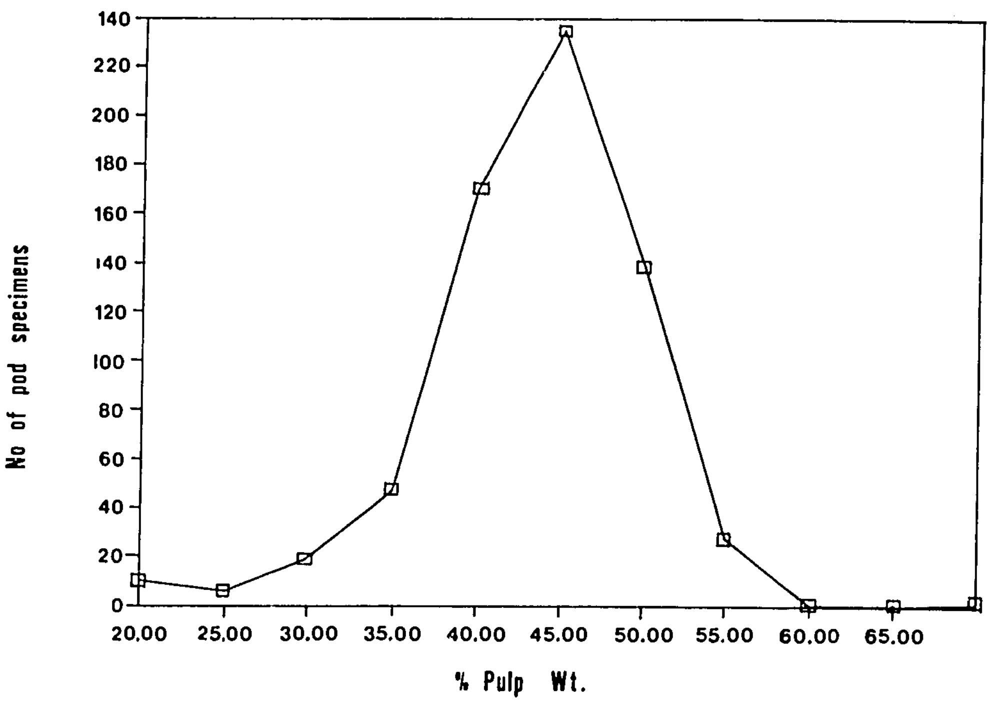
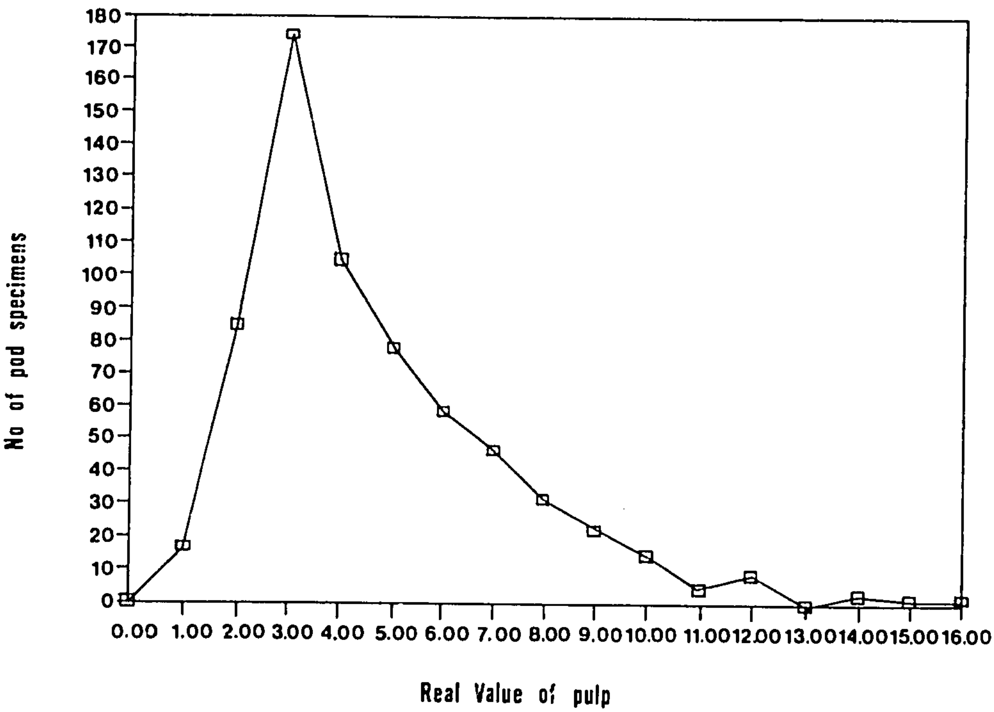


Fig.4 Study of pod specimens

(689 specimens from 9 provinces in the Northeast, 1986)



4.1.2 Assessment of pod specimens.

The collecting mission undertook the specimens collection through the collaboration with provincial agricultural extension officers throughout the country during October 1986 - February 1987 by providing the specimens which obtained from competition and collection (table 3). However, a number of specimens were discarded because they were undersized. (more than 30 pods per kilogram.)

The table 1 has shown that the number of 689 specimens were collected from 9 provinces in the Northeast of Thailand, 1986. From these specimens, 23 specimens were selected as accession table 1 based on Real Value of pulp which is above 10. Similary to the data in table 2 and 4 the number of 21 accessions were derived from 1,122 specimens in table 2. Also in table 5 ,7 selected accessions were obtained from competition it could be seen from summarized table 6-7. *It is noticed that the excellent accession has the RV as high as 21 and the number of pod is from 13-15 pods per kilogram.* Most of the accessions were found in the area along the Me Kong River as shown in Fig. 4. Besides this the sweet tamarind specimens were also collected.

Table 2 Number of specimens collected in 1986-1987

Name of provinces	Sour type: No. of specimens from compettion		Sour type: No. of specimens from collection		Sour type: No. of selected specimens for analysis		Sweet type: No. of specimens from competition		Sweet type: No. of specimens from collection		Sweet type: NO. of selected specimens for analysis	
	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987	1986	1987
1.Roi Et	-	-	55	-	55	-	-	-	-	-	-	-
2.Buri Ram	-	-	70	-	70	-	-	-	-	-	-	-
3.Chaiyaphum	-	-	41	-	41	-	-	-	-	-	-	-
4.Loei	-	-	96	-	96	-	-	-	-	-	-	-
5.Mukdahan	-	-	203	-	203	-	-	-	-	-	-	-
6.Nakhon Ratchasima	-	-	42	-	42	-	-	-	-	-	-	-
7.Nong Khai	-	-	85	-	85	-	-	-	-	-	-	-
8.Sakon Nakhon	-	-	92	-	92	-	-	-	-	-	-	-
9.Udon Thani	-	-	5	-	5	-	-	-	-	-	-	-
Total	-	-	689	-	689	-	-	-	-	-	-	

Note - specimens obtained in form of pod.

Table 3 Number of specimens collected in the year 1986-1987

Name of regions and provinces	Sour type: No. of specimens from competition 1986	Sour type: No. of specimens from competition 1987	Sour type: No. of specimens from collection 1986	Sour type: No. of specimens from collection 1987	Sour type: No. of selected specimens for analysis 1986	Sour type: No. of selected specimens for analysis 1987	Sweet type: No. of specimens from competition 1986	Sweet type: No. of specimens from competition 1987	Sweet type: No. of specimens from collection 1986	Sweet type: No. of specimens from collection 1987	Sweet type: No. of selected specimens for analysis 1986	Sweet type: No. of selected specimens for analysis 1987
<u>North-Eastern</u>												
1.Nong Khai	-	59	85	-	85	7	-	25	-	-	-	4
2.NaKhon Ratchasima	-	95	42	-	42	-	-	-	-	-	-	-
3.Udon Thani	-	85	5	21	5	-	-	-	-	-	-	-
4.Mukdahan	-	116	203	-	203	31	-	86	-	-	-	-
5.Kalasin	-	61	-	-	-	11	-	21	-	-	-	3
6.Ubon Ratcha-	-	144	-	-	-	84	-	176	-	-	-	6
7.Yasothon	-	78	-	-	-	18	-	-	-	-	-	-
8.Roi Et	-	-	55	3	55	3	-	-	-	-	-	-
9.Maha Sarakham	-	31	-	-	-	7	-	-	-	-	-	-
10.Nakhon Phanom	-	-	-	17	-	17	-	-	-	-	-	-
11.Sakon Nakhon	-	-	92	55	92	55	-	-	-	-	-	25
12.Loei	-	50	96	-	96	-	-	6	-	-	-	-
13.Buri Ram	-	-	70	-	70	-	-	-	-	-	-	-
14.Chaiyaphum	-	-	41	-	41	-	-	-	-	-	-	-
<u>Northern</u>												
1. Phetchabun	-	15	-	-	-	8	-	151	-	-	-	-
2. Phichit	-	-	-	1	-	1	-	-	-	-	-	-
3. Chiang Rai	-	142	-	5	-	-	-	-	-	-	-	-
4. Phitsanulok	-	76	-	-	-	-	-	-	-	-	-	-

Name of regions and provinces	Sour type: No. of specimens from competition 1986	1987	Sour type: No. of specimens from collection 1986	1987	Sour type: No. of selected specimens for analysis 1986	1987	Sweet type: No. of specimens from competition 1986	1987	Sweet type: No. of specimens from collection 1986	1987	Sweet type: No. of selected specimens for analysis 1986	1987
<u>Central Plain</u>												
1.Nonthaburi	-	-	-	20	-	-	-	-	-	-	-	-
2.Nakhon Pathom	-	-	-	25	-	25	-	-	-	-	-	-
3.Samut Sakhon	-	-	-	4	-	4	-	-	-	-	-	-
4. Sing Buri	-	-	-	1	-	1	-	-	-	-	-	-
<u>Southern</u>												
1. Satun	-	-	-	3	-	3	-	-	-	-	-	-
2. Phuket	-	-	-	8	-	8	-	-	-	-	-	-
3. Phatthalung	-	-	-	7	-	-	-	-	-	-	-	-
Total	-	952	689	170	689	283	-	465	-	-	-	42
Grand total	952		859		972		465		-		42	

Note - specimens obtained in form of pods.

Table 4 Physical characters of sour tamarind pod used as primary criteria for asscession selection in the year 1986-1987

Code	Wt.of 10 pods (gm)	Ave. Wt. of pod (gm)	No. of pod/kg.	Pulp Wt. (gm)	% Pulp Wt.	Real value* of pulp	Rank
86-2-13-001	-	77.83	12.85	40.80	52.4250	21.3894	1
87-2-01-035	-	-	-	-	-	20.2000	2
87-2-01-029	-	-	-	-	-	18.3900	3
87-1-02-001	-	-	-	-	-	17.9800	4
87-2-08-003	600.00	60.00	16.67	32.50	54.1667	17.6042	5
87-1-11-004	610.80	61.08	16.37	32.36	52.9797	17.1442	6
87-3-09-003	264.50	26.45	37.81	21.03	79.5050	16.7206	7
86-2-13-019	-	83.18	12.02	36.70	44.1210	16.1924	8
86-2-13-018	-	78.86	12.68	35.51	45.0360	15.9923	9
86-2-08-095	-	32.92	30.68	22.31	67.7770	15.1195	10
87-1-02-002	-	-	-	-	-	15.0000	11
87-2-08-027	551.00	55.10	18.15	28.60	51.9056	14.8450	12
87-2-17-021	515.20	51.52	19.41	27.60	53.5714	14.7857	13
86-2-13-020	-	58.03	17.23	29.21	50.3461	14.7061	14
87-2-09-017	509.50	50.95	19.63	27.20	53.3857	14.5209	15
86-2-08-038	-	22.92	43.63	18.20	79.4070	14.4521	16
87-1-11-003	501.00	50.10	19.96	26.64	53.1737	14.1655	17
86-2-08-008	-	51.73	19.33	29.28	46.9310	13.7414	18
86-2-13-015	-	57.98	17.25	28.13	48.5240	13.6498	19
86-2-13-008	-	50.59	19.77	26.17	51.7360	13.5393	20
86-2-13-002	-	53.33	18.75	26.70	50.0700	13.3687	21
87-2-17-049	468.80	46.88	21.33	24.30	51.3845	12.5958	22
87-2-08-025	450.71	45.07	22.19	23.75	52.6946	12.5150	23
87-2-17-011	475.55	47.56	21.03	24.24	50.9726	12.3557	24

Code	Wt.of 10 pods (gm)	Ave. Wt. of pod (gm)	No. of pod/kg.	Pulp Wt. (gm)	% Pulp Wt.	Real value* of pulp	Rank
87-1-02-003	-	-	-	-	-	12.0000	25
87-2-08-007	354.05	35.41	28.24	20.59	58.1556	11.9742	26
86-2-13-009	-	61.73	16.20	27.03	43.7900	11.8364	27
86-2-08-077	-	41.69	23.99	22.19	53.2200	11.8095	28
87-2-17-009	455.10	45.51	21.97	23.18	50.9339	11.8065	29
87-2-08-005	555.00	55.50	18.02	25.50	45.9459	11.7162	30
86-2-13-017	-	53.40	18.73	24.93	46.6740	11.6363	31
86-2-13-011	-	54.84	18.23	25.20	45.9520	11.5799	32
86-2-08-028	-	50.78	19.69	24.18	47.6120	11.5126	33
87-2-17-016	331.55	33.16	30.16	19.52	58.8750	11.4924	34
87-2-08-014	507.03	50.70	19.72	24.11	47.5514	11.4646	35
86-2-13-004	-	51.19	19.54	24.21	47.2940	11.4499	36
87-2-17-008	441.60	44.16	22.64	22.46	50.8605	11.4233	37
86-2-08-047	-	45.40	22.03	22.68	49.9560	11.3300	38
87-1-02-004	-	-	-	-	-	11.2800	39
87-3-20-002	323.17	32.32	30.94	18.99	58.7616	11.1588	40
86-2-13-005	-	38.72	25.83	20.73	53.5380	11.0984	41
87-1-02-005	-	-	-	-	-	10.8000	42
87-2-08-023	538.80	53.88	18.56	23.95	44.4506	10.6459	43
86-2-08-178	-	47.15	21.21	22.40	47.5080	10.6418	44
86-2-08-083	-	43.71	22.88	21.38	48.9090	10.4567	45
87-2-17-026	378.40	37.84	26.43	19.89	52.5634	10.4549	46
87-2-01-007	407.40	40.74	24.55	20.59	50.5400	10.4062	47
86-2-08-183	-	38.42	26.03	19.96	51.9520	10.3696	48
87-4-13-003	430.00	43.00	23.26	21.01	48.8605	10.2656	49
86-2-08-016	-	47.54	21.03	21.93	46.1290	10.1161	50
86-2-13-014	-	73.68	13.57	27.20	36.9190	10.0420	51

4.1.3 Collection of grafted plants from accessions.

From table 5 showing the total number of 1529 grafted from 45 accessions. In some accessions, it was unable to obtain 24 survived grafted plants as mentioned in the methodology for testing. However, the least number of grafted plant of some accessions were four plants that were accepted for a reliable data. Actually, each accession was attempted to propagate more than 100 grafted shoots, but there was some problems concerning to the mother plant and environmental condition that grafting was not satisfied.

Table 5 Number of grafted plants from accessions

Code of accessions	No.of grafted plants	collection place(province)
86 - 2 - 13 - 001	4	Sakon Nakhon
86 - 2 - 13 - 019	24	ditto
86 - 2 - 13 - 018	17	ditto
86 - 2 - 13 - 020	15	ditto
86 - 2 - 13 - 015	50	ditto
86 - 2 - 13 - 008	5	ditto
86 - 2 - 13 - 002	4	ditto
86 - 2 - 13 - 009	15	ditto
86 - 2 - 13 - 017	35	ditto
86 - 2 - 13 - 011	6	ditto
86 - 2 - 13 - 004	14	ditto
86 - 2 - 13 - 005	12	ditto
86 - 2 - 13 - 014	18	ditto
86 - 2 - 08 - 038	4	Mukdahan
86 - 2 - 08 - 028	25	ditto
86 - 2 - 08 - 083	7	ditto
86 - 2 - 08 - 183	10	ditto
86 - 2 - 08 - 016	15	ditto
86 - 2 - 08 - 095	25	ditto
87 - 2 - 08 - 003	12	ditto
87 - 2 - 08 - 027	7	ditto
87 - 2 - 08 - 025	8	ditto
87 - 2 - 08 - 014	5	ditto
87 - 2 - 08 - 023	9	ditto
87 - 2 - 08 - 005	14	ditto

Code of accessions	No.of grafted plants	collection place(province)
87 - 2 - 17 - 021	57	Ubon Ratchathani
87 - 2 - 17 - 022	64	ditto
87 - 2 - 17 - 011	86	ditto
87 - 2 - 17 - 009	70	ditto
87 - 2 - 17 - 016	86	ditto
87 - 2 - 17 - 008	82	ditto
87 - 2 - 17 - 026	31	ditto
87 - 2 - 01 - 035	50	Nakhon Ratchasima
87 - 2 - 09 - 017	43	Yasothon
87 - 3 - 20 - 002	22	Samut Sakhon
87 - 4 - 13 - 003	12	Satun
87 - 2 - 01 - 005	95	Kalasin
87 - 1 - 02 - 001	99	Chiang Rai
87 - 1 - 02 - 002	49	ditto
87 - 1 - 02 - 003	57	ditto
87 - 1 - 02 - 004	100	ditto
87 - 1 - 02 - 005	87	ditto
87 - 3 - 09 - 001	21	Nakhon Pathom
87 - 2 - 07 - 001	24	Maha Sarakham
87 - 2 - 07 - 002	34	ditto
Total	1529	

4.2 Testing of germplasm.

4.2.1 Biomass study

From table 6 and 7 the classification of biomass accession based on ranked order, it was found that there was the great difference on total score which derived from the growth characters. The result showed that the low score represent the vigorous plant-type while the high score was dwarf one.

The result of field and container experiment was highly contrast on ranked order. Since the heredity and environmental factors might cause the variation from seed to seed. For the vigorous one, the accession No. 77 of the field experiment has been used as the biomass production accession. It was noticed that the biomass accession in containers which arranged in closed spacing that causes high competition in community such as the biomass accession no. 46 might be suitable for closed planting in biomass production purpose. For detail see annex on table 1-19.

Table 6 Accumulated score of Biomass accssions on growth in the field (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988 ---->			<---------- 1989 ---------->					
1	77	4	24	3	4	3	8	5	4	55
2	81	8	6	6	3	13	25	11	14	86
3	30	11	28	28	16	30	19	20	13	165
4	35	32	47	35	33	23	25	21	12	228
5	10	20	11	51	32	27	84	33	29	287
6	20	16	64	39	62	48	32	52	33	346
7	9	52	93	46	48	21	12	43	36	351
8	89	87	36	17	39	9	23	84	59	354
9	76	28	28	38	53	52	58	46	55	358
10	27	52	52	59	22	37	76	31	40	369
11	87	62	34	26	79	19	58	37	56	371
12	18	53	62	31	44	53	66	51	40	400
13	78	26	50	12	88	37	92	55	76	436
14	42	120	100	90	73	22	11	10	12	447
15	11	26	35	62	40	45	54	104	98	464
16	31	27	55	59	35	70	97	82	57	482
17	37	79	50	83	50	131	51	33	31	508
18	32	55	68	83	45	91	93	57	37	529
19	41	67	115	95	109	40	52	39	44	561
20	29	44	22	29	135	33	87	117	98	565
21	17	55	58	56	25	93	79	114	92	572
22	38	80	87	96	53	95	96	56	59	660

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988 ---->			<---------- 1989 ----------->					
23	15	35	21	90	57	67	102	168	134	674
24	84	109	47	30	81	74	104	113	132	690
25	16	29	56	64	55	72	97	163	172	708
26	14	87	35	81	173	49	59	68	163	715
27	26	139	104	67	127	04	51	93	66	751
28	45	131	75	147	117	76	48	77	92	763
29	25	60	73	90	52	87	100	176	141	779
30	8	88	67	152	162	07	42	94	70	782
31	1	66	116	101	11	38	68	148	153	801
32	67	73	161	155	208	24	67	13	9	810
33	83	64	108	22	107	14	152	138	141	846
34	34	132	137	163	94	96	100	77	70	869
35	86	134	71	101	95	114	138	114	138	905
36	24	114	128	175	82	95	75	146	109	924
37	75	127	121	153	145	132	97	78	86	939
38	40	90	92	203	131	117	98	103	116	950
39	39	156	115	41	80	127	159	135	143	956
40	28	168	168	96	142	79	49	133	126	961
41	36	100	72	166	129	46	153	111	91	968
42	33	165	182	205	127	22	108	44	23	976
43	19	122	53	87	90	58	155	184	169	1018
44	70	162	188	165	180	18	58	62	89	1022
45	62	168	159	129	173	47	151	91	93	1111
46	79	102	161	182	101	41	174	171	180	1112
47	61	202	177	148	137	160	125	85	84	1118
48	22	123	110	168	80	105	145	201	216	1148

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988		---->	<----------		1989		---------->	
49	6	200	156	170	133	180	98	137	115	1189
50	85	167	144	104	165	103	143	174	199	1199
51	12	127	178	126	122	151	149	179	175	1207
52	7	188	154	150	104	154	146	175	151	1222
53	80	106	154	117	202	181	184	137	154	1238
54	88	209	179	134	159	115	150	137	164	1247
55	72	168	235	127	208	149	126	124	116	1253
56	48	220	142	213	157	151	83	150	172	1288
57	43	122	149	199	185	191	187	137	122	1292
58	53	227	203	218	221	143	97	99	93	1301
59	56	170	192	170	207	131	154	136	158	1318
60	71	132	179	148	178	214	202	161	140	1354
61	54	211	168	127	212	190	197	119	138	1362
62	5	164	155	182	134	199	181	171	192	1378
63	2	190	113	108	82	157	255	254	257	1416
64	60	172	202	238	164	205	193	119	128	1421
65	90	214	164	87	177	201	217	170	192	1422
66	13	165	100	159	194	194	190	207	216	1425
67	74	146	179	161	211	202	157	184	198	1438
68	57	176	195	139	168	180	202	196	200	1456
69	69	205	180	174	185	174	186	204	171	1479
70	4	166	210	159	92	207	225	241	223	1523
71	23	181	115	193	168	202	241	256	253	1609
72	3	140	227	179	94	240	258	253	258	1649
73	55	257	231	256	250	231	172	120	132	1649
74	58	236	233	198	228	229	210	184	193	1711

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988		---->	<----------		1989		----------->	
75	52	230	214	217	229	204	203	224	208	1729
76	82	209	201	191	241	208	257	214	216	1737
77	59	227	247	249	243	228	216	185	186	1781
78	21	146	229	235	188	239	239	257	259	1792
79	47	178	230	235	232	226	225	255	260	1811
80	68	252	206	234	247	194	209	215	219	1816
81	44	220	234	205	238	238	217	236	243	1831
82	65	210	255	246	220	135	230	230	223	1849
83	64	263	249	224	214	238	234	220	224	1866
84	73	268	269	269	270	268	217	170	192	1923
85	49	206	217	251	228	251	258	267	267	1945
86	50	262	262	252	251	258	247	244	246	2022
87	63	257	264	239	262	262	267	237	237	2025
88	46	237	219	251	263	264	269	270	270	2043
89	51	249	254	252	252	244	252	257	242	2053
90	66	262	264	266	267	260	255	254	257	2085

Table 7 Accumulated score of biomass accessions on growth in container (Duncan's Multiple Range test, $\alpha = 0.01$)

Ranked order	Accession no.	Score Apr. 1988	Jul. 1988	Oct. 1988	Jan. 1989	Apr. 1989	Jul. 1989	Oct. 1989	Dec. 1989	Total score
1	46	32	12	22	3	2	11	8	8	98
2	84	77	7	4	10	17	1	20	9	145
3	74	20	50	28	6	7	26	4	7	148
4	47	14	10	16	17	30	45	18	19	169
5	49	3	15	38	1	1	33	52	50	193
6	90	74	29	21	9	51	5	7	6	202
7	51	47	32	51	38	3	31	2	2	206
8	58	28	27	41	7	9	8	44	44	208
9	79	32	28	24	27	18	35	22	39	225
10	59	97	10	17	5	12	13	37	38	229
11	78	123	13	12	23	19	2	24	21	237
12	71	156	5	5	2	46	18	5	4	241
13	43	42	43	34	25	29	25	27	28	253
14	37	60	33	36	36	22	46	13	15	261
15	77	107	9	10	63	15	50	10	25	264
16	14	63	11	11	39	52	36	35	37	274
17	87	78	52	1	47	21	24	29	29	281
18	60	21	21	45	55	24	53	31	33	283
19	67	205	4	6	8	8	9	21	31	292
20	45	107	8	7	34	13	69	25	30	293
21	75	116	15	35	52	64	10	6	5	305
22	70	84	45	42	42	14	29	23	27	306
23	69	125	23	27	26	62	57	1	1	322
24	81	200	14	15	21	11	17	32	17	327

Ranked order	Accession no.	Score Apr. 1988	Jul. 1988	Oct. 1988	Jan. 1989	Apr. 1989	Jul. 1989	Oct. 1989	Dec. 1989	Total score
25	52	54	55	64	24	42	70	9	14	332
26	72	55	80	82	58	23	21	14	18	351
27	6	128	2	2	13	28	30	78	78	359
28	68	135	22	29	48	43	22	30	34	363
29	66	93	65	62	44	39	41	11	13	368
30	80	183	6	9	64	37	7	16	48	370
31	40	52	49	49	16	25	38	71	71	371
32	57	54	73	88	37	27	71	12	10	372
33	21	192	26	20	31	32	47	15	16	379
34	50	20	58	69	50	44	14	64	61	380
35	53	189	1	3	35	5	12	72	70	387
36	62	113	85	84	4	55	3	26	26	396
37	85	138	40	37	40	41	34	43	23	396
38	41	167	68	19	33	54	51	3	3	398
39	54	161	42	58	12	4	6	60	58	401
40	35	49	84	81	60	33	42	34	36	419
41	32	86	51	48	51	56	59	33	35	419
42	4	172	31	23	11	20	49	59	56	421
43	5	117	36	33	22	26	56	69	66	425
44	33	65	67	65	41	49	28	61	62	438
45	8	149	34	26	15	16	44	81	80	445
46	61	76	86	83	32	28	64	36	40	445
47	39	233	19	16	73	45	20	19	22	447
48	19	197	24	18	39	77	54	54	41	450
49	48	182	53	70	11	6	4	65	64	462

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988		---->	<----------		1989		----------->	
50	76	154	63	61	28	53	27	41	42	469
51	63	101	74	71	71	59	63	17	20	476
52	25	179	46	44	30	10	62	58	54	483
53	56	186	16	53	9	60	52	51	51	488
54	86	103	83	85	69	35	61	40	12	488
55	26	120	87	86	43	29	16	57	55	493
56	33	193	39	32	77	58	88	48	47	494
57	24	152	69	66	14	52	60	47	49	509
58	36	118	59	56	20	66	55	80	81	535
59	88	89	77	77	67	48	74	38	68	538
60	83	193	18	13	78	70	85	49	32	538
61	1	163	38	39	54	57	39	74	75	539
62	31	76	76	75	46	79	40	76	76	544
63	64	218	25	25	49	47	78	50	52	544
64	44	80	89	89	56	39	73	62	59	547
65	12	144	54	74	61	31	23	83	84	554
66	20	159	44	30	66	81	80	55	53	568
67	11	163	61	57	74	68	15	67	65	570
68	29	218	41	31	72	63	65	39	43	572
69	82	234	60	55	76	69	37	21	24	576
70	73	96	70	76	75	74	43	75	77	586
71	18	76	72	68	59	72	77	84	83	591
72	89	162	81	79	84	71	68	42	11	598
73	65	136	75	73	79	67	84	56	57	627
74	30	184	82	80	82	84	32	53	63	640
75	7	195	57	54	57	61	48	86	86	644

Ranked order	Accession no.	Score								Total score
		Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Dec.	
		<---- 1988 ---->			<---------- 1989 ----------->					
76	10	221	66	59	53	73	81	46	46	645
77	22	245	56	50	80	50	75	45	45	646
78	16	202	64	60	45	64	82	63	72	652
79	17	237	3	8	65	87	72	66	67	605
80	9	242	20	14	88	83	67	77	74	665
81	55	221	35	72	89	34	79	70	69	669
82	28	182	48	46	86	80	76	88	88	694
83	42	176	96	90	82	85	19	82	82	712
84	15	178	78	74	68	82	66	85	85	716
85	13	265	47	43	81	86	83	73	73	751
86	3	248	62	63	83	78	58	87	87	766
87	2	248	37	40	85	90	87	9	90	767
88	34	239	71	67	87	88	90	79	79	800
89	23	248	79	78	70	76	89	89	89	818
90	27	270	88	87	90	89	86	68	60	838

4.2.2 Fruit study

4.2.2.1 To observe the accession mother plants at original site.

From table 8 showing the characteristics of sour accessions that collected from the whole country for two successive years (1987,1989). The growth habits and yield of individual accession showed great difference due to the climatic and genetic factors.

Table 8 Characteristics of sour type accession

Accession No.	Age (Yrs)	Girth (Cm)	Height (Cm)	Width (Cm)	Length (Cm)	Canopy (m3)	Yield (kg.) 1988	/ 1989	Real value of Pulp(RV)	Collection site (Province)
86-2-08-038	83	320	1300	1320	1100	1887	3.50	3.20	14.4521	Mukdaharn
86-2-08-028	20	210	880	830	730	533	0.20	55.00	11.5120	ditto
86-2-08-083	87	220	1100	1000	1080	1188	13.00	64.00	10.4558	ditto
86-2-08-183	25	130	1100	1000	930	1023	15.00	8.00	10.3686	ditto
86-2-08-016	32	300	2000	1700	1700	5780	316.00	50.00	10.1161	ditto
86-2-08-095	11	140	900	1000	1000	900	15.00	76.00	15.1195	ditto
86-2-08-003	29	155	950	1100	1200	1254	14.00	165.00	17.6042	ditto
86-2-08-027	43	200	1200	1400	1300	2184	2.00	6.40	14.8450	ditto
86-2-08-025	43	200	1000	1100	1100	1210	20.00	340.00	12.5150	ditto
86-2-08-014	10	100	720	940	940	636	0.80	3.50	11.4646	ditto
86-2-08-023	86	220	1800	1500	1300	3510	2.00	3.00	10.6459	ditto
86-2-08-005	25	140	1620	1200	1200	1814	8.50	7.50	11.7162	ditto
86-2-13-001	30	119	900	700	700	441	1.25	5.00	21.3894	Sakon Nakhon
86-2-13-019	40	230	1500	1000	1300	1950	53.00	60.00	16.1924	ditto
86-2-13-018	20	54	1500	500	500	375	65.00	44.00	15.9941	ditto
86-2-13-020	34	86	521	820	551	235	5.00	5.00	14.7061	ditto
86-2-13-015	40	190	1500	1650	800	1980	120.00	80.00	13.6513	ditto
86-2-13-008	28	139	900	900	600	486	30.00	30.00	13.5398	ditto
86-2-13-002	40	142	1500	1100	900	1485	0.50	1.00	13.3687	ditto
86-2-13-009	11	124	1000	700	800	560	27.00	3.50	11.8378	ditto
86-2-13-017	30	168	1200	1500	1200	2160	73.00	87.00	11.6340	ditto
86-2-13-011	66	320	2500	1900	1900	9025	371.00	10.00	11.5799	ditto
86-2-13-004	40	159	1500	1300	1100	2145	51.50	50.00	11.4499	ditto
86-2-13-005	23	217	1200	900	1000	108	1.00	15.00	11.0984	ditto
86-2-13-014	54	140	2000	900	1200	2160	39.00	50.00	10.0420	ditto

Accession No.	Age (Yrs)	Girth (Cm)	Height (Cm)	Width (Cm)	Length (Cm)	Canopy (m3)	Yield (kg.) 1988 /	1989	Real value of Pulp(RV)	Collection site (Province)
87-2-17-021	45	322	2500	2400	1530	9180	36.00	-	14.7857	Ubon Ratchathani
87-2-17-022	60	340	1900	1600	2000	6080	56.00	300.00	12.5958	ditto
87-2-17-011	35	170	1500	1400	1500	3150	16.28	10.00	12.3557	ditto
87-2-17-009	70	280	1100	1300	2500	3575	5.40	20.00	11.8068	ditto
87-2-17-016	40	180	1000	1200	1600	1920	0.72	1.00	11.4924	ditto
87-2-17-008	60	200	1100	1050	1500	1733	84.45	75.00	11.4233	ditto
87-2-17-026	30	220	1100	1300	1200	1716	226.00	-	10.4549	ditto
87-2-07-001	65	140	2500	1500	1500	5625	3.20	10.00	10.3200	Maha Sarakham
87-2-07-003	70	269	2500	2000	2000	10000	14.40	12.50	10.2770	ditto
87-2-09-017	35	170	900	1100	2000	1980	60.00	70.00	14.5209	Yasothon
87-2-01-035	24	85	1200	1000	1100	1320	2.20	100.00	20.2000	Nakhon Ratchasima
87-3-09-003	96	280	2000	1160	1100	2552	200.00	120.00	16.7206	Nakhon pathom
87-3-20-002	13	67	800	500	500	200	-	-	11.1588	Samut sakhon
87-4-13-003	30	160	1250	1100	950	1306	100.00	100.00	10.2656	Satun
87-1-02-001	35	160	1500	1500	1200	2700	80.00	44.00	17.9800	Chiang Rai
87-1-02-002	27	118	1014	1050	1400	1491	-	155.00	15.0000	ditto
87-1-02-003	60	183	700	800	1800	1008	95.00	5.00	12.0000	ditto
87-1-02-004	36	170	1280	1120	1500	2150	120.00	30.00	11.2800	ditto
87-1-02-005	50	167	920	920	1100	931	100.00	60.00	10.8000	ditto
87-2-1-005	50	235	1600	2200	1500	5280	60.00	132.00	9.5807	Kalasin

4.2.2.2 To test the accession grafted plants in the field.

From table 10 the accessions of sour and sweet tamarind grafted plants which had been grown in the field for evaluation, at the age about 1 year after growing. They could be grouped into 3 categories based on growth which expressed by total score. For sour tamarind, that was 1-42, 43-84 and 85-126 as the fast growing group (14 accessions), moderate growing group (14 accessions) and slow growing group (16 accessions), respectively. For sweet tamarind, that was 1-23, 24-46 and 47-69 as the fast growing group (7 cultivar), moderate growing group (10 cultivars), and slow growing group (6 cultivars). For detail see annex on table 20-21

However, further result of this study should be followed until these plants reached the flowering stage.

Table 9 Detailed data of sour type accessions with statistical analysis on December, 1989 (Duncan's Multiple Range Test, α = 0.01)

Rank order	Accession no.	Score of Height	Score of width	Score of length	Total Score
1	87-1-02-001	1	7	2	10
2	87-2-17-009	5	4	3	12
3	87-2-09-017	4	2	7	13
4	87-2-17-011	6	6	4	16
5	87-2-17-008	12	3	5	20
6	87-1-02-005	2	10	9	21
7	86-2-13-014	9	12	1	22
8	87-1-02-002	3	13	10	26
9	86-2-08-028	11	1	15	27
10	87-2-17-026	21	5	6	32
11	87-1-02-004	7	15	12	34
12	87-2-01-005	14	8	14	36
13	87-2-17-016	18	11	11	40
14	87-2-17-021	8	18	16	42
15	87-2-08-025	16	14	13	43
16	87-1-02-003	10	17	18	45
17	87-3-20-002	13	16	19	48
18	87-2-01-035	19	9	23	51
19	86-2-13-001	23	26	8	57
20	87-2-08-023	20	22	17	59
21	87-2-17-002	15	23	22	60
22	87-2-08-014	17	25	20	62
23	87-4-13-003	29	19	21	69
24	87-2-08-003	25	20	27	72
25	87-2-07-001	26	27	24	77

Rank order	Accession no.	Score of Height	Score of width	Score of length	Total Score
26	86-2-13-002	28	24	25	77
27	86-2-13-009	22	31	26	79
28	86-2-08-083	31	21	31	83
29	86-2-13-004	30	30	28	88
30	87-2-07-003	27	32	29	88
31	86-2-08-183	36	29	30	95
32	86-2-13-005	24	36	37	97
33	87-2-08-027	33	33	32	98
34	86-2-13-008	32	35	33	100
35	86-2-08-038	38	28	35	101
36	87-2-07-001	35	34	34	103
37	86-2-13-017	34	40	42	116
38	86-2-13-019	43	37	36	116
39	86-2-13-001	41	38	39	118
40	86-2-08-016	37	41	43	121
41	86-2-13-020	39	43	41	123
42	87-2-08-005	44	39	40	123
43	86-2-13-018	42	44	38	124
44	86-2-13-015	40	42	44	126

Table 10 Detailed data of sweet type accessions with statistical analysis on December, 1989 (Duncan's Multiple Range Test, α = 0.01)

Rank order	Cultivar	Score of Height	Score of width	Score of length	Total Score
1	Pakduk	1	1	1	3
2	Nualchan	3	2	2	7
3	Pechkaset	2	3	4	9
4	Chauwnuasethakit	10	5	5	20
5	Nampheung	8	7	8	23
6	Pramualvit	6	11	6	23
7	Muktip	5	15	3	23
8	Pannanikom	15	4	10	29
9	Taltip	4	20	7	31
10	Saeng-Ar-tit	7	6	18	31
11	Pra-Roj	12	10	9	31
12	Kru-Buapan	13	9	14	36
13	Jae-Home	17	8	12	37
14	Sichompoo	9	13	16	38
15	Kru-In	11	12	17	40
16	Ban-Phai-Yai	14	17	13	44
17	Muen-Jong	16	14	15	45
18	Nimnuan	19	18	11	48
19	Khantee	18	19	20	57
20	Sithong	20	16	21	57
21	Nai-whan	21	21	22	64
22	Ban-Fakloei	23	23	19	65
23	Nasinuan	22	22	23	67

4.2.2.3 To analyse the chemical composition of pulp of sour and sweet types accession

From table 11 the composition of sweet tamarind pulp in term of sugar, tartaric acid and crude fiber contents are 39.06-47.71%, 2.009-3.179% and 0.8833 - 1.976% respectively, for sour tamarind, the contents of sugar, tartaric acid and crude fiber are 4.80-39.94%, 2.463-11.271 % and 1.1399-4.4728% respectively.

In sweet tamarind, the variation of different composition are very low, on the contrary of sour tamarind are larger, The sweetness and sourness of the pulp depends on the ratio of tartaric acid and sugar content for example, table 11-12 the suger content of KRU-IN cultivar and accession number 86-2-13-008 are almost equal thereupon the wide ratio (1:14) is sweet if the narrow ratio (1:6) is sour but the tartaric acid contents of sour tamarind are widely varied.

From this result it can be concluded that the percentage of tartaric acid and sugar are determinator of the tamarind taste and flavour.

The utilization derives from table 12 found that some accessions show outstanding properties viz. the accession number 86-2-13-017 gave the highest tartaric content upto 11.27% which its pulp is suitable for commercial tartaric acid extraction, the accession number 86-2-13-008 gave highest sugar content up to 39.94% for fructose production, the accession number 87-2-01-035 gave the highest concentrated tamarind flesh which is the semi-raw product for confectionery, sauce, soft-drink etc, and other interesting accessions that can be developed for other purposes from this primary data.

Table 11 Chemical analysis of pulp. of sweet tamarind.

Cultivar name	% Tartaric	% Sugar Tartaric	Sugar ratio	% Crude fiber
SITHONG	3.179	41.07	1:13	1.4375
PIYAI	2.009	47.19	1:23	1.9736
PRAROJ	2.704	43.09	1:16	0.8833
SRICHOMPOO	2.390	42.52	1:18	1.9571
KRU-IN	2.699	39.06	1:14	1.0167
JAEHOM	2.741	44.68	1:16	1.3285
PANNANIKOM	2.339	47.71	1:20	1.1025

Table 12 Chemical analysis of pulp of sour type accession.

Accession no.	% Tartaric	% Sugar Tartaric	Sugar ratio	% Crude fiber
Sakon Nakhon				
86-2-13-001	4.323	17.02	1:4	1.7416
86-2-13-019	4.310	10.03	1:2	1.8925
86-2-13-018	6.501	13.81	1:2	1.8061
86-2-13-020	4.885	22.60	1:5	2.1800
86-2-13-015	5.780	13.07	1:2	2.1136
86-2-13-008	6.479	39.94	1:6	1.4938
86-2-13-002	2.463	14.99	1:6	1.9223
86-2-13-009	3.801	14.40	1:4	2.3334
86-2-13-017	11.271	15.42	1:1	2.1587
86-2-13-011	8.661	24.94	1:3	1.9617
86-2-13-004	4.480	20.85	1:5	2.4048
86-2-13-005	4.456	21.70	1:5	1.8542
86-2-13-014	6.499	30.45	1:5	1.9522

Accession no.	% Tartaric	% Sugar Tartaric	Sugar ratio	% Crude fiber
Mukdaharn				
86-2-08-038	4.224	23.53	1:6	2.1334
86-2-08-028	3.993	12.94	1:3	2.3949
86-2-08-083	2.904	18.52	1:6	1.5057
86-2-08-183	2.886	32.17	1:11	2.0404
86-2-08-016	3.460	19.64	1:6	1.6791
87-2-08-003	3.769	13.365	1:4	1.8938
87-2-08-027	4.269	20.37	1:5	2.7630
87-2-08-014	3.732	18.205	1:5	1.4937
87-2-08-023	4.049	18.955	1:5	2.3758
87-2-08-005	4.354	16.33	1:4	1.8035
87-2-08-025	3.520	21.52	1:6	2.3262
Ubon Ratchathani				
87-2-17-021	8.459	17.15	1:2	2.0983
87-2-17-022	6.582	11.47	1:2	1.9979
87-2-17-011	8.982	21.64	1:2	1.6741
87-2-17-009	5.329	38.25	1:7	2.3579
87-2-17-016	-	-	-	-
87-2-17-008	5.662	29.40	1:5	2.2601
87-2-17-026	6.753	37.60	1:6	2.4547
Nakhon Ratchasima				
87-2-01-035	5.384	4.80	1:1	4.4728
Yasothon				
87-2-09-017	7.407	23.10	1:3	2.1814

Accession no.	% Tartaric	% Sugar Tartaric	Sugar ratio	% Crude fiber
Satun				
87-4-13-003	10.272	18.01	1:2	3.4017
Kalasin				
87-2-01-005	9.582	17.495	1:2	1.1399
Maha Sarakham				
87-2-07-001	5.592	-	-	2.5035
Nakhon Pathom				
87-3-09-001	8.799	19.39	1:2	1.7689
Samut Sakhon				
87-3-20-002	-	-	-	-
Chiang Rai				
87-1-02-001	6.716	33.15	1:5	1.6358
87-1-02-002	5.562	22.76	1:4	1.5284
87-1-02-003	5.674	14.29	1:3	3.6209
87-1-02-004	3.759	15.72	1:4	3.3532
87-1-02-005	6.508	12.82	1:2	2.1356
Dwarf No.1	3.148	5.49	1:2	1.8511

4.3 Rootstock Study

4.3.1 The search for dwarf rootstock

From Table 13 showing the morphological characteristics of the accession no. 87-2-021 planted as control to compare with the dwarf rootstock No. 1 and 2, the result indicated that morphological characters eg. canopy, internode length and leaf area of dwarf no. 1 were quite different from control.

Table 13 Comparison of Morphological Characteristics of Dwarf Rootstock and Accession

Plant No.	Girth (cm)	Canopy* (m^3)	Age (yrs)	Internode Length** (cm)	Leaf area/100 leaves*** (cm^2)
87-2-17-021 Control	322	9180.00	45	1.705	110.82
Dwarf No 1	77	149.76	30	1.491	79.86
Dwarf No 2	73	274.40	20	1.833	95.28

* Measured at 100 centimetres above ground level

** Internode Length from an average of 10 shoots.

*** Automatic Areameter Model No. AAC-400 Hayashi Denkon Co., LTD.

From table 14 the search for dwarf rootstock mother plants have been identified among the biomass accessions that planting in the field. The statistical analysis has been done, the positive correlation between number of stomata and growth characters (viz. height, width, length, diameter and canopy) were significant at 0.05 and 0.01 levels. For detail see annex on table 22.

Table 14 Correlation of Biomass Accessions in the field, between number of stomata and some growth parameters

Plant characters	Height	Width	Length	Diameter	Canopy
Stomatal number	+0.470*	+0.561**	+0.519*	+0.528*	+0.532*

* Significant (P<0.05)

** Highly significant (P<0.01)

4.3.2 The search for rootstock plant other than tamarind rootstock.

Table 15 showing the unsucessful result of leguminous rootstock with tamarind due to the incompatibility of grafting union.

Table 15 Intergeneric grafting of tamarind

Rootstock species	No.of grafting	No.of successful combination
Pithecellubium dulce	50	none
Samanea saman Merr	50	none
Caesalpnia coriaria (jacq) Wild	50	none
Sesbania grandiflora Desv.	50	none
Caesalpinia pulcherrima (L.) Swarty	50	none
Delonix regia	50	none
Cassia grandis	50	none

4.3.2 Chemical treatment for the production of dwarf rootstock

From Table 16 The chemical treatment for the induction of dwarf rootstocks by using a certain inhibitors viz. SADH, CCC, MH and Paclobutrazol effected highly significant on growth characters. Especially both CCC and Paclobutrazol seemed to induce dwarfness However, the field experiment had been observed.

From table 17 the chemical treatment for the production of dwarf rootstocks by using certain inhibitors viz. SADH, CCC, MH and Paclobutrazol had shown that the dwarfness of tamarind seedling in the field was not only effected at the specific concentration of the chemical substances but also the specific time for example SADH 3000 ppm., CCC 2000 ppm. SADH, MH 2000 ppm. and Paclobutrazol 3000 ppm. only did the significant dwarfness in December. Afterward the influence of the chemical substances were gradually decreased and seedling growth became normal. It can be concluded that all inhibitors could only effected temporarily in arresting growth of seedling in the early period after chemical treatment.

Table 16 Effect of Chemical Substances on Growth of Seedling on April 1988*

Plant Growth Substances	Concentration (ppm)	Height (cm)	Width (cm)	Length (cm)	Canopy (cm^3)	Lenght of node (cm)	Diameter (cm)
Control	0	71.33 ABC	19.33 ABC	21.00 ABC	29121.33 ABC	1.21 ABCDE	0.64 ABC
SADH	1000	71.00 ABC	23.00 A	23.00 A	37634.67 A	1.29 ABC	0.61 ABCDE
	2000	75.00 AB	20.33 AB	22.00 AB	33646.67 AB	1.19 BCDE	0.64 ABC
	3000	65.67 ABCDE	19.67 AB	18.67 ABCD	25208.67 ABCDE	1.10 DEFG	0.60 ABCDE
	4000	66.33 ABCDE	20.00 AB	18.00 ABCDE	25228.67 ABCDE	1.21 ABCDE	0.64 ABCD
	5000	65.67 ABCDE	20.33 AB	17.33 ABCDE	23198.67 ABCDE	1.20 BCD	0.64 ABC
CCC	1000	62.67 BCDEF	16.00 BCDE	18.67 ABCDE	19161.67 BCDE	1.27 ABC	0.57 BCDEF
	2000	64.00 ABCDE	13.67 DE	12.67 D	11226.00 DE	1.27 ABC	0.56 DEFG
	3000	66.33 ABCDE	16.67 BCDE	17.00 ABCDE	18878.00 BCDE	1.29 ABC	0.55 EFG
	4000	61.33 CDEF	12.67 E	13.33 CD	10388.00 E	1.29 ABC	0.55 EFG
	5000	55.67 DEF	15.33 BCDE	14.33 BCD	15931.00 CDE	1.34 A	0.52 FG

Plant Growth Substances	Concentration (ppm)	Height (cm)	Width (cm)	Length (cm)	Canopy (cm^3)	Lenght of node (cm)	Diameter (cm)
MH	1000	77.00 A	18.67 ABCDE	18.67 ABCD	27714.00 ABCD	1.23 ABCD	0.64 ABCD
	2000	67.67 ABCD	14.00 CDE	15.67 ABCD	15007.67 CDE	1.16 CDEF	0.62 ABCDE
	3000	56.67 DEF	15.67 BCDE	18.00 ABCD	16012.33 CDE	1.19 BCDE	0.61 ABCDE
	4000	58.33 CDEF	17.00 BCDE	19.00 ABCD	18641.33 BCDE	1.33 AB	0.65 AB
	5000	56.00 DEF	16.33 BCDE	18.33 ABCD	17174.33 BCDE	1.15 CDEFG	0.57 CDEF
Paclobutrazol	1000	53.67 EF	17.00 BCDE	19.33 ABCD	17596.00 BCDE	1.03 EFG	0.66 A
	2000	41.00 GH	20.67 AB	20.67 ABC	17546.67 BCDE	0.93 I	0.57 BCDEF
	3000	38.67 GH	19.00 ABCDE	19.67 ABCD	14862.00 CDE	0.94 HI	0.48 G
	4000	36.00 H	16.33 BCDE	15.67 ABCD	9449.00 E	0.06 FGH	0.50 FG
	5000	50.33 FG	17.33 BCDE	18.00 ABCD	15809.33 CDE	1.03 GHI	0.58 ABCDEF

* Duncan's Multiple Range Test, α = 0.01

Table 17 Effect of Chemical substances on growth rate of seedling in the Field.
(Duncan's Multiple Range Test, α = 0.01

Plant Growth substance	Concentration (ppm.)	increased percentage of canopy. Oct. 1988	Dec. 1988	Feb. 1989	Apr. 1989
Control	0	104.51 CDE	2.02 EF	1.22 C	1.89 C
SADH	1000	45.58 E	12.00 CDEF	5.58 C	6.40 C
	2000	84.27 DE	13.23 CDEF	2.72 C	2.32 C
	3000	22.33 E	19.08 ABCD	19.40 C	16.76 C
	4000	56.12 DE	3.14 DEF	3.48 C	3.48 C
	5000	50.80 E	7.73 CDEF	13.22 C	16.52 C
CCC	1000	44.17 E	18.50 ABCDE	7.60 C	6.81 C
	2000	88.69 DE	36.66 A	2.97 C	3.69 C
	3000	133.28 BCDE	6.41 DEF	3.03 C	7.86 C
	4000	130.20 BCDE	3.34 DEF	129.36 B	129.36 B
	5000	162.70 BCDE	5.57 DEF	296.38 A	296.38 A

Plant Growth substance	Concentration (ppm.)	increased percentage of canopy.			
		Oct.	Dec.	Feb.	Apr.
		<-------1988--------	-------->	<------1989--------	-------->
Control	0	104.51 CDE	2.02 EF	1.22 C	1.89 C.
MH	1000	342.15 A	16.11 BCDEF	2.84 C	2.84 C
	2000	218.06 ABCD	29.78 AB	2.53 C	6.00 C
	3000	279.15 AB	15.12 BCDEF	3.99 C	4.64 C
	4000	110.93 CDE	2.77 DEF	4.18 C	4.40 C
	5000	256.25 ABC	0.77 F	3.09 C	2.33 C
Paclobutrazol	1000	65.12 DE	14.80 BCDEF	6.37 C	8.28 C
	2000	112.87 CDE	7.72 CDEF	4.13 C	2.60 C
	3000	141.11 BCDE	22.94 ABC	18.67 C	18.11 C
	4000	145.93 BCDE	3.50 DEF	4.99 C	4.44 C
	5000	89.83 DE	7.01 CDEF	3.03 C	2.90 C
CV. (%)		49.68	53.98	38.48	39.96

4.4 Cultural Practices and Demonstration Plot

4.4.1 Cultural practices.

4.4.1.1 To study the effect of plant regulators on fruit setting.

Table 18 Showing the preliminary study on the effect of plant growth regulators on fruit setting result had shown that 4-CPA 15 ppm; GA_3 15 ppm, NAA 100 ppm, SADH 2000 ppm gave the promising result.

Table 18 Effect of growth regulators on fruit setting of sweet tamarind

Growth Regulator	Rate of Concentration (ppm)	Experimental site I No. of pod/plant	Experimental site II No. of pod/plant
4-CPA	5	55.2	
	10	144.8	
	15	216.0	
	20	123.4	
GA_3	5	93.6	55.0
	10	72.2	51.5
	15	103.0	61.3
	20	20.4	40.8
NAA	50	96.0	42.3
	100	117.0	93.0
	150	107.4	88.8
	200	83.2	51.0
SADH	500	80.0	21.0
	100	15.4	3.3
	1500	80.0	53.3
	2000	99.4	56.5
Control	0	81.6	1.5

4.4.1.2 To study the effect of plant regulators on widening the crotch angles of tamarind.

From Table 20 showing the effect of growth substances on the branch angle, found that there was no statistical difference in all kinds and concentrations of chemical. However, the treated plants had been transplanted from containers to the field for further study on the angle of branches.

From table 21, the result had shown that there was no significance among treatments as compared to the control in the field.

Table 19 Effect of growth substances on angle of branches

Growth substance	Concentration (ppm)	Angle (°)
Control	0	70.909
TIBA	25	71.325
	50	72.851
	75	71.803
	100	72.942
BA	25	78.123
	50	76.060
	75	75.194
	100	74.856
test		NS
CV (%)		5.83

Table 20 Effect of growth substances on growth characteristics of seedling in the field. (Duncan's Multiple Range Test, α = 0.01)

Growth Substances	Concentration (ppm)	Height (cm.)	Diameter of Trunk* (cm.)	Length of Branches (cm.)	Angle** of branches (°)	Diameter*** of branches (cm.)
Control	0	95.00 AB	0.92 A	33.00 A	68.00 A	0.38 A
BA	25	93.33 AB	0.93 A	30.00 AB	61.00 C	0.36 A
	50	97.33 AB	0.93 A	26.67 B	71.00 A	0.37 A
	75	95.00 AB	0.85 A	26.67 B	61.67 BC	0.34 A
	100	98.33 A	0.94 A	25.67 B	69.00 A	0.35 A
TIBA	25	102.00 A	0.88 A	30.67 AB	67.33 A	0.38 A
	50	99.67 A	0.89 A	28.00 B	69.00 A	0.38 A
	75	91.33 AB	0.82 A	28.67 AB	67.00 A	0.37 A
	100	65.33 B	0.88 A	25.67 B	67.00 A	0.34 A
CV (%)		13.43	5.80	6.61	2.98	5.53

* Measured at 10 centimetres above ground level

** The crotch angle from an average of 5 angles of branches

*** Measured at 1 centimetre from main stem

4.4.1.3 To study the effect of spacing on growth.

From table 21 the experiment on different spacing of planting, it is found that the growth of plants for 10 months after planting gave high significance on the number of shoots and girth of 2.0 x 1.5 meter spacing but there was no difference on height of plants ; for 16 months, the height and girth of plants at spacing of 2.0 x 1.5 meter and 2.0 x 2.0 meter were significantly higher than another, but there was no difference on the number of shoots; for 22 months, the number of shoots at 2.0 x 1.0 meter and 2.0 x 2.0 meter of planting were significantly higher than another, but there was no difference on the height and girth of stem; for 30 months, the number of shoots of plants at spacing of 2.0 x 2.0 meter were significantly higher than the others. From the result showed that the spacing of 2.0 x 2.0 meter is the most suitable space for shoot production on multiplication purpose.

Table 21 The average number of shoot, girth and height of plant at different times after planting.
(Duncan's Multiple Range Test, $\alpha = 0.01$)

Spacing (m)	No. of shoot				Height of Plant (cm)				Girth (cm)			
	10 month	16 month	22 month	30 month	10 month	16 month	22 month	30 month	10 month	16 month	22 month	30 month
2.0 x 1.0	6.92 b	29.14	93.00 b	179.33 b	37.98	72.45 ab	127.33	144.67 b	1.86 a	3.79 ab	7.50	18.18
2.0 x 1.5	10.26 a	34.11	108.00 ab	188.00 b	41.97	79.48 a	137.67	188.33 a	2.15 a	4.51 a	9.05	18.93
2.0 x 2.0	9.70 a	28.74	145.33 a	223.67 a	38.32	66.48 b	138.00	195.67 a	1.93 a	3.68 b	8.70	19.12
Test	-	N.S	-	-	N.S	-	N.S	-	-	-	N.S	N.S
CV (%)	9.87	21.21	16.88	7.14	6.07	4.61	11.46	5.04	4.39	8.63	14.44	4.22

4.4.1.4 To study the yong leaf production for human consumption.

From table 22 showed the result of 5 chemical substances viz ethephon, thiourea, urea, potassium nitrate and 2,4-D at concentration 0, 50, 100, 150, 200 and 250 ppm. Thiourea, urea and potassium nitrate were not effective on young leaf emergence, but 2,4-D caused the leaf burned symptom and still remained on the shoot without young leaf emergence. For ethephon at various concentration caused the leaf abscission and developed the young leaves, the most effective concentration was 200 ppm, thus it is the best chemical substance for young leaf production of tamarind.

The young leaf of tamarind is commonly used as vegetable providing the sour taste and special flavour that is popular among Asian cuisines.

Table 22 study on the effect of chemical substances for young leaf production, (weight in gram)

Chemical Substances	Concentration (ppm.)					
	0	50	100	150	200	250
Ethephon	*	929.20	1008.40	1122.60	1413.20	1136.40
Thio Urea	*	*	*	*	*	*
Urea	*	*	*	*	*	*
Potassium Nitrate	*	*	*	*	*	*
2-4 D	*	**	**	**	**	**

* Non effect without young leaf emergence

** Leaf burn and effected leaft still attached to the shoot without young leaf emergence.

4.4.1.5 To study the change of pulp colour in storage.

From table 23 and table 24 the comparative result on different methods and containers for pulp storage found that a treatment of cold storage and transparent container gave the best one by which the change of pulp colour was the least at the final observation. But for the economic aspect, the powdered salt application at 10 per cent and transparent container was the most suitable because of low expenditure, simple practice and ease of handling.

Table 23   Effect of the different methods on pulp storage.
(Duncan's Multiple Range Test, $\alpha = 0.01$)

Powdered Salt (%)		Steam (Minutes)		Sodiummetabisulphite (ppm)		Temperature treatment		Cold storage (C)	
Rate of Application	Optical Density IO / FO	Rate of Application	Optical Density IO / FO	Rate of Application	Optical Density IO / FO	Rate of Application	Optical Density IO / FO	Rate of application	Opitcal Density IO / FO
Control 0	0.053 A 0.20 HI	Control 0	0.053 C 0.20 HI	Control 0	0.053 B 0.20 HI	Control 0	0.053 D 0.20 HI	Control 0	0.053 A 0.20 HI
		Steam 15	0.153 B 0.35 ABC	Sodium 10	0.154 A 0.13 HI	Sundry 3 days	0.174 C 0.33 ABCD	Cold Storage 5	0.027 A 0.05 KL
Salt 5	0.044 A 0.03 JK	20	0.195 B 0.33 AB	20	0.149 A 0.19 HI	Hot air 40	0.149 C 0.22 FGH	0	0.021 A 0- [illegible] L
						incubation(c)			
		30	0.379 A 0.40 A	30	0.105 AB 0.13 IJ	45	0.165 C 0.31 BCDE	-	-
10	0.022 A 0.03 KL	-	- -	40	0.076 AB 0.22 FGH	50	0.183 BC 0.33 ABCD	-	-
		-	- -	50	0.079 AB 0.13 HI	55	0.195 BC 0.33 ABC	-	-
15	0.030 A 0.05 KL	-	- -	60	0.080 AB 0.19 HI	60	0.203 BC 0.31 BCDE	-	-
20	0.027 A 0.05 KL	-	- -	70	0.093 AB 0.24 EFGH	65	0.260 B 0.29 CDEF	-	-
25	0.030 A 0.05 KL	-	- -	80	0.111 AB 0.21 GH	70	0.391 A 0.40 AB	-	-
30	0.029 A 0.03 KL	-	- -	90	0.122 AB 0.25 DEFGH	-	-	-	-
-	- -	-	- -	100	0.148 A 0.29 CDEFG	-	-	-	

* IO : Initial observation on 5 August 1988
FO : Final observation on 20 January 1990

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Table 24 Effect of the different containers on pulp storage.
(Duncan's Multiple Range Test, α = 0.01)

Powdered Salt (%)			Cold Storage (C)		
Rate of Application	Optical Density T	/ O	Rate of Application	Optical Density T	/ O
Control 0	0.20 HI	0.13 A	Control 0	0.20 HI	0.13 A
Salt 2.5	0.09 JK	0.12 B	Storage 5	0.05 KL	0.03 I
5.0	0.08 JK	0.09 D	0	0 L	0.11 C
7.5	0.09 JK	0.06 F	-	-	-
10.0	0.03 KL	0.08 E	-	-	-
12.5	0.05 KL	0.03 H	-	-	-
15.0	0.05 KL	0.05 G	-	-	-

T = Transparence

O = Opaque

4.4.2 Demonstration plot.

From table 25 Four hundred grafted plants of five cultivars of sweet tamarind have been grown in the demonstation plot. It was observed at thirty eigth per cent of them flowered within one year after planting and the fruit set was forty nine per cent at the third year. The sweet tamarind had been thrived in the Northeast of Thailand. Thus it is beleived that it can be one of the economic fruit crops in the semi arid areas.

5. CONCLUSION / REMARK

5.1 Germplasm collection

5.1.1 Study of pod specimen

The primary work had been started in the year 1986, the 689 pod specimens of sour tamarind from 9 provinces in the Northeast were collected and analysed concerning with number of pods per kilogram, pulp weight and percentage of pulp weight which brought about the criteria for selection of the accession in term of real value of pulp (RV.)

Later on 1987, the collection of pod specimens were added up to the total of 1811 pod specimens and out of these specimens, 51 accessions were selected for evaluation. It is noticed that the excellent accession from RV is as high as 21 and the number of pod is from 13-15 pods per kilogram.

All of these tamarind accessions were collected from all over the country, but mostly found in the areas located along the Mae Kong river.

5.1.2 Collection of grafted plants from accessions.

A total of 1529 grafted plants from 45 accessions that has been survived from the collection in the year 1987 and 1988 planted in the experimental plot of 20 acres at Khon Kaen University for evaluation.

5.2 Testing of germplasm

5.2.1 Biomass study

The biomass study of tamarind accessions, 2 excellent accessions were found, the first one, has wide spreading canopy and very vigorous which is suitable for wide spacing of planting system suitable for biomass production. The later one has high capability in competing with others in the dense population.

5.2.2 Fruit study.

5.2.2.1 To observe the accession mother plants at original site.

The growth habits and yield of individual accession was greatly differed due to the climatic and genetic factors.

5.2.2.2 To test the accession grafted plants in the field.

The accessions of sour and sweet tamarind grafted plants could be grouped into 3 categories based on growth. For sour tamarind, there are 14, 14 and 16 accessions for fast, moderate and slow growing groups, respectively. Similarly the sweet tamarind, there are 7, 10 and 6 cultivars for fast, moderate and slow growing, respectively.

5.2.2.3 To analyse the chemical composition of pulp of sour and sweet accession.

The chemical composition of pulp viz. tartaric acid, sugar and crude fiber content of sweet tamarind showed less difference where as those in sour tamarind varied largely.

The sweetness of pulp is depending on the ratio of tartaric acid and sugar concentration. The wide ratio is sweet and the narrow one is sour.

Amongst the pulp of sour tamarind accessions, the chemical compositions are highly different.

The percentage of tartaric acid and sugar are determinator of the tamarind taste and flavour.

From the chemical analysis of pulp of sour tamarind accessions, one excellent accession which is suitable for tartaric acid, sugar and flesh production was selected etc.

5.3 Rootstock Study

5.3.1 The search for dwarf rootstock.

One dwarf rootstock was found based on its morphological characteristics.

5.3.2 The search for rootstock plant other than tamarind rootstock.

The intergeneric grafting of leguminous rootstock with tamarind is impracticable.

5.3.3 Chemical treatment for the production of dwarf rootstock

The chemical substances which are used in dwarf seedling production viz SADH, CCC, MH and Paclobutrazol showed the effect on the plant growth at specific concentration and time.

The effectiveness of these chemical substances was gradually diminished when the age of plant increased, finally the growth of the plant became normal.

5.4 Cultural Practices and Demonstration Plot.

5.4.1 Cultural practices.

5.4.1.1 To study the effect of plant regulators on fruit setting.

The preliminary study on a certain concentrations of 4-CPA, GA_3, NAA, SADH for fruit setting gave a promising result.

5.4.1.2 To study the effect of plant regulators on widening the crotch angles of tamarind.

No effect of chemical substances (TIBA and BA) on widening the crotch angles of tamarind at both seedling and later stages.

5.4.1.3 To study the effect of spacing on growth.

- The spacing of 2.0 x 2.0 meter is the most suitable for shoot production on multiplication purpose.

5.4.1.4 To study the young leaf production for human consumption.

The ethephon at 200 ppm concentration is the best chemical substance for young leaf production of tamarind.

5.4.1.5 To study the change of pulp colour in storege.

The powdered salt application at 10 per cent with transparent container is the most suitable in the aspect of economic and handling.

5.4.2 Demonstration plot.

The sweet tamarind plantation well established in the semi-arid area.

For the northeast environmental condition of Thailand, the grafted plant started flowering and fruit setting after 1 and 3 years after planting respectively.

ANNEX

13

Table 1 Detailed data of Biomass accessions in the field with statistical analysis on January 1989 (Duncan's Multiple Range Test, α = 0.01)

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
1	77	97.17 A	77	87.00 A	81	85.00 A
2	81	95.67 AB	1	83.33 AB	77	83.67 AB
3	30	93.33 ABC	17	80.67 ABC	35	82.50 ABC
4	1	89.50 ABCD	9	79.17 ABC	30	82.50 ABC
5	32	86.67 ABCDE	81	78.83 ABC	1	80.67 ABC
6	89	85.50 ABCDEF	18	78.67 ABC	18	78.67 ABC
7	11	85.17 ABCDEF	27	78.00 ABC	27	78.17 ABC
8	27	84.17 ABCDEF	11	77.00 ABCD	17	78.10 ABC
9	10	84.17 ABCDEF	30	77.00 ABCD	24	77.00 ABC
10	35	83.50 ABCDEF	10	76.67 ABCD	37	76.17 ABCD
11	31	82.83 ABCDEF	37	75.50 ABCD	31	76.17 ABCD
12	76	81.33 ABCDEFGH	20	75.50 ABCD	89	75.83 ABCD
13	25	79.67 ABCDEFGH	31	74.83 ABCD	10	75.67 ABCD
14	17	79.67 ABCDEFGH	16	74.67 ABCD	9	75.50 ABCD
15	84	79.50 ABCDEFGH	38	74.50 ABCD	15	75.17 ABCD
16	38	79.50 ABCDEFGH	42	74.50 ABCD	16	75.17 ABCD
17	3	79.14 ABCDEFGH	76	73.83 ABCD	20	74.00 ABCD
18	87	79.00 ABCDEFGH	25	73.33 ABCD	32	73.67 ABCD
19	15	78.83 ABCDEFGH	4	72.83 ABCD	78	73.00 ABCD
20	7	78.33 ABCDEFGH	35	72.83 ABCD	87	72.83 ABCD
21	78	78.17 ABCDEFGH	89	72.50 ABCD	25	72.83 ABCD
22	42	78.17 ABCDEFGH	32	71.83 ABCDE	38	72.50 ABCDE
23	2	78.00 ABCDEFGH	15	71.67 ABCDE	19	72.33 ABCDE
24	83	78.00 ABCDEFGH	34	71.33 ABCDE	76	72.33 ABCDE
25	79	78.00 ABCDEFGH	19	71.33 ABCDE	11	72.17 ABCDE

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
26	13	77.50 ABCDEFGH	39	71.00 ABCDE	2	71.83 ABCDE
27	39	77.33 ABCDEFGH	41	70.50 ABCDE	39	71.17 ABCDE
28	16	76.83 ABCDEFGH	24	69.33 ABCDE	86	71.00 ABCDE
29	37	76.83 ABCDEFGH	45	69.17 ABCDE	84	70.00 ABCDE
30	9	76.67 ABCDEFGH	13	69.00 ABCDE	34	69.50 ABCDE
31	29	76.17 ABCDEFGH	86	69.00 ABCDE	45	69.17 ABCDE
32	18	76.17 ABCDEFGH	7	68.33 ABCDE	83	69.17 ABCDE
33	20	75.50 ABCDEFGH	2	68.17 ABCDE	40	68.33 ABCDE
34	33	74.67 ABCDEFGH	5	68.17 ABCDE	4	68.33 ABCDE
35	36	74.50 ABCDEFGH	79	68.00 ABCDE	42	68.00 ABCDE
36	86	74.00 ABCDEFGH	12	67.33 ABCDE	12	67.50 ABCDE
37	28	72.83 ABCDEFGH	84	666.1 ABCDE	75	66.50 ABCDE
38	41	73.33 ABCDEFGH	3	65.67 ABCDE	61	66.33 ABCDE
39	4	71.67 ABCDEFGH	48	65.67 ABCDE	3	65.83 ABCDE
40	34	71.67 ABCDEFGH	40	65.50 ABCDE	33	65.67 ABCDE
41	60	71.50 ABCDEFGH	87	65.33 ABCDE	79	65.67 ABCDE
42	19	71.00 ABCDEFGH	26	65.33 ABCDE	26	65.67 ABCDE
43	26	71.00 ABCDEFGH	6	64.17 ABCDE	28	65.67 ABCDE
44	6	70.67 ABCDEFGH	36	63.67 ABCDE	41	65.67 ABCDE
45	24	70.00 ABCDEFGH	29	63.67 ABCDE	8	65.50 ABCDE
46	5	70.00 ABCDEFGH	22	63.00 ABCDE	6	65.00 ABCDE
47	75	69.50 ABCDEFGH	61	62.17 A. CDE	13	64.33 ABCDE
48	90	69.17 ABCDEFGH	78	61.67 CDE	48	64.33 ABCDE
49	88	69.00 ABCDEFGH	88	61.33 BCDE	23	64.17 ABCDE
50	12	68.50 ABCDEFGH	43	61.17 ABCDE	36	64.00 ABCDE
51	85	68.33 ABCDEFGH	83	61.17 ABCDE	57	63.83 ABCDE
52	61	68.33 ABCDEFGH	57	61.00 ABCDE	7	63.67 ABCDE

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
53	80	67.83 ABCDEFGH	33	61.00 ABCDE	62	63.50 ABCDE
54	71	67.83 ABCDEFGH	70	60.67 ABCDE	5	62.83 ABCDE
55	62	67.50 ABCDEFGH	69	60.50 ABCDE	60	62.83 ABCDE
56	14	67.00 ABCDEFGH	8	59.50 ABCDE	85	62.83 ABCDE
57	45	67.00 ABCDEFGH	71	59.50 ABCDE	14	62.33 ABCDE
58	40	66.67 ABCDEFGH	85	59.33 ABCDE	21	62.17 ABCDE
59	22	66.17 ABCDEFGH	23	59.33 ABCDE	29	62.00 ABCDE
60	23	65.83 ABCDEFGH	14	59.00 ABCDE	64	61.17 ABCDE
61	8	65.67 ABCDEFGH	75	58.83 ABCDE	88	61.17 ABCDE
62	70	65.17 ABCDEFGH	28	58.83 ABCDE	90	59.67 ABCDE
63	54	64.67 ABCDEFGH	21	58.67 ABCDE	43	57.83 ABCDE
64	69	64.67 ABCDEFGH	56	58.00 ABCDE	70	57.67 ABCDE
65	57	64.00 ABCDEFGH	62	57.83 ABCDE	72	57.50 ABCDE
66	56	63.17 ABCDEFGH	74	57.83 ABCDE	69	56.83 ABCDE
67	21	62.83 BCDEFGH	90	57.50 ABCDE	71	56.50 ABCDE
68	67	61.83 BCDEFGH	60	57.00 ABCDE	54	55.83 ABCDE
69	53	61.00 BCDEFGH	67	55.83 ABCDE	74	55.83 ABCDE
70	48	60.83 BCDEFGH	80	55.33 ABCDE	65	55.50 ABCDE
71	72	60.83 BCDEFGH	65	54.83 ABCDE	67	54.83 ABCDE
72	43	60.50 BCDEFGH	72	54.68 ABCDE	53	54.67 ABCDE
73	52	60.17 CDEFGH	47	53.50 ABCDE	52	54.50 ABCDE
74	49	60.17 CDEFGH	44	52.33 ABCDE	47	54.50 ABCDE
75	58	59.50 CDEFGH	64	52.17 ABCDE	22	54.33 ABCDE
76	74	59.17 CDEFGH	49	52.00 ABCDE	58	54.00 ABCDE
77	82	59.00 CDEFGH	58	51.83 ABCDE	56	54.00 ABCDE
78	65	58.67 CDEFGH	59	51.33 ABCDE	49	53.50 ABCDE
79	64	58.67 CDEFGH	82	49.50 BCDE	80	53.00 ABCDE
80	55	58.50 CDEFGH	53	49.50 BCDE	50	52.83 ABCDE

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
81	68	58.17 CDEFGH	54	49.33 BCDE	59	52.17 ABCDE
82	44	57.33 DEFGH	68	48.50 BCDE	44	51.50 ABCDE
83	51	56.33 DEFGH	52	48.17 BCDE	51	51.17 ABCDE
84	59	56.33 DEFGH	55	46.67 CDE	68	49.83 ABCDE
85	47	56.00 DEFGH	50	46.33 CDE	82	48.50 ABCDE
86	50	52.83 EFGH	51	46.00 CDE	55	48.33 ABCDE
87	46	51.67 EFGH	63	46.00 CDE	63	47.33 ABCDE
88	63	50.33 FGH	46	44.83 CDE	46	46.67 CDE
89	66	46.83 GH	66	40.67 DE	66	39.33 DE
90	73	44.67 H	73	35.83 E	73	35.83 E

Table 2 Detailed data of Biomass accessions in the field with statistical analysis on April 1989 (Duncan's Multiple Range Test, α = 0.01)

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
1	77	105.33 A	77	79.83 A	77	98.17 A
2	89	101.00 AB	42	74.67 AB	89	87.17 AB
3	29	96.33 ABC	81	82.67 ABC	9	86.50 AB
4	30	92.83 ABCD	87	68.67 ABCD	35	85.00 ABC
5	81	92.00 ABCD	89	68.67 ABCD	81	84.83 ABC
6	10	90.50 ABCD	9	68.00 ABCDE	79	83.00 ABC
7	87	90.17 ABCDE	41	67.83 ABCDE	20	82.83 ABC
8	11	89.33 ABCDE	35	67.67 ABCDE	87	82.67 ABC
9	78	87.67 ABCDEF	27	77.00 ABCDEF	10	81.83 ABCD
10	42	87.50 ABCDEF	29	65.67 ABCDEF	42	81.83 ABCD
11	35	85.83 ABCDEFG	84	65.00 ABCDEF	27	81.17 ABCDE
12	9	85.17 ABCDEFG	10	64.83 ABCDEF	30	81.00 ABCDE
13	76	84.83 ABCDEFG	79	64.50 ABCDEF	78	77.17 ABCDEF
14	14	84.50 ABCDEFG	30	64.00 ABCDEFG	18	76.83 ABCDEF
15	37	84.00 ABCDEFG	78	64.00 ABCDEFG	41	76.67 ABCDEF
16	15	82.83 ABCDEFGH	20	64.00 ABCDEFG	31	76.50 ABCDEF
17	27	82.83 ABCDEFGH	14	63.17 ABCDEFG	11	76.50 ABCDEF
18	41	82.83 ABCDEFGH	76	62.33 ABCDEFG	14	76.33 ABCDEF
19	45	82.00 ABCDEFGH	18	62.17 ABCDEFG	16	76.17 ABCDEF
20	18	81.83 ABCDEFGH	11	61.83 ABCDEFG	29	76.00 ABCDEF
21	25	81.83 ABCDEFGH	26	61.67 ABCDEFG	76	75.67 ABCDEF
22	79	81.50 ABCDEFGH	34	61.00 ABCDEFG	38	75.50 ABCDEF
23	16	80.67 ABCDEFGH	31	60.83 ABCDEFG	24	75.33 ABCDEF
24	85	80.33 ABCDEFGH	32	60.67 ABCDEFG	17	75.00 ABCDEF
25	20	80.33 ABCDEFGH	28	60.33 ABCDEFG	15	74.33 ABCDEF

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
26	86	80.17 ABCDEFGH	15	60.17 ABCDEFG	37	74.17 ABCDEF
27	33	80.00 ACDEFGH	8	59.83 ABCDEFG	25	74.17 ABCDEF
28	83	80.00 ABCDEFGH	45	59.83 ABCDEFG	40	73.67 ABCDEF
29	32	79.50 ABCDEFGH	85	59.68 ABCDEFG	45	73.67 ABCDEF
30	84	79.00 ABCDEFGH	16	59.67 ABCDEFG	72	73.17 ABCDEF
31	31	78.33 ABCDEFGH	17	59.67 ABCDEFG	8	73.17 ABCDEF
32	39	78.33 ABCDEFGH	25	59.50 ABCDEFG	75	72.83 ABCDEF
33	34	77.50 ABCDEFGH	40	59.33 ABCDEFG	84	72.67 ABCDEF
34	70	77.33 ABCDEFGH	22	59.17 ABCDEFG	22	72.33 ABCDEF
35	28	77.17 ABCDEFGH	24	58.33 ABCDEFG	26	72.00 ABCDEF
36	38	77.00 ABCDEFGH	88	58.17 ABCDEFG	83	72.00 ABCDEF
37	22	76.50 ABCDEFGH	38	57.50 ABCDEFG	88	70.83 ABCDEF
38	17	76.00 ABCDEFGH	70	56.33 ABCDEFG	32	70.67 ABCDEF
39	1	75.67 ABCDEFGH	33	55.83 ABCDEFG	28	70.67 ABCDEF
40	24	74.50 ABCDEFGH	67	55.50 ABCDEFG	67	70.50 ABCDEF
41	36	74.33 ABCDEFGH	39	55.33 ABCDEFG	34	70.00 ABCDEF
42	88	74.33 ABCDEFGH	62	55.33 ABCDEFG	56	69.67 ABCDEF
43	12	74.17 ABCDEFGH	53	55.17 ABCDEFG	86	69.17 ABCDEF
44	67	73.33 ABCDEFGH	56	55.17 ABCDEFG	19	68.83 ABCDEF
45	56	72.83 ABCDEFGH	86	55.00 ABCDEFG	36	68.83 ABCDEF
46	2	72.67 ABCDEFGH	75	54.83 ABCDEFG	70	68.67 ABCDEF
47	40	72.67 ABCDEFGH	2	54.17 ABCDEFG	53	68.17 ABCDEF
48	26	72.17 ABCDEFGH	61	54.00 ABCDEFG	1	67.83 ABCDEF
49	8	72.00 ABCDEFGH	48	53.83 ABCDEFG	69	67.67 ABCDEF
50	48	71.33 ABCDEFGH	83	53.83 ABCDEFG	85	67.33 ABCDEF
51	7	71.33 ABCDEFGH	1	53.50 ABCDEFG	7	67.00 ABCDEF
52	62	71.33 ABCDEFGH	7	53.50 ABCDEFG	48	65.83 ABCDEF
53	53	71.33 ABCDEFGH	12	53.33 ABCDEFG	62	65.67 ABCDEF

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
54	75	71.00 ABCDEFGH	72	53.17 ABCDEFG	39	65.33 ABCDEF
55	80	70.83 ABCDEFGH	57	51.83 ABCDEFG	61	65.00 ABCDEF
56	6	70.50 ABCDEFGH	19	51.67 ABCDEFG	33	64.50 ABCDEF
57	61	70.33 ABCDEFGH	90	51.50 ABCDEFG	74	64.50 ABCDEF
58	19	70.33 ABCDEFGH	6	51.17 ABCDEFG	13	64.33 BCDEF
59	4	68.17 BCDEFGH	54	51.17 ABCDEFG	12	64.17 BCDEF
60	60	67.67 BCDEFGH	36	51.00 ABCDEFG	43	63.67 BCDEF
61	5	67.33 BCDEFGH	68	50.67 ABCDEFG	80	63.67 BCDEF
62	57	67.17 BCDEFGH	69	50.67 ABCDEFG	68	63.50 BCDEF
63	43	66.83 BCDEFGH	23	50.50 ABCDEFG	57	62.83 BCDEF
64	54	66.67 BCDEFGH	13	50.50 ABCDEFG	2	62.67 BCDEF
65	72	66.33 BCDEFGH	80	50.33 ABCDEFG	52	62.33 BCDEF
66	23	66.17 BCDEFGH	52	50.17 BCDEFG	6	62.33 BCDEF
67	69	66.00 BCDEFGH	5	49.50 BCDEFG	54	62.17 BCDEF
68	82	66.00 BCDEFGH	43	49.33 BCDEFG	82	61.33 BCDEF
69	90	66.00 BCDEFGH	55	48.83 BCDEFG	4	61.00 BCDEF
70	71	65.83 BCDEFGH	71	48.17 BCDEFG	60	61.00 BCDEF
71	68	65.67 BCDEFGH	74	48.17 BCDEFG	5	60.00 BCDEF
72	13	65.50 BCDEFGH	82	47.83 BCDEFG	59	58.83 BCDEF
73	52	64.67 CDEFGH	47	47.33 BCDEFG	23	58.33 BCDEF
74	74	62.83 CDEFGH	58	46.83 BCDEFG	71	58.17 BCDEF
75	58	62.50 CDEFGH	60	45.83 BCDEFG	90	57.50 BCDEF
76	64	62.33 CDEFGH	21	45.50 BCDEFG	47	57.33 BCDEF
77	47	61.00 CDEFGH	44	45.33 BCDEFG	3	56.83 BCDEF
78	59	60.83 CDEFGH	59	45.17 BCDEFG	55	56.83 BCDEF
79	44	59.83 DEFGH	4	45.17 BCDEFG	51	56.50 BCDEF
80	21	59.67 DEFGH	51	44.67 CDEFG	58	55.83 BCDEF

Ranked Order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	Length (cm.)
81	3	59.00 DEFGH	64	43.50 CDEFG	64	55.50 BCDEF
82	49	58.83 DEFGH	3	41.50 DEFG	44	54.50 BCDEF
83	65	58.83 DEFGH	66	40.50 DEFG	21	53.83 BCDEF
84	55	58.17 DEFGH	65	39.50 DEFG	49	52.17 CDEF
85	51	56.83 DEFGH	49	39.17 DEFG	50	51.17 CDEF
86	63	54.33 EFGH	50	38.67 EFG	65	51.17 CDEF
87	50	52.50 FGH	46	37.33 FG	66	48.33 DEF
88	46	51.00 GH	63	36.67 FG	63	47.17 EF
89	73	50.67 GH	73	36.50 FG	46	46.00 F
90	66	47.17 H	37	34.67 G	73	45.33 F

Table 3 Detailed data of Biomass accessions in the field with statistical analysis on July 1989 (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
1	77	137.33 A	26	183.50 A	9	119.67 A
2	89	130.50 AB	28	177.17 A	42	118.67 AB
3	81	130.00 AB	77	114.17 B	81	116.50 ABC
4	42	128.50 AB	41	113.00 B	77	115.83 ABC
5	9	126.83 AB	42	113.00 B	35	109.17 ABCD
6	30	126.50 AB	9	112.00 B	30	108.67 ABCD
7	1	126.00 AB	30	109.33 B	38	108.33 ABCDE
8	10	125.67 AB	48	108.67 B	10	107.83 ABCDE
9	20	125.33 AB	89	105.67 B	26	106.67 ABCDE
10	35	124.50 AB	35	105.17 B	11	106.33 ABCDE
11	29	123.33 AB	8	103.67 B	20	106.33 ABCDE
12	78	121.67 ABC	20	103.33 B	89	105.83 ABCDE
13	33	121.33 ABC	67	102.33 B	14	104.50 ABCDE
14	45	119.67 ABC	17	101.83 B	8	104.50 ABCDE
15	76	119.17 ABC	14	101.50 B	24	103.50 ABCDE
16	70	117.67 ABC	45	100.17 B	67	103.33 ABCDE
17	8	117.67 ABC	6	100.00 B	18	103.17 ABCDE
18	41	115.83 ABCD	87	100.00 B	45	103.17 ABCDE
19	18	115.67 ABCD	81	98.83 B	87	102.33 ABCDE
20	11	115.50 ABCD	86	98.33 B	32	102.33 ABCDE
21	87	115.33 ABCD	70	98.67 B	70	102.17 ABCDE
22	16	115.00 ABCD	27	98.33 B	7	102.00 ABCDE
23	28	114.17 ABCD	40	97.00 B	76	102.00 ABCDE
24	86	114.17 ABCD	11	96.33 B	28	100.00 ABCDE
25	17	114.00 ABCD	1	96.00 B	37	100.00 ABCDE

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
26	27	113.00 ABCD	24	95.67 B	48	100.00 ABCDE
27	37	112.67 ABCD	84	95.00 B	40	99.83 ABCDE
28	25	112.50 ABCD	75	94.00 B	27	99.83 ABCDE
29	32	112.50 ABCD	15	93.67 B	75	99.50 ABCDE
30	88	112.17 ABCD	18	93.50 B	41	98.83 ABCDE
31	14	111.67 ABCD	29	93.33 B	15	98.33 ABCDE
32	53	111.33 ABCD	34	93.17 B	53	98.50 ABCDE
33	84	111.17 ABCD	53	93.00 B	34	98.00 ABCDE
34	24	111.00 ABCD	72	92.83 B	61	98.00 ABCDE
35	34	110.83 ABCD	25	92.00 B	72	98.00 ABCDE
36	38	110.00 ABCD	31	91.83 B	1	97.83 ABCDE
37	22	109.83 ABCD	16	91.83 B	25	97.83 ABCDE
38	67	109.17 ABCD	61	91.50 B	16	97.33 ABCDE
39	6	108.67 ABCD	37	91.33 B	78	96.83 ABCDE
40	75	103.67 ABCD	85	91.17 B	17	96.00 ABCDE
41	26	108.50 ABCD	78	91.00 B	12	95.17 ABCDE
42	15	108.17 ABCD	83	90.83 B	6	95.00 ABCDE
43	31	107.33 ABCD	74	89.50 B	39	94.67 ABCDE
44	36	107.33 ABCD	32	89.33 B	84	94.00 ABCDE
45	79	106.83 ABCD	33	89.33 B	29	93.83 ABCDE
46	85	106.17 ABCD	55	89.00 B	56	93.83 ABCDE
47	2	105.83 ABCD	62	88.33 B	19	93.17 ABCDE
48	40	105.50 ABCD	22	88.00 B	31	93.00 ABCDE
49	48	105.17 ABCD	56	87.83 B	74	92.67 ABCDE
50	60	104.17 ABCD	19	87.00 B	33	92.67 ABCDE
51	62	103.83 ABCD	69	87.00 B	13	91.00 ABCDE
52	12	103.67 ABCD	7	87.00 B	36	90.67 ABCDE

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
53	61	103.50 ABCD	38	86.50 B	62	90.67 ABCDE
54	5	102.67 ABCD	43	85.67 B	83	90.00 ABCDE
55	54	102.33 ABCD	39	85.67 B	2	78.17 ABCDE
56	83	101.83 ABCD	12	85.50 B	86	78.00 ABCDE
57	72	101.67 ABCD	36	85.33 B	85	87.67 ABCDE
58	19	100.17 ABCD	86	84.33 B	43	87.67 ABCDE
59	56	99.83 ABCD	88	83.33 B	55	87.67 ABCDE
60	58	99.17 ABCD	5	83.17 B	22	87.50 ABCDE
61	39	98.00 ABCD	60	82.83 B	88	86.67 ABCDE
62	57	98.00 ABCD	52	81.17 B	57	86.17 ABCDE
63	13	97.33 ABCD	80	80.50 B	71	85.17 ABCDE
64	60	96.83 ABCD	79	79.83 B	90	84.67 ABCDE
65	74	95.67 ABCD	2	79.67 B	79	84.17 ABCDE
66	69	95.33 ABCD	44	79.50 B	68	83.83 ABCDE
67	55	95.33 ABCD	54	79.50 B	5	83.50 ABCDE
68	90	95.00 ABCD	10	79.50 B	60	83.10 ABCDE
69	71	94.83 ABCD	59	78.83 B	69	83.00 ABCDE
70	68	94.33 ABCD	71	78.83 B	52	81.50 ABCDE
71	52	93.83 ABCD	4	78.50 B	80	80.67 ABCDE
72	7	93.17 ABCD	47	78.50 B	65	80.67 ABCDE
73	59	93.00 ABCD	68	78.50 B	44	80.50 ABCDE
74	47	92.33 ABCD	58	78.33 B	39	79.50 ABCDE
75	43	91.83 ABCD	21	77.33 B	54	79.33 ABCDE
76	4	91.67 ABCD	13	77.17 B	58	79.33 ABCDE
77	23	91.67 ABCD	64	77.00 B	64	79.17 ABCDE
78	44	89.67 ABCD	57	76.50 B	4	78.17 ABCDE
79	65	89.17 ABCD	65	73.33 B	47	77.33 ABCDE
80	64	89.17 ABCD	66	72.67 B	50	76.67 ABCDE

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
81	73	85.33 ABCD	23	71.50 B	21	76.67 ABCDE
82	82	84.67 BCD	50	70.33 B	51	76.17 ABCDE
83	21	84.33 BCD	51	69.50 B	23	74.33 ABCDE
84	3	84.33 BCD	73	69.00 B	73	72.83 ABCDE
85	50	83.00 BCD	90	68.67 B	49	72.17 ABCDE
86	49	81.33 BCD	82	65.83 B	3	71.83 ABCDE
87	51	79.67 BCD	49	65.67 B	66	71.33 BCDE
88	66	78.83 BCD	3	61.67 B	63	69.67 CDE
89	46	70.83 CD	63	61.67 B	82	63.67 DE
90	63	64.00 D	46	60.00 B	46	60.33 E

Table 4 Detailed data of Biomass accessions in the field with statistical analysis on October 1989 (Ducan's Multiple Range Test, $\alpha = 0.01$)

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
1	77	165.83 A	77	140.00 A	81	145.00 A
2	30	159.17 AB	67	135.00 AB	70	136.67 AB
3	42	156.00 ABC	42	130.00 ABC	77	136.67 AB
4	81	154.17 ABC	41	130.00 ABC	42	133.33 ABC
5	67	147.50 ABCD	35	129.17 ABCD	35	130.00 ABCD
6	33	146.67 ABCDE	81	127.50 ABCDE	67	139.17 ABCDE
7	89	145.83 ABCDEF	27	127.50 ABCDE	10	128.33 ABCDEF
8	32	144.83 ABCDEFG	89	125.83 ABCDE	27	127.50 ABCDEFG
9	37	144.50 ABCDEFG	30	125.83 ABCDE	30	125.83 ABCDEFGH
10	10	144.17 ABCDEFG	87	124.17 ABCDEF	9	125.00 ABCDEFGH
11	35	144.17 ABCDEFG	9	124.17 ABCDEF	38	124.17 ABCDEFGH
12	20	144.17 ABCDEFG	37	120.83 ABCDEFG	37	124.17 ABCDEFGHI
13	29	144.33 ABCDEFGH	33	120.00 ABCDEFG	87	123.33 ABCDEFGHI
14	87	144.83 ABCDEFGH	18	118.33 ABCDEFG	76	120.00 ABCDEFGHI
15	86	141.67 ABCDEFGH	76	118.33 ABCDEFG	41	120.00 ABCDEFGHIJ
16	27	140.83 ABCDEFGHI	10	118.33 ABCDEFG	78	119.17 ABCDEFGHIJ
17	76	140.00 ABCDEFGHIJ	62	117.50 ABCDEFG	61	119.17 ABCDEFGHIJ
18	18	140.00 ABCDEFGHIJ	20	117.50 ABCDEFG	14	119.17 ABCDEFGHIJ
19	78	140.00 ABCDEFGHIJ	38	117.50 ABCDEFG	18	118.33 ABCDEFGHIJ
20	41	139.17 ABCDEFGHIJ	78	116.67 ABCDEFG	34	118.00 ABCDEFGHIJ
21	31	139.17 ABCDEFGHIJ	14	116.67 ABCDEFG	75	117.50 ABCDEFGHIJ
22	9	138.33 ABCDEFGHIJK	31	115.83 ABCDEFGH	20	117.50 ABCDEFGHIJ
23	8	137.50 ABCDEFGHIJK	61	115.00 ABCDEFGH	32	116.67 ABCDEFGHIJ
24	1	136.83 ABCDEFGHIJK	26	115.00 ABCDEFGH	45	116.67 ABCDEFGHIJ

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
25	45	136.67 ABCDEFGHIJK	60	115.00 ABCDEFGH	33	115.83 ABCDEFGHIJ
26	38	136.67 ABCDEFGHIJK	32	115.00 ABCDEFGH	62	115.83 ABCDEFGHIJ
27	75	135.00 ABCDEFGHIJK	70	114.17 ABCDEFGH	26	115.00 ABCDEFGHIJ
28	34	134.17 ABCDEFGHIJK	45	113.38 ABCDEFGH	11	115.00 ABCDEFGHIJ
29	14	134.17 ABCDEFGHIJK	34	113.33 ABCDEFGH	40	115.00 ABCDEFGHIJ
30	53	131.67 ABCDEFGHIJKL	75	113.33 ABCDEFGH	55	115.00 ABCDEFGHIJ
31	88	131.67 ABCDEFGHIJKL	53	113.33 ABCDEFGH	36	114.17 ABCDEFGHIJ
32	36	130.83 ABCDEFGHIJKL	40	112.50 ABCDEFGH	5	114.17 ABCDEFGHIJ
32	70	130.83 ABCDEFGHIJKL	55	112.50 ABCDEFGH	72	113.33 ABCDEFGHIJ
34	28	129.17 ABCDEFGHIJKLM	8	111.67 ABCDEFGH	48	113.33 ABCDEFGHIJ
35	84	129.17 ABCDEFGHIJKLM	17	110.83 ABCDEFGH	60	113.33 ABCDEFGHIJ
36	11	128.00 ABCDEFGHIJKLM	84	110.00 ABCDEFGH	56	112.50 ABCDEFGHIJ
37	6	127.50 ABCDEFGHIJKLM	6	110.00 ABCDEFGH	8	112.50 ABCDEFGHIJ
38	54	127.33 ABCDEFGHIJKLM	54	110.00 ABCDEFGH	53	112.50 ABCDEFGHIJ
39	17	127.00 ABCDEFGHIJKLM	43	110.00 ABCDEFGH	31	111.67 ABCDEFGHIJ
40	40	126.83 ABCDEFGHIJKLM	11	109.17 ABCDEFGH	17	110.83 ABCDEFGHIJ
41	83	125.83 ABCDEFGHIJKLM	72	109.17 ABCDEFGH	39	110.83 ABCDEFGHIJ
42	26	125.33 ABCDEFGHIJKLM	80	108.33 ABCDEFGH	84	110.00 ABCDEFGHIJ
43	24	124.67 ABCDEFGHIJKLM	53	107.50 ABCDEFGH	54	109.17 ABCDEFGHIJ
44	25	124.17 ABCDEFGHIJKLM	56	107.50 ABCDEFGH	88	109.17 ABCDEFGHIJ
45	61	124.17 ABCDEFGHIJKLM	39	106.67 ABCDEFGH	90	109.17 ABCDEFGHIJ
46	80	123.33 ABCDEFGHIJKLM	28	105.83 ABCDEFGHI	43	108.33 ABCDEFGHIJ
47	16	123.33 ABCDEFGHIJKLM	24	105.00 ABCDEFGHI	71	108.33 ABCDEFGHIJ
48	62	122.83 ABCDEFGHIJKLM	36	105.00 ABCDEFGHI	86	108.17 ABCDEFGHIJ
49	39	121.67 ABCDEFGHIJKLM	29	105.00 ABCDEFGHI	80	106.67 ABCDEFGHIJ
50	72	120.83 ABCDEFGHIJKLMN	71	105.00 ABCDEFGHI	7	106.67 ABCDEFGHIJ
51	85	120.83 ABCDEFGHIJKLMN	86	105.00 ABCDEFGHI	15	106.67 ABCDEFGHIJ
52	43	120.50 ABCDEFGHIJKLMN	79	105.00 ABCDEFGHI	74	105.83 ABCDEFGHIJ

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
53	58	118.33 BCDEFGHIJKLMN	48	104.17 ABCDEFGHI	28	105.83 ABCDEFGHIJ
54	15	118.00 BCDEFGHIJKLMN	7	104.17 ABCDEFGHI	83	105.83 ABCDEFGHIJ
55	22	117.83 BCDEFGHIJKLMN	16	104.17 ABCDEFGHI	29	105.00 ABCDEFGHIJ
56	56	117.50 BCDEFGHIJKLMN	1	104.17 ABCDEFGHI	24	105.00 ABCDEFGHIJ
57	55	117.50 BCDEFGHIJKLMN	19	103.33 ABCDEFGHI	79	105.00 ABCDEFGHIJ
58	12	117.00 BCDEFGHIJKLMN	85	103.33 ABCDEFGHI	57	104.17 ABCDEFGHIJK
59	60	116.67 BCDEFGHIJKLMN	90	102.50 ABCDEFGHIJ	59	104.17 ABCDEFGHIJK
60	13	116.67 BCDEFGHIJKLMN	74	101.67 ABCDEFGHIJ	12	104.17 ABCDEFGHIJK
61	59	116.67 BCDEFGHIJKLMN	12	101.67 ABCDEFGHIJ	16	104.17 ABCDEFGHIJK
62	79	116.67 BCDEFGHIJKLMN	88	101.67 ABCDEFGHIJ	19	103.33 BCDEFGHIJK
63	48	115.83 BCDEFGHIJKLMN	15	101.33 ABCDEFGHIJ	6	102.50 BCDEFGHIJK
64	71	115.83 BCDEFGHIJKLMN	69	100.83 ABCDEFGHIJ	58	101.67 BCDEFGHIJK
65	19	115.83 BCDEFGHIJKLMN	59	100.00 ABCDEFGHIJ	85	100.00 BCDEFGHIJK
66	90	115.83 BCDEFGHIJKLMN	25	100.00 ABCDEFGHIJ	25	100.00 BCDEFGHIJK
67	69	115.00 BCDEFGHIJKLMN	58	98.33 BCDEFGHIJ	82	100.00 BCDEFGHIJK
68	2	114.17 BCDEFGHIJKLMN	57	98.33 BCDEFGHIJ	1	100.00 BCDEFGHIJK
69	5	113.33 BCDEFGHIJKLMN	64	98.33 BCDEFGHIJ	89	100.00 BCDEFGHIJK
70	57	112.50 BCDEFGHIJKLMN	68	97.50 BCDEFGHIJ	68	99.17 BCDEFGHIJK
71	7	110.83 CDEFGHIJKLMN	82	96.67 BCDEFGHIJ	65	98.33 BCDEFGHIJK
72	74	109.17 CDEFGHIJKLMN	22	95.83 BCDEFGHIJ	13	97.50 BCDEFGHIJK
73	64	106.67 DEFGHIJKLMN	52	95.00 BCDEFGHIJ	69	96.03 BCDEFGHIJK
74	52	106.67 DEFGHIJKLMN	5	94.17 BCDEFGHIJ	22	95.83 BCDEFGHIJK
75	68	105.83 DEFGHIJKLMN	13	93.33 CDEFGHIJ	44	95.00 BCDEFGHIJK
76	82	105.00 DEFGHIJKLMN	44	90.00 CDEFGHIJ	2	94.17 BCDEFGHIJK
77	63	103.33 DEFGHIJKLMN	4	88.33 DEFGHIJ	52	93.33 CDEFGHIJK
78	65	102.17 DEFGHIJKLMN	73	86.67 EFGHIJ	64	92.50 CDEFGHIJK
79	73	100.83 DEFGHIJKLMN	2	86.67 EFGHIJ	50	91.67 CDEFGHIJK

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
80	3	99.33 DEFGHIJKLMN	63	86.67 EFGHIJ	63	91.67 CDEFGHIJK
81	4	99.17 EFGHIJKLMN	65	86.67 FGHIJ	73	89.17 DEFGHIJK
82	23	98.33 FGHIJKLMN	50	83.33 GHIJ	66	88.33 DEFGHIJK
83	50	97.50 GHIJKLMN	21	82.50 GHIJ	4	87.50 DEFGHIJK
84	47	96.33 HIJKLMN	66	82.50 GHIJ	51	86.67 EFGHIJK
85	44	94.17 IJKLMN	47	81.67 GHIJ	3	85.00 FGHIJK
86	51	93.33 JKLMN	23	80.83 GHIJ	47	83.33 GHIJK
87	21	91.67 KLMN	51	80.83 GHIJ	21	82.50 HIJK
88	66	83.67 LMN	3	75.83 HIJ	23	80.83 IJK
89	49	83.33 MN	49	65.83 IJ	49	76.67 JK
90	46	75.00 N	46	63.50 J	46	63.33 K

Table 5 Detailed data of Biomass accessions in the field with statistical analysis on October 1989 (Ducan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
1	77	178.00 A	77	145.50 A	81	151.67 A
2	30	168.33 AB	67	140.83 AB	77	142.50 AB
3	42	163.83 ABC	35	138.00 ABC	67	137.50 ABC
4	67	163.33 ABCD	42	133.00 ABCD	35	136.67 ABC
5	35	161.33 ABCDE	30	132.17 ABCDE	42	135.50 ABC
6	81	159.67 ABCDEF	41	132.17 ABCDEF	30	133.33 ABCD
7	37	158.50 ABCDEFG	81	130.50 ABCDEF	10	130.83 ABCDE
8	10	156.67 ABCDEFGH	27	130.50 ABCDEF	32	129.67 ABCDE
9	32	156.33 ABCDEFGHI	9	130.00 ABCDEFG	9	129.17 ABCDE
10	33	155.17 ABCDEFGHIJ	89	128.33 ABCDEFG	18	128.83 ABCDE
11	20	151.33 ABCDEFGHIJK	20	128.00 ABCDEFG	20	128.33 ABCDE
12	29	151.33 ABCDEFGHIJKL	37	128.00 ABCDEFG	37	127.17 ABCDEF
13	18	150.67 ABCDEFGHIJKLM	33	127.83 ABCDEFG	27	127.17 ABCDEF
14	31	150.50 ABCDEFGHIJKLM	10	127.50 ABCDEFG	26	125.50 ABCDEFG
15	76	148.33 ABCDEFGHIJKLMN	87	126.67 ABCDEFG	38	124.67 ABCDEFG
16	8	148.00 ABCDEFGHIJKLMN	31	126.33 ABCDEFGH	24	124.67 ABCDEFG
17	89	147.50 ABCDEFGHIJKLMN	18	126.17 ABCDEFGH	41	124.33 ABCDEFG
18	9	146.50 ABCDEFGHIJKLMN	76	123.83 ABCDEFGHI	70	124.17 ABCDEFG
19	27	146.33 ABCDEFGHIJKLMN	26	123.83 ABCDEFGHI	87	123.33 ABCDEFG
20	36	146.17 ABCDEFGHIJKLMN	32	123.33 ABCDEFGHI	33	122.17 ABCDEFG
21	41	146.00 ABCDEFGHIJKLMN	38	122.50 ABCDEFGHIJ	61	121.67 ABCDEFG
22	87	145.83 ABCDEFGHIJKLMN	62	119.67 ABCDEFGHIJ	76	121.67 ABCDEFG
23	38	145.67 ABCDEFGHIJKLMN	70	119.67 ABCDEFGHIJ	11	120.50 ABCDEFGH
24	78	145.00 ABCDEFGHIJKLMN	17	119.17 ABCDEFGHIJ	8	120.50 ABCDEFGH

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
25	86	143.83 ABCDEFGHIJKLMN	61	119.17 ABCDEFGHIJ	78	120.50 ABCDEFGH
26	1	141.17 ABCDEFGHIJKLMNO	34	119.17 ABCDEFGHIJ	75	119.17 ABCDEFGH
27	45	141.33 ABCDEFGHIJKLMNOP	78	118.00 ABCDEFGHIJ	31	118.83 ABCDEFGH
28	54	140.83 ABCDEFGHIJKLMNOP	53	117.17 ABCDEFGHIJ	24	188.00 ABCDEFGH
29	75	140.83 ABCDEFGHIJKLMNOP	43	117.17 ABCDEFGHIJ	36	117.83 ABCDEFGH
30	53	139.67 ABCDEFGHIJKLMNOP	60	116.67 ABCDEFGHIJ	62	117.50 ABCDEFGH
31	11	137.03 ABCDEFGHIJKLMNOP	75	115.83 ABCDEFGHIJ	45	117.50 ABCDEFGH
32	28	137.00 ABCDEFGHIJKLMNOP	55	115.83 ABCDEFGHIJ	89	116.67 ABCDEFGH
33	26	136.33 ABCDEFGHIJKLMNOP	8	115.50 ABCDEFGHIJ	72	116.67 ABCDEFGH
34	17	134.17 ABCDEFGHIJKLMNOP	45	114.67 ABCDEFGHIJ	17	116.33 ABCDEFGH
35	25	133.83 ABCDEFGHIJKLMNOP	11	114.50 ABCDEFGHIJ	53	116.33 ABCDEFGH
36	6	133.33 ABCDEFGHIJKLMNOP	40	114.17 ABCDEFGHIJ	40	115.83 ABCDEFGH
37	24	133.67 ABCDEFGHIJKLMNOP	6	113.83 ABCDEFGHIJ	7	115.50 ABCDEFGH
38	61	132.50 ABCDEFGHIJKLMNOPQ	72	113.33 ABCDEFGHIJ	15	115.50 ABCDEFGH
39	83	132.50 ABCDEFGHIJKLMNOPQ	71	112.50 ABCDEFGHIJK	55	115.00 ABCDEFGH
40	14	131.67 ABCDEFGHIJKLMNOPQ	39	112.50 ABCDEFGHIJK	60	114.17 ABCDEFGH
41	62	131.67 ABCDEFGHIJKLMNOPQ	84	112.17 ABCDEFGHIJK	29	113.17 ABCDEFGH
42	54	131.67 ABCDEFGHIJKLMNOPQ	36	112.17 ABCDEFGHIJK	6	113.83 ABCDEFGH
43	88	131.67 ABCDEFGHIJKLMNOPQ	54	111.67 ABCDEFGHIJK	56	113.33 ABCDEFGH
44	40	131.33 ABCDEFGHIJKLMNOPQ	24	111.67 ABCDEFGHIJK	48	113.33 ABCDEFGH
45	72	131.83 BCDEFGHIJKLMNOPQ	28	111.33 ABCDEFGHIJK	84	113.33 ABCDEFGH
46	84	130.50 BCDEFGHIJKLMNOPQ	29	110.00 ABCDEFGHIJK	43	112.50 ABCDEFGH
47	43	130.50 BCDEFGHIJKLMNOPQ	15	110.00 ABCDEFGHIJK	28	112.17 ABCDEFGH
48	70	130.33 BCDEFGHIJKLMNOPQ	69	110.00 ABCDEFGHIJK	80	112.17 ABCDEFGH
49	15	130.00 BCDEFGHIJKLMNOPQ	25	110.00 ABCDEFGHIJK	39	111.67 ABCDEFGH
50	16	130.00 BCDEFGHIJKLMNOPQ	83	109.17 ABCDEFGHIJKL	71	110.00 ABCDEFGH

Ranked order	Accession no.	Height (cm.)		Accession no.	Width (cm.)		Accession no.	length (cm.)	
51	71	129.67	BCDEFGHIJKLMNOPQ	7	108.67	ABCDEFGHIJKL	19	110.00	ABCDEFGH
52	80	126.67	BCDEFGHIJKLMNOPQ	79	108.33	ABCDEFGHIJKL	83	110.00	BCDEFGH
53	58	125.83	BCDEFGHIJKLMNOPQ	56	108.33	ABCDEFGHIJKL	54	109.67	BCDEFGH
54	39	125.83	BCDEFGHIJKLMNOPQ	80	108.00	ABCDEFGHIJKL	90	109.17	BCDEFGH
55	69	125.00	BCDEFGHIJKLMNOPQR	1	107.17	ABCDEFGHIJKL	88	109.17	BCDEFGH
56	59	125.00	BCDEFGHIJKLMNOPQR	12	107.00	ABCDEFGHIJKL	86	108.33	BCDEFGH
57	12	124.17	BCDEFGHIJKLMNOPQR	86	106.67	BCDEFGHIJKL	25	107.50	BCDEFGHI
58	60	124.17	BCDEFGHIJKLMNOPQR	14	105.50	BCDEFGHIJKL	74	107.50	BCDEFGHI
59	19	123.00	BCDEFGHIJKLMNOPQR	19	105.50	BCDEFGHIJKL	79	106.67	BCDEFGHI
60	85	122.50	BCDEFGHIJKLMNOPQR	48	105.00	BCDEFGHIJKL	16	106.67	BCDEFGHI
61	55	122.50	BCDEFGHIJKLMNOPQR	52	105.00	BCDEFGHIJKL	57	106.67	BCDEFGHI
62	56	121.33	BCDEFGHIJKLMNOPQR	16	105.00	BCDEFGHIJKL	12	105.50	BCDEFGHI
63	7	121.00	BCDEFGHIJKLMNOPQR	5	105.00	BCDEFGHIJKL	65	105.50	BCDEFGHI
64	13	120.83	BCDEFGHIJKLMNOPQR	59	104.17	BCDEFGHIJKL	5	104.67	BCDEFGHI
65	5	120.83	BCDEFGHIJKLMNOPQR	85	104.17	BCDEFGHIJKL	14	104.50	BCDEFGHI
66	22	120.83	BCDEFGHIJKLMNOPQR	88	104.17	BCDEFGHIJKL	59	104.17	BCDEFGHI
67	2	120.50	CDEFGHIJKLMNOPQR	57	103.80	BCDEFGHIJKL	82	103.33	BCDEFGHI
68	48	117.50	CDEFGHIJKLMNOPQR	90	102.50	BCDEFGHIJKLM	69	103.00	BCDEFGHI
69	79	116.67	CDEFGHIJKLMNOPQR	74	102.50	BCDEFGHIJKLM	58	102.83	BCDEFGHI
70	90	116.67	CDEFGHIJKLMNOPQR	64	102.17	BCDEFGHIJKLM	68	102.83	BCDEFGHI
71	74	116.00	DEFGHIJKLMNOPQR	58	100.33	CDEFGHIJKLM	4	102.17	BCDEFGHI
72	57	15.83	DEFGHIJKLMNOPQR	68	100.33	CDEFGHIJKLM	1	101.67	BCDEFGHI
73	82	15.00	EFGHIJKLMNOPQR	22	100.00	CDEFGHIJKLM	52	101.33	BCDEFGHI
74	52	14.17	EFGHIJKLMNOPQR	4	99.50	CDEFGHIJKLM	85	100.00	CDEFGHI
75	64	63.17	EFGHIJKLMNOPQR	44	96.67	DEFGHIJKLM	13	100.00	CDEFGHI

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
76	63	13.33 FGHIJKLMNOPQR	82	96.67 DEFGHIJKLM	73	98.83 CDEFGHI
77	68	111.50 GHIJKLMNOPQR	13	95.00 DEFGHIJKLM	22	98.00 CDEFGHI
78	4	110.67 HIJKLMNOPQR	73	93.83 EFGHIJKLM	2	97.17 CDEFGHI
79	65	108.83 IJKLMNOPQR	63	93.33 EFGHIJKLM	64	97.00 CDEFGHI
80	51	108.33 JKLMNOPQR	2	93.00 FGHIJKLM	51	96.67 CDEFGHI
81	73	108.00 JKLMNOPQR	65	92.00 FGHIJKLM	50	96.67 CDEFGHI
82	50	105.00 KLMNOPQR	51	90.00 GHIJKLM	63	95.00 CDEFGHI
83	3	103.67 LMNOPQR	50	87.50 HIJKLM	44	95.00 CDEFGHI
84	23	103.33 MNOPQR	66	86.67 IJKLM	23	91.67 DEFGHI
85	44	101.67 NOPQR	23	85.83 IJKLM	66	88.83 EFGHI
86	47	100.83 NOPQR	21	85.50 IJKLM	21	85.50 FGHI
87	21	95.83 OP	47	84.17 JKLM	47	85.00 FGHI
88	66	94.17 PQR	3	71.17 KLM	3	84.17 GHI
89	49	85.83 QR	49	71.67 LM	49	78.33 HI
90	46	79.33 R	46	66.83 M	46	67.17 I

Table 6 Ranked Score of Biomass accessions on growth in the field on April 1988
(Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score Height (cm)	Width (cm)	Length(cm)	Total Score
1.	77	1	1	2	4
2.	81	4	3	1	8
3.	30	3	2	6	11
4.	20	8	4	4	16
5.	10	2	7	11	20
6.	11	5	8	13	26
6.	78	7	14	5	26
8.	31	6	9	12	27
9.	76	10	15	3	28
10.	16	9	5	15	29
11.	35	14	10	8	32
12.	15	17	11	17	35
13.	29	11	6	27	44
14.	9	13	13	26	52
14.	27	19	24	9	52
16.	18	18	18	17	53
17.	17	21	12	22	55
17.	32	16	16	23	55
19.	25	29	17	14	60
20.	87	23	23	16	62
21.	83	26	28	10	64
22.	1	12	30	24	66
23.	41	15	19	33	67
24.	67	32	22	19	73

Ranked order	Accession no.	Score Height (cm)	Score Width (cm)	Score Length(cm)	Total Score
25.	37	28	33	18	79
26.	38	20	25	35	80
27.	14	36	20	31	87
27.	89	22	44	21	87
29.	8	33	26	29	88
30	40	27	21	42	90
31.	36	25	32	43	100
32.	79	35	27	40	102
33.	80	38	34	34	106
34.	84	45	39	25	109
35.	24	30	36	48	114
36.	42	24	37	59	120
37.	19	37	29	56	122
37.	43	50	42	30	122
39.	22	48	31	44	123
40.	12	41	40	46	127
40.	75	39	52	36	127
42.	45	49	45	37	131
43.	34	44	41	47	132
43.	71	66	38	28	132
45.	86	46	49	39	134
46.	26	52	35	52	139
47.	3	31	43	66	140
48.	21	43	50	53	146
48.	74	55	53	38	146
50.	39	54	48	54	156
51.	70	64	57	41	162

Ranked order	Accession no.	Score Height (cm)	Width (cm)	Length(cm)	Total Score
52.	5	51	51	62	164
53.	13	40	55	70	165
53.	33	56	59	50	165
55.	4	34	65	67	166
56.	85	63	46	58	167
57.	28	69	54	45	168
57.	62	65	71	32	168
57.	72	60	47	61	168
60.	56	61	60	49	170
61.	60	47	68	57	172
62.	57	62	63	51	176
63.	47	78	80	20	178
64.	23	59	62	60	181
65.	7	53	58	77	188
66.	2	42	67	81	190
67.	6	68	61	71	200
68.	61	82	56	64	202
69.	69	67	70	68	205
70.	49	58	73	75	206
71.	82	57	83	69	209
71.	88	72	72	65	209
73.	65	77	78	55	210
74.	54	73	66	72	211
75.	90	75	76	63	214
76.	44	70	74	76	220
76.	48	71	75	74	220
78.	53	76	69	82	227

Ranked order	Accession no.	Score			Total Score
		Height (cm)	Width (cm)	Length(cm)	
79.	59	83	64	80	227
80.	52	74	77	79	230
81.	58	81	82	73	236
82.	46	80	79	78	237
83.	51	84	81	84	249
84.	68	79	84	89	252
85.	55	86	85	86	257
85.	63	85	89	83	257
87.	50	87	88	87	262
87.	66	90	87	85	262
89.	64	89	86	88	263
90.	73	88	90	90	268

Table 7 Ranked Order of Biomass Accession in the Field (August)
(Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
1	81	2	3	1	6
2.	10	4	5	2	11
3.	15	7	11	3	21
4.	29	8	7	7	22
5.	77	1	1	21	24
6.	30	3	12	13	28
6.	76	11	8	9	28
8.	87	6	13	15	34
9.	14	12	19	4	35
9.	11	15	4	16	35
11	89	5	2	29	36
12.	84	9	26	12	47
12.	35	18	24	5	47
14.	78	22	14	14	50
14.	37	36	6	8	50
16.	27	10	10	32	52
17.	19	19	23	11	53
18.	31	20	9	26	55
19.	16	13	18	25	56
20.	17	32	16	10	58
21.	18	14	17	31	62
22.	20	28	9	27	64
23.	8	27	21	19	67

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
24.	32	17	31	20	68
25.	86	21	22	28	71
26.	36	23	25	24	72
27.	25	31	20	22	73
28.	45	25	27	23	75
29.	38	16	53	18	87
30.	40	34	28	30	92
31.	9	38	29	26	93
32.	13	30	33	37	100
32.	42	26	35	39	100
34.	26	37	32	35	104
35.	83	40	34	34	108
36.	22	52	30	28	110
37.	2	29	42	42	113
38.	23	41	38	36	115
38.	39	33	36	46	115
38.	41	35	39	41	115
41.	1	24	49	43	116
42.	75	48	40	33	121
43.	24	42	48	38	128
44.	34	46	47	44	137
45.	48	51	43	48	142
46.	85	39	65	40	144
47.	43	44	60	45	149

Ranked order	Accession no.	Score Height	Score Width	Score Length	Total Score
48.	80	45	59	50	154
48.	7	47	58	49	154
50.	5	43	54	58	155
51.	6	61	44	51	156
52.	62	55	52	52	159
53.	79	56	51	54	161
53.	67	50	37	74	161
55.	90	60	57	47	164
56.	28	67	45	56	168
57.	54	49	67	53	169
58.	61	68	46	63	177
59.	12	58	56	64	178
60.	71	54	63	62	179
60.	88	53	50	76	179
60.	74	64	55	60	179
63.	69	57	64	59	180
64.	33	62	41	79	182
65.	70	65	68	55	188
66.	56	70	61	61	192
67.	57	72	66	57	195
68.	82	59	73	69	201
69.	60	75	62	65	202
70.	53	66	71	66	203
71.	4	63	80	67	210
72.	52	71	70	73	214

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
73.	49	73	72	72	217
74.	46	80	69	70	219
75.	21	74	74	78	226
76.	3	69	78	80	227
77.	47	79	76	75	230
78.	55	83	77	71	231
79.	58	77	79	77	233
80.	44	78	75	81	234
81.	72	85	82	68	235
82.	68	76	87	83	246
83.	59	81	81	85	247
84.	64	82	83	84	249
85.	51	84	84	86	254
86.	65	88	85	82	255
87.	50	89	86	87	262
89.	66	86	88	90	264
88.	63	87	89	88	264
90.	73	90	90	89	269

Table 8 Ranked Score of Biomass accessions on growth in the field on October 1988
(Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score Height	Score Width	Score Length	Total Score
1	77	1	1	1	3
2	81	2	2	2	6
3.	78	3	5	4	12
4.	89	5	6	6	17
5.	83	11	3	8	22
6.	87	14	9	3	26
7.	30	10	4	14	28
8.	29	6	8	15	29
9.	84	7	16	7	30
10.	18	4	22	5	31
11.	35	17	7	11	35
12.	76	15	10	13	38
13.	20	12	17	9	3[illegible]
14.	39	8	21	12	41
15.	9	13	11	22	46
16.	10	21	20	10	51
17.	17	16	12	28	56
18.	27	18	25	16	59
18.	31	9	32	18	59
20.	11	31	14	17	62
21.	16	28	15	21	64

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
22.	26	25	19	23	67
23.	14	44	13	24	81
24.	37	33	23	27	83
24.	32	19	26	38	83
26.	90	24	18	45	87
26.	19	35	33	19	87
28.	15	26	39	25	90
28.	25	43	27	20	90
30.	41	23	36	36	95
31.	38	27	29	40	96
31.	28	29	37	30	96
33.	42	32	34	33	99
34.	1	22	50	29	101
34.	86	20	24	57	101
36.	85	48	30	26	104
37.	2	30	28	50	108
38.	80	34	49	34	117
39.	12	38	40	48	126
40.	54	37	58	32	127
40.	72	39	35	53	127
42.	62	53	41	35	129
43.	88	47	44	43	134
44.	57	64	38	37	139
45.	45	36	31	80	147
46.	71	66	51	31	148

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
46.	61	61	46	41	148
45.	45	36	31	80	147
46.	71	66	51	31	148
46.	61	61	46	41	148
48.	7	46	48	56	150
49.	8	59	47	46	152
50.	75	19	57	47	153
51.	67	63	43	49	155
52.	4	40	64	55	159
52.	13	52	63	44	159
54.	82	42	61	58	161
55.	34	51	52	60	163
56.	70	57	56	52	165
57.	36	58	42	66	166
58.	22	56	53	59	168
59.	6	55	54	61	170
59	56	41	67	62	170
61.	69	[illegible]	66	54	174
62.	24	50	55	70	175
63.	3	60	68	51	179
64.	79	45	62	75	182
64	5	67	73	42	182
66.	74	69	59	63	191
67.	23	68	60	65	193
68.	58	62	69	67	198

Ranked order	Accession no.	Score			Total Score
		Height	Width	Length	
69.	43	78	45	76	199
70.	40	70	65	68	203
71.	33	65	76	64	205
71.	44	82	84	39	205
73.	48	72	72	69	213
74.	52	73	71	73	217
75	53	71	70	77	218
76.	64	76	77	71	224
77.	68	74	78	82	234
78.	21	80	74	81	235
78.	47	83	80	72	235
80.	60	75	89	74	238
81.	63	79	81	79	239
82.	65	81	82	83	246
83.	59	87	75	87	249
84.	46	86	87	78	251
84.	49	77	86	88	251
86.	51	84	83	85	252
86.	50	89	79	84	252
88.	55	85	85	86	256
89.	66	88	88	90	266
90.	73	90	90	89	269

Table 9 Ranked Score of Biomass accessions on growth in the field on January 1989 (Duncan's Multiple Range Test, α =0.01)

Ranked order	Accession no.	Score Height	width	Length	Total Score
1	77	1	1	2	4
2	81	2	5	1	8
3	1	4	2	5	11
4	30	3	9	4	16
5	27	8	7	7	22
6	17	14	3	8	25
7	10	9	10	13	32
8	35	10	20	3	33
9	31	11	13	11	35
10	89	6	21	12	39
11	11	7	8	25	40
12	18	32	6	6	44
13	32	5	22	18	45
14	9	30	4	14	48
15	37	29	11	10	50
16	25	13	18	21	52
17	76	12	17	24	53
18	38	16	15	22	53
19	16	28	14	16	55
20	15	19	23	15	57
21	20	33	12	17	62
22	42	22	16	35	73
23	87	18	41	20	79

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
24	39	27	26	27	80
25	84	15	37	29	81
26	2	23	33	26	82
27	24	45	28	9	82
28	78	21	48	19	88
29	19	42	25	23	90
30	4	39	19	34	92
31	3	17	38	39	94
32	34	40	24	30	94
33	86	36	31	28	95
34	79	25	35	41	101
35	13	26	30	47	103
36	7	20	32	52	104
37	83	24	51	32	117
38	41	38	27	44	119
39	45	57	29	31	117
40	12	50	36	36	122
41	33	34	53	40	127
42	26	43	42	42	127
43	36	35	44	50	129
44	40	58	40	33	131
45	6	44	43	46	133
46	5	54	34	54	134
47	29	31	45	59	135
48	61	52	47	38	137

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
49	28	37	62	43	142
50	75	47	61	37	145
51	48	70	39	48	157
52	88	49	49	61	159
53	8	61	56	45	162
54	60	41	68	55	164
55	85	51	58	56	165
56	23	60	59	49	168
57	57	65	52	51	173
58	62	55	65	53	173
59	14	56	60	57	173
60	90	48	67	62	177
61	71	54	57	67	178
62	22	59	46	75	180
63	70	62	54	64	180
64	69	64	55	66	185
65	43	72	50	63	185
66	21	67	63	58	188
67	80	53	70	79	202
68	56	66	64	77	207
69	67	68	69	71	208
70	72	71	72	65	208
71	74	76	66	69	211
72	54	63	81	68	212
73	64	79	75	60	214

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
74	65	78	72	70	220
75	53	69	80	72	221
76	49	74	76	78	228
77	58	75	77	76	228
78	52	73	83	73	229
79	47	85	73	74	232
80	44	82	74	82	238
81	82	77	79	85	241
82	59	84	78	81	243
83	68	81	82	84	247
84	55	80	84	86	250
85	50	86	85	80	251
86	51	83	86	83	252
87	63	88	87	87	262
88	46	87	88	88	263
89	66	89	89	89	267
90	73	90	90	90	270

Table 10 Ranked Score of Biomass accessions on growth in the field on April 1989 (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
1	77	1	1	1	3
2	89	2	5	2	9
3	81	5	3	5	13
4	87	7	4	8	19
5	9	12	6	3	21
6	42	10	2	10	22
7	35	11	8	4	23
8	10	6	12	9	27
9	30	4	14	12	30
10	29	3	10	20	33
11	78	9	15	13	37
12	27	17	9	11	37
13	41	18	7	15	40
14	79	22	13	6	41
15	11	8	20	17	45
16	20	25	16	7	48
17	14	14	17	18	49
18	76	13	18	21	52
19	18	20	14	19	53
20	15	16	26	25	67
21	31	31	23	16	70
22	16	23	30	19	72
23	84	30	11	33	74

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
24	45	19	28	39	76
25	28	35	25	39	79
26	25	21	39	27	87
27	32	29	24	38	91
28	17	31	31	24	93
29	38	36	37	22	95
30	24	40	35	23	95
31	34	33	22	41	96
32	85	24	29	50	103
33	26	48	21	35	104
34	22	37	34	34	105
35	40	47	33	28	107
36	8	49	27	31	107
37	86	26	45	43	114
38	83	28	50	36	114
39	88	42	36	37	115
40	70	34	38	46	118
41	33	27	39	56	122
42	67	44	40	40	124
43	39	32	41	54	127
44	37	15	90	26	131
45	56	45	44	42	131
46	75	54	46	32	132
47	1	39	51	48	138
48	53	53	43	47	143

Ranked order	Accession no.	Score			Total Score
		Height	width	Length	
49	36	41	60	45	146
50	62	52	42	53	147
51	72	65	54	30	149
52	12	43	53	59	151
53	48	50	49	52	151
54	7	51	52	51	154
55	2	46	47	64	157
56	19	58	56	44	158
57	61	57	48	55	160
58	69	67	62	45	174
59	6	56	58	66	180
60	57	62	59	63	180
61	80	55	65	61	181
62	54	64	59	67	190
63	43	63	68	60	191
64	68	71	61	62	194
65	13	72	64	58	194
66	5	61	67	71	199
67	90	69	57	75	201
68	23	66	63	73	202
69	74	74	71	57	202
70	52	73	66	65	204
71	60	60	75	70	205
72	4	59	79	69	207
73	82	68	72	68	208

Ranked order	Accession no.	Score Height	Score width	Score Length	Total Score
74	71	70	70	74	214
75	47	77	73	76	226
76	59	78	78	72	228
77	58	75	74	80	229
78	55	84	69	88	231
79	64	76	81	81	238
80	44	79	77	82	238
81	21	80	76	83	239
82	3	81	82	77	240
83	51	85	80	79	244
84	49	82	85	84	251
85	65	83	84	86	253
86	50	87	86	85	258
87	66	90	83	87	260
88	63	86	88	88	262
89	46	88	87	89	264
90	73	89	89	90	268

Table 11 Ranked Score of Biomass accessions on growth in the field on July 1989 (Duncan's Multiple Range Test, α =0.01)

Ranked order	Accession no.	Score			Total Score
		Height	width	length	
1	77	1	3	4	8
2	42	4	5	2	11
3	9	5	6	1	12
4	30	6	7	6	19
5	89	2	9	12	23
6	81	3	19	3	25
7	35	10	10	5	25
8	20	9	12	11	32
9	8	17	11	14	42
10	45	14	16	18	48
11	28	23	2	24	49
12	26	41	1	9	51
13	41	18	4	30	52
14	11	20	24	10	54
15	76	15	20	23	58
16	70	16	21	21	58
17	87	21	18	19	58
18	14	31	15	13	59
19	18	19	30	17	66
20	67	38	13	16	67
21	1	7	25	36	68
22	24	34	26	15	75
23	27	26	22	28	76

Ranked order	Accession no.	Score			Total Score
		Height	width	length	
24	17	25	14	40	79
25	48	49	8	26	83
26	10	8	68	8	84
27	29	11	31	45	87
28	37	27	39	25	91
29	78	12	41	39	92
30	32	29	44	20	93
31	38	36	53	7	96
32	16	22	37	38	97
33	53	32	33	32	97
34	75	40	28	29	97
35	31	43	36	48	97
36	6	39	17	42	98
37	40	48	23	27	98
38	25	28	35	37	100
39	34	35	32	33	100
40	15	42	29	31	102
41	84	33	27	44	104
42	33	13	45	50	108
43	61	53	38	34	125
44	72	57	34	35	126
45	86	24	58	56	138
46	85	46	40	57	143
47	22	37	48	60	145
48	7	72	52	22	146

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
49	12	52	56	41	149
50	88	30	59	61	150
51	62	51	47	53	151
52	83	56	42	54	152
53	36	44	57	52	153
54	56	59	49	46	154
55	19	58	50	47	155
56	74	65	43	49	157
57	39	61	55	43	159
58	2	47	65	55	167
59	55	67	46	59	172
60	79	45	64	65	174
61	5	54	60	67	181
62	80	50	63	71	184
63	69	66	51	69	186
64	43	75	54	58	187
65	13	63	76	51	190
66	60	64	61	68	193
67	54	55	67	75	197
68	57	62	78	62	202
69	71	69	70	63	202
70	52	71	62	70	203
71	68	70	73	66	209
72	58	60	74	76	210
73	59	73	69	74	216

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
74	90	68	85	64	217
75	44	78	66	73	217
76	47	74	72	79	225
77	4	76	71	78	225
78	65	79	79	72	230
79	64	80	77	77	234
80	21	83	75	81	239
81	23	77	81	83	241
82	50	85	82	80	247
83	73	81	84	84	249
84	51	87	83	82	252
85	66	88	80	87	255
86	82	82	86	89	257
87	3	84	88	86	258
88	49	86	87	85	258
89	63	90	89	88	267
90	46	89	90	90	269

Table 12 Ranked Score of Biomass accessions on growth in the field on October 1989 (Duncan's Multiple Range Test, α =0.01)

Ranked order	Accession no.	Score Height	width	length	Total Score
1	77	1	1	3	5
2	42	3	3	4	10
3	81	4	6	1	11
4	67	5	2	6	13
5	30	2	9	9	20
6	35	11	5	5	21
7	27	16	7	8	31
8	37	9	12	12	33
9	10	10	16	7	33
10	87	14	10	13	37
11	41	20	4	15	39
12	9	22	11	10	43
13	33	6	13	25	44
14	76	17	15	14	46
15	18	18	14	19	51
16	20	12	18	22	52
17	78	19	20	16	55
18	38	26	19	11	56
19	32	8	26	23	57
20	70	33	27	2	62
21	14	29	21	18	68
22	45	25	28	24	77
23	34	28	29	20	77

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
24	75	27	30	21	78
25	31	21	22	39	82
26	89	7	8	69	84
27	61	45	23	17	85
28	62	48	17	26	91
29	26	42	24	27	93
30	8	23	34	37	94
31	53	30	31	38	99
32	40	40	32	29	103
33	11	36	40	28	104
34	36	32	48	31	111
35	84	35	36	42	113
36	86	15	51	48	114
37	17	39	35	40	114
38	29	13	49	55	117
39	54	38	38	43	119
40	60	59	25	35	119
41	55	57	33	30	120
42	72	50	41	33	124
43	28	34	46	53	133
44	39	49	45	41	135
45	56	56	44	36	136
46	88	31	62	44	137
47	6	33	37	63	137
48	80	46	42	49	137

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
49	43	52	39	46	137
50	83	41	43	54	138
51	24	43	47	56	146
52	1	24	56	68	148
53	48	63	53	34	150
54	71	64	50	47	161
55	16	47	55	61	163
56	15	54	63	51	168
57	90	66	59	45	170
58	79	62	52	57	171
59	5	69	74	32	171
60	85	51	58	65	174
61	7	71	54	50	175
62	25	44	66	66	176
63	12	58	61	60	179
64	5	53	67	64	184
65	19	65	57	62	184
66	74	72	60	52	184
67	59	61	65	59	185
68	57	70	68	58	196
69	22	55	72	74	201
70	69	67	64	73	204
71	13	60	75	72	207
72	82	76	71	67	214
73	68	75	70	70	215

Ranked order	Accession no.	Score Height	width	length	Total Score
74	64	73	69	78	220
75	2	68	79	78	223
76	52	74	73	77	224
77	65	78	81	71	230
78	44	85	76	75	236
79	63	77	80	80	237
80	73	79	78	81	238
81	4	81	77	73	241
82	50	83	88	85	244
83	3	80	88	85	253
84	66	88	84	82	254
85	47	84	85	86	255
86	23	82	86	88	256
87	51	86	87	84	257
88	21	87	83	87	257
89	49	89	89	89	267
90	46	90	90	90	270

Table 13 Ranked Score of Biomass accessions on growth in the field on December 1989 (Duncan's Multiple Range Test, α =0.01)

Ranked order	Accession no.	Score Height	width	length	Total Score
1	77	1	1	2	4
2	67	4	2	3	9
3	42	3	4	5	12
4	35	5	3	4	12
5	30	2	5	6	13
6	81	6	7	1	14
7	10	8	14	7	29
8	37	7	12	12	31
9	20	11	11	11	33
10	9	18	9	9	36
11	32	9	20	8	37
12	18	13	17	10	40
13	27	19	8	13	40
14	33	10	13	20	43
15	41	21	6	17	44
16	76	15	18	22	55
17	87	22	15	19	56
18	31	14	16	27	57
19	69	17	10	32	59
20	38	23	21	15	59
21	26	33	19	14	66
22	34	28	26	16	70
23	8	16	33	24	73

Ranked order	Accession no.	Score			Total Score
		Height	width	length	
24	78	24	27	25	76
25	61	38	25	21	84
26	75	29	31	26	86
27	70	48	23	18	89
28	36	20	42	29	91
29	17	34	24	34	92
30	45	27	34	31	92
31	53	30	28	35	93
32	62	41	22	30	93
33	29	12	46	41	98
34	11	31	35	23	98
35	24	37	44	28	109
36	6	36	37	42	115
37	40	44	36	36	116
38	72	45	38	33	116
39	43	47	29	46	122
40	28	32	45	47	126
41	60	58	30	40	128
42	84	46	41	45	132
43	55	61	32	39	132
44	15	49	47	38	134
45	86	25	57	56	138
46	54	42	43	53	138
47	71	51	39	50	140
48	25	35	49	57	141

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
49	83	39	50	52	141
50	39	54	40	49	143
51	7	63	51	37	151
52	1	26	55	72	153
53	80	52	54	48	154
54	56	62	53	43	158
55	14	40	58	65	163
56	88	43	66	55	164
57	19	59	59	51	169
58	69	55	48	68	171
59	16	50	62	60	172
60	48	68	60	44	172
61	12	57	56	62	175
62	79	69	52	59	180
63	59	56	64	66	186
64	5	65	63	64	192
65	90	70	68	54	192
66	58	53	71	69	193
67	74	71	69	58	198
68	85	60	65	74	199
69	57	72	67	61	200
70	52	74	61	73	208
71	13	64	77	75	216
72	22	66	73	77	216
73	82	73	76	67	216

Ranked order	Accession no.	Score Height	Score width	Score length	Total Score
74	68	77	72	70	219
75	4	78	74	71	223
76	65	79	81	63	223
77	64	75	70	79	224
78	2	67	80	78	225
79	73	81	78	76	235
80	63	76	79	82	237
81	51	80	82	80	242
82	44	85	75	83	243
83	50	82	83	81	246
84	23	84	85	84	253
85	66	88	84	85	257
86	3	83	88	88	258
87	21	87	86	86	259
88	47	86	87	87	260
89	49	89	89	89	267
90	46	90	90	90	270

Table 14 Detailed data of Biomass accessions in the container with statistical analysis (Duncan's Multiple Range Test, α = 0.01)

Ranked Order	Accession no.	Height in January 1989 (cm.)	Accession no.	Height in April 1989 (cm.)
1	49	192.86 A	49	196.00 A
2	71	186.95 AB	46	195.00 A
3	46	183.67 ABC	51	191.33 A
4	62	180.61 ABCD	54	184.33 AB
5	59	177.83 ABCDE	53	183.83 AB
6	74	176.64 ABCDE	48	179.50 ABC
7	58	175.80 ABCDE	74	178.33 AB8
8	67	175.17 ABCDE	67	176.50 ABC
9	90	174.30 ABCDEF	58	176.33 ABC
10	84	170.83 ABCDEF	25	176.00 ABC
11	4	171.83 ABCDEF	81	175.17 ABC
12	54	170.83 ABCDEF	59	174.50 ABC
13	6	170.08 ABCDEF	45	174.00 ABC
14	24	167.33 ABCDEF	70	173.67 ABC
15	8	167.17 ABCDEF	77	173.17 ABC
16	40	167.17 ABCDEF	8	172.83 ABC
17	47	167.05 ABCDEF	84	172.50 ABC
18	48	167.00 ABCDEF	79	172.33 ABC
19	56	165.42 ABCDEF	78	172.33 ABC
20	36	165.11 ABCDEF	4	172.17 ABC
21	81	164.80 ABCDEF	87	172.00 ABC
22	5	164.25 ABCDEF	37	171.83 ABC
23	78	164.17 ABCDEF	72	171.50 ABC
24	52	163.92 ABCDEF	60	170.67 ABC

Ranked Order	Accession no.	Height in January 1989 (cm.)	Accession no.	Height in April 1989 (cm.)
25	43	163.75 ABCDEF	40	170.50 ABC
26	69	163.64 ABCDEF	5	170.33 ABC
27	79	163.42 ABCDEF	57	169.83 ABC
28	76	163.17 ABCDEF	61	168.83 ABC
29	14	162.92 ABCDEF	43	167.83 ABC
30	25	162.50 ABCDEF	47	167.33 ABC
31	21	162.25 ABCDEF	12	167.17 ABC
32	61	161.83 ABCDEF	21	166.33 ABC
33	41	161.11 ABCDEF	35	166.00 ABC
34	45	160.92 ABCDEF	55	164.83 ABC
35	53	160.78 ABCDEF	86	164.50 ABC
36	37	160.75 ABCDEF	24	164.50 ABC
37	57	160.17 ABCDEF	80	164.17 ABC
38	51	160.11 ABCDEF	6	164.00 ABC
39	19	160.00 ABCDEF	44	163.83 ABC
40	85	159.83 ABCDEF	66	163.67 ABC
41	33	159.33 ABCDEF	85	163.50 ABC
42	70	159.25 ABCDEF	52	163.50 ABC
43	26	158.20 ABCDEF	68	163.50 ABC
44	66	157.78 ABCDEF	50	163.33 ABC
45	16	156.33 ABCDEFG	39	162.67 ABC
46	31	156.22 ABCDEFG	71	162.33 ABC
47	87	156.08 ABCDEFG	64	162.17 ABC
48	68	155.97 ABCDEFG	88	161.83 ABC
49	64	155.75 ABCDEFG	33	161.83 ABC
50	50	155.30 ABCDEFG	22	161.67 ABC
51	32	155.00 ABCDEFG	90	161.00 ABC

Ranked Order	Accession no.	Height in January 1989 (cm.)	Accession no.	Height in April 1989 (cm.)
52	75	154.80 ABCDEFG	14	160.67 ABC
53	10	154.75 ABCDEFG	76	160.00 ABC
54	1	153.95 ABCDEFG	41	159.67 ABC
55	60	153.64 ABCDEFG	62	159.33 ABC
56	44	152.67 ABCDEFG	32	159.17 ABC
57	7	152.58 ABCDEFG	1	159.00 ABC
58	72	152.50 ABCDEFG	38	158.33 ABC
59	18	152.17 ABCDEFG	63	158.17 ABC
60	35	151.83 ABCDEFG	56	158.00 ABC
61	12	151.08 ABCDEFG	7	156.83 ABC
62	30	150.83 ABCDEFG	69	156.67 ABC
63	77	150.83 ABCDEFG	29	156.33 ABC
64	80	149.83 ABCDEFG	16	155.83 ABC
65	17	149.58 ABCDEFG	75	155.83 ABC
66	20	149.30 ABCDEFG	36	155.83 ABC
67	88	146.17 ABCDEFG	65	155.67 ABC
68	15	145.83 ABCDEFG	11	155.17 ABC
69	86	145.75 ABCDEFG	82	154.67 ABC
70	23	145.42 ABCDEFG	83	154.00 ABC
71	63	145.28 ABCDEFG	89	153.83 ABC
72	29	144.92 BCDEFG	18	153.67 ABC
73	39	144.55 BCDEFG	10	153.50 ABC
74	11	143.64 BCDEFG	73	153.33 ABC
75	73	143.11 BCDEFG	26	152.17 ABC
76	82	143.08 BCDEFG	23	151.83 ABC
77	38	142.92 BCDEFG	19	150.67 ABC
78	83	142.33 BCDEFG	3	149.33 ABC

Ranked Order	Accession no.	Height in January 1989 (cm.)	Accession no.	Height in April 1989 (cm.)
79	65	142.05 BCDEFG	31	148.50 ABC
80	22	140.30 BCDEFG	28	147.17 ABC
81	13	140.17 BCDEFG	20	146.83 ABC
82	42	138.08 CDEFG	15	146.33 ABC
83	3	137.94 CDEFG	9	145.83 ABC
84	89	136.42 CDEFG	30	145.50 ABC
85	2	134.97 DEFG	42	144.50 ABC
86	28	133.80 DEFG	13	144.17 ABC
87	34	131.50 EFG	17	144.17 ABC
88	9	131.42 EFG	34	137.67 BC
89	55	126.83 FG	27	132.00 BC
90	27	110.67 G	2	127.17 C

Table 15 Detailed data of Biomass accessions in the Container with statistical analysis (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Height(cm.) in July	Accession no.	height(cm.) in OCtober	Accession no.	Height(cm.) in December
1	84	207.83 A	69	326.67 A	69	335.83 A
2	78	198.17 AB	51	311.00 AB	51	321.83 AB
3	62	195.83 AB	41	306.00 ABC	41	320.83 ABC
4	48	195.33 AB	74	305.50 ABC	71	312.50 ABCD
5	90	194.17 AB	71	303.67 ABCD	75	312.50 ABCD
6	54	191.50 AB	75	303.33 ABCD	90	311.67 ABCDE
7	80	191.50 AB	90	297.50 ABCDE	74	310.33 ABCDEF
8	56	190.67 AB	46	296.67 ABCDEF	46	309.17 ABCDEF
9	67	190.50 AB	52	295.00 ABCDEF	84	309.17 ABCDEF
10	75	190.00 AB	77	294.83 ABCDEF	57	308.00 ABCDEF
11	46	190.00 AB	68	294.17 ABCDEF	89	308.00 ABCDEF
12	53	188.83 AB	57	293.33 ABCDEF	86	307.50 ABCDEF
13	59	186.17 ABC	37	291.67 ABCDEFG	66	304.17 ABCDEFG
14	50	185.50 ABC	72	290.73 ABCDEFGH	52	304.17 ABCDEFG
15	11	185.17 ABC	21	290.00 ABCDEFGH	37	302.50 ABCDEFGH
16	26	183.50 ABC	80	288.17 ABCDEFGHI	21	302.50 ABCDEFGH
17	81	183.33 ABC	63	286.17 ABCDEFGHIJ	81	301.67 ABCDEFGHI
18	71	183.00 ABC	47	285.67 ABCDEFGHIJ	72	300.83 ABCDEFGHI
19	42	182.83 ABC	39	281.67 ABCDEFGHIJK	47	299.17 ABCDEFGHI
20	39	182.00 ABC	84	280.33 ABCDEFGHIJK	63	296.17 ABCDEFGHIJ
21	72	182.00 ABC	82	278.33 ABCDEFGHIJKL	78	294.17 ABCDEFGHIJ
22	68	181.83 ABC	79	277.83 ABCDEFGHIJKL	39	293.33 ABCDEFGHIJK
23	12	181.83 ABC	70	277.17 ABCDEFGHIJKL	85	291.83 ABCDEFGHIJK
24	87	181.50 ABC	78	276.50 ABCDEFGHIJKL	82	291.67 ABCDEFGHIJK
25	43	181.33 ABC	45	275.83 ABCDEFGHIJKL	77	291.67 ABCDEFGHIJK

Ranked order	Accession no.	Height(cm.) in July	Accession no.	height(cm.) in OCtober	Accession no.	Height(cm.) in December
26	74	181.00 ABC	62	275.00 ABCDEFGHIJKL	62	287.00 ABCDEFGHIJK
27	76	180.83 ABC	43	273.33 BCDEFGHIJKLM	70	286.83 ABCDEFGHIJK
28	33	180.33 ABC	67	273.33 BCDEFGHIJKLM	43	286.67 ABCDEFGHIJK
29	70	180.00 ABC	87	273.17 BCDEFGHIJKLM	87	285.83 ABCDEFGHIJKL
30	6	179.67 ABC	65	272.50 BCDEFGHIJKLMN	45	285.83 ABCDEFGHIJKL
31	51	179.33 ABC	60	270.17 BCDEFGHIJKLMNO	67	283.33 ABCDEFGHIJKLM
32	30	179.00 ABC	81	270.00 BCDEFGHIJKLMNO	83	282.50 ABCDEFGHIJKLMN
33	49	178.33 ABC	32	270.00 BCDEFGHIJKLMNO	60	282.50 ABCDEFGHIJKLMN
34	85	178.33 ABC	35	267.50 BCDEFGHIJKLMNOP	65	282.50 ABCDEFGHIJKLMN
35	79	178.00 ABC	14	267.50 BCDEFGHIJKLMNOP	32	281.67 ABCDEFGHIJKLMN
36	14	177.50 ABC	61	266.50 BCDEFGHIJKLMNOPQ	35	280.83 ABCDEFGHIJKLMN
37	82	176.67 ABC	59	266.00 BCDEFGHIJKLMNOPQ	14	280.00 ABCDEFGHIJKLMN
38	40	176.33 ABC	86	265.83 BCDEFGHIJKLMNOPQR	59	278.33 BCDEFGHIJKLMN
39	1	176.17 ABC	29	265.00 BCDEFGHIJKLMNOPQR	79	277.00 BCDEFGHIJKLMNO
40	31	175.33 ABC	68	265.00 BCDEFGHIJKLMNOPQR	61	276.00 BCDEFGHIJKLMNO
41	66	175.00 ABC	78	264.83 BCDEFGHIJKLMNOPQR	19	275.00 BCDEFGHIJKLMNOP
42	35	173.67 ABC	89	263.33 BCDEFGHIJKLMNOPQRS	76	274.17 BCDEFGHIJKLMNOP
43	73	172.67 ABC	85	260.00 BCDEFGHIJKLMNOPQRST	29	273.33 BCDEFGHIJKLMNOP
44	8	172.33 ABC	58	259.33 BCDEFGHIJKLMNOPQRSTU	58	271.83 BCDEFGHIJKLMNOPQ
45	47	172.33 ABC	22	258.33 BCDEFGHIJKLMNOPQRSTUV	22	269.17 BCDEFGHIJKLMNOPQR
46	37	171.67 ABC	10	257.50 BCDEFGHIJKLMNOPQRSTUV	10	268.33 BCDEFGHIJKLMNOPQR
47	21	171.50 ABC	24	257.50 CDEFGHIJKLMNOPQRSTUV	38	266.33 BCDEFGHIJKLMNOPQR
48	7	171.50 ABC	38	254.17 CDEFGHIJKLMNOPQRSTUVW	80	265.00 CDEFGHIJKLMNOPQR
49	4	170.33 ABC	83	250.83 DEFGHIJKLMNOPQRSTUVW	24	264.17 CDEFGHIJKLMNOPQRS
50	77	170.33 ABC	64	250.33 DEFGHIJKLMNOPQRSTUVWX	49	262.50 DEFGHIJKLMNOPQRS
51	41	170.00 ABC	56	249.00 EFGHIJKLMNOPQRSTUVWX	56	261.17 DEFGHIJKLMNOPQRS
52	56	169.83 ABC	49	248.50 EFGHIJKLMNOPQRSTUVWX	64	260.33 DEFGHIJKLMNOPQRST

Ranked order	Accession no.	Height(cm.) in July	Accession no.	Height(cm.) in OCtober	Accession no.	Height(cm.) in December
53	60	167.83 ABC	30	248.50 EFGHIJKLMNOPQRSTUVWX	20	258.33 DEFGHIJKLMNOPQRST
54	19	167.67 ABC	19	247.50 EFGHIJKLMNOPQRSTUVWX	25	257.50 DEFGHIJKLMNOPQRSTU
55	36	167.67 ABC	20	245.00 EFGHIJKLMNOPQRSTUVWX	26	255.83 DEFGHIJKLMNOPQRSTU
56	5	167.17 ABC	65	243.50 FGHIJKLMNOPQRSTUVWX	4	255.00 EFGHIJKLMNOPQRSTU
57	69	167.00 ABC	25	243.33 FGHIJKLMNOPQRSTUVWX	65	253.50 FGHIJKLMNOPQRSTU
58	3	166.33 ABC	23	243.33 FGHIJKLMNOPQRSTUVWX	54	249.50 GHIJKLMNOPQRSTU
59	32	166.17 ABC	4	243.33 FGHIJKLMNOPQRSTUVWX	44	248.33 GHIJKLMNOPQRSTUV
60	24	165.67 ABC	54	239.50 GHIJKLMNOPQRSTUVWXY	27	248.33 GHIJKLMNOPQRSTUV
61	86	165.00 ABC	33	236.67 HIJKLMNOPQRSTUVWXYZ	50	247.00 HIJKLMNOPQRSTUV
62	25	164.67 ABC	44	236.67 HIJKLMNOPQRSTUVWXYZ	33	246.67 HIJKLMNOPQRSTUV
63	63	163.67 ABC	16	236.67 HIJKLMNOPQRSTUVWXYZ	30	246.67 HIJKLMNOPQRSTUV
64	61	163.17 ABC	50	[illegible] IJKLMNOPQRSTUVWXYZ	46	246.67 HIJKLMNOPQRSTUV
65	29	162.83 ABC	45	235.83 IJKLMNOPQRSTUVWXYZ	11	245.50 IJKLMNOPQRSTUV
66	15	162.67 ABC	17	234.83 IJKLMNOPQRSTUVWXYZ	5	245.33 IJKLMNOPQRSTUV
67	9	162.50 ABC	11	234.50 IJKLMNOPQRSTUVWXYZ	17	245.17 IJKLMNOPQRSTUV
68	89	161.17 ABC	27	234.17 IJKLMNOPQRSTUVWXYZ	88	241.67 JKLMNOPQRSTUV
69	45	160.50 ABC	5	232.50 JKLMNOPQRSTUVWXYZ	55	241.00 JKLMNOPQRSTUV
70	52	160.50 ABC	55	229.33 KLMNOPQRSTUVWXYZ	53	240.00 JKLMNOPQRSTUV
71	57	160.33 ABC	40	229.33 KLMNOPQRSTUVWXYZ	40	240.00 JKLMNOPQRSTUV
72	17	160.17 ABC	53	227.67 KLMNOPQRSTUVWXYZ	16	239.17 JKLMNOPQRSTUV
73	44	160.00 ABC	13	224.33 LMNOPQRSTUVWXYZ	13	236.83 KLMNOPQRSTUV
74	88	159.33 ABC	1	220.00 MNOPQRSTUVWXYZ	9	229.17 LMNOPQRSTUV
75	22	159.33 ABC	73	219.17 NOPQRSTUVWXYZ	1	228.33 MNOPQRSTUVW
76	28	159.33 ABC	31	218.33 OPQRSTUVWXYZ	31	228.33 MNOPQRSTUVW
77	18	158.83 ABC	9	215.83 PQRSTUVWXYZ	73	228.33 MNOPQRSTUVW
78	64	158.67 ABC	6	213.50 QRSTUVWXYZ	6	226.17 NOPQRSTUVW
79	55	158.00 ABC	34	212.50 RSTUVWXYZ	34	225.83 NOPQRSTUVW

Ranked order	Accession no.	Height(cm.) in July	Accession no.	height(cm.) in OCtober	Accession no.	Height(cm.) in December
80	20	157.67 ABC	36	210.83 STUVWXYZ	8	221.67 OPQRSTUVW
81	10	157.67 ABC	8	209.17 TUVWXYZ	[illegible]	220.83 OPQRSTUVW
82	16	157.50 ABC	42	209.17 TUVWXYZ	42	219.17 PQRSTUVW
83	13	154.33 ABC	12	206.50 UVWXYZ	18	216.67 QRSTUVW
84	65	153.50 ABC	16	205.33 VWXYZ	12	216.67 QRSTUVW
85	83	152.50 ABC	15	201.67 WXYZ	15	213.33 RSTUVW
86	27	151.33 ABC	7	197.50 XYZ	7	208.33 STUVW
87	2	148.33 BC	3	190.00 YZ	3	205.00 TUVW
88	38	148.33 BC	29	189.17 YZ	28	201.67 UVW
89	23	146.67 BC	23	185.00 Z	23	193.33 VW
90	34	130.00 C	2	165.00	2	175.00 W

Table 16 Ranked Score of Biomass accessions on growth in the container on April 1988
(Duncan's Multiple Range Test, $\alpha = 0.01$)

Ranked order	Accession no.	Score Height (cm)	Width (cm)	Length(cm)	Total Score
1.	49	1	1	1	3
2.	47	7	3	4	14
3.	50	5	7	8	20
3.	74	2	9	9	20
5.	60	3	12	6	21
6.	58	8	10	10	28
7.	46	4	26	2	32
7.	79	9	8	15	32
9.	43	6	6	30	42
10.	51	19	11	17	47
11.	35	10	15	24	49
12.	40	13	36	3	52
13.	52	22	25	7	54
13.	57	16	22	16	54
15.	72	20	23	12	55
16.	37	17	29	14	60
17.	14	41	17	5	63
18.	33	36	16	13	65
19.	90	15	5	54	74
20.	18	45	13	18	76
21.	31	25	32	19	76
22.	61	11	37	28	76
23.	84	46	20	11	77
24.	87	51	2	25	78

Ranked order	Accession no.	Score Height (cm)	Width (cm)	Length(cm)	Total Score
25.	44	18	39	23	80
26.	70	28	21	35	84
27.	32	30	30	26	86
28.	88	37	4	48	89
29.	66	43	14	36	93
30.	73	32	35	29	96
31.	59	49	28	20	97
32.	63	31	27	43	101
33.	86	12	33	58	103
34.	77	66	19	22	107
34.	45	33	53	21	107
36.	62	29	43	41	113
37.	75	23	38	55	116
38.	5	27	41	49	117
39.	36	26	61	31	118
40.	26	42	51	27	120
41.	78	63	18	42	123
42.	69	35	45	45	125
43.	6	47	31	50	128
44.	68	56	47	32	135
45.	65	50	40	46	136
46.	85	38	44	56	138
47.	12	21	79	44	144
48.	8	14	71	64	149

Ranked order	Accession no.	Score Height (cm)	Width (cm)	Length(cm)	Total Score
49.	24	44	74	34	152
50.	76	61	55	38	154
51.	71	53	46	57	156
52.	20	57	62	40	159
53.	54	24	50	57	161
54.	89	34	49	79	162
55.	1	52	60	51	163
56.	11	60	64	39	163
57.	41	64	42	61	167
58.	4	40	73	59	172
59.	42	65	58	53	176
60.	15	48	68	62	178
61.	25	54	65	60	179
62.	28	82	67	33	182
62.	48	55	57	70	182
64.	80	84	24	75	183
65.	30	39	77	68	184
66.	56	67	54	65	186
67.	53	78	59	52	189
68.	21	59	70	63	192
69.	38	81	75	37	193
69.	83	79	14	80	193
71.	7	71	52	72	195
72.	19	74	76	47	197
73.	81	70	48	82	200
74.	16	72	63	67	202
75.	67	58	66	81	205

Ranked order	Accession no.	Score			Total Score
		Height (cm)	Width (cm)	Length(cm)	
76.	29	69	78	71	218
76.	64	62	72	84	218
78.	10	68	84	69	221
78.	55	75	80	66	221
80.	39	77	82	74	233
81.	82	89	56	89	234
82.	17	85	69	83	237
83.	34	80	83	76	239
84.	9	83	81	78	242
85.	22	73	86	86	245
86.	2	87	88	73	248
86.	3	86	85	77	248
86	23	76	87	85	248
89.	13	8C	89	88	265
90.	27	90	90	90	270

Table 17 Accumulated Score of Biomass accessions on growth in the container
(Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score in July 1988	Score in October 1988	Total
1.	49	1	1	2
2.	46	3	2	5
3.	90	2	7	9
4.	60	4	6	10
4	79	5	5	10
6.	74	8	3	11
6.	84	7	4	11
8.	58	6	9	15
9.	67	9	8	17
10.	37	11	12	23
11.	47	10	16	26
12.	43	14	14	28
13.	45	20	10	30
14.	5	16	15	31
14.	36	13	18	31
16.	8	18	17	35
17.	12	17	21	38
18.	70	15	25	40
19.	4	22	19	41
20.	35	12	33	45
21.	75	26	23	49
22.	40	19	35	54
22.	69	41	13	54
22.	87	32	22	54

Ranked order	Accession no.	Score in July 1988	Score in October 1988	Total
25.	52	21	34	55
25.	59	31	24	55
27	51	27	29	56
27.	54	24	32	56
27.	71	45	11	56
27.	77	36	20	56
27.	85	29	27	56
32.	32	28	31	59
33.	31	23	39	62
33.	64	25	37	62
35.	50	35	41	76
35.	68	34	42	76
37.	14	47	30	77
38.	53	53	26	79
39.	1	43	38	81
40.	6	54	28	82
41.	33	39	45	84
41.	81	48	36	84
43.	57	37	51	88
43.	89	30	58	88
45.	66	50	40	90
45.	86	40	50	90
47.	61	42	52	94
47.	72	38	56	94
49.	20	51	44	95
49.	73	33	62	95
51.	25	49	47	96

Ranked order	Accession no.	Score in July 1988	Score in October 1988	Total
52.	41	56	46	102
52.	78	59	43	102
54.	30	44	63	107
55	88	55	53	108
56.	11	57	54	111
56.	15	52	59	111
58.	44	46	67	113
59.	9	67	48	115
60.	29	62	55	117
61.	76	60	61	121
62.	80	73	49	122
63.	48	61	66	127
64.	19	71	57	128
65.	21	70	60	130
66.	24	64	68	132
67.	63	66	69	135
68.	26	63	73	136
69.	62	65	72	137
70.	7	68	70	138
71.	56	74	65	139
72.	18	58	64	142
73.	10	72	71	143
74.	65	69	78	147
75.	16	75	74	149
76.	22	76	76	152

Ranked order	Accession no.	Score in July 1988	Score in October 1988	Total
76.	28	77	75	152
78.	83	79	77	156
79.	39	80	79	159
80.	42	78	83	161
81.	38	82	80	162
82.	23	81	82	163
83.	17	86	81	167
84.	3	84	84	168
85.	34	83	86	169
86.	2	85	85	170
87.	13	87	87	174
88.	55	88	88	176
89.	82	89	89	178
90.	27	90	90	180

Table 18 Accumulated Score of Biomass accessions on growth in the Container (Duncan's Multiple Range test, α = 0.010)

Ranked order	Accession no.	Score in January 1989	Score in April 1989	Total
1	49	1	1	2
2	46	3	2	5
3	74	6	7	13
4	58	7	9	16
5	67	8	8	16
6	54	12	4	16
7	59	5	12	17
8	48	18	6	24
9	84	10	17	27
10	4	11	20	31
11	8	15	16	31
12	81	21	11	32
13	25	30	10	40
14	53	35	5	40
15	40	16	25	41
16	51	38	3	41
17	78	23	19	42
18	79	27	18	45
19	47	17	30	47
20	45	34	13	47
21	71	2	46	48
22	5	22	26	48
23	6	13	28	51
24	43	25	29	54

Ranked order	Accession no.	Score		Total
		in January 1989	in April 1989	
25	70	42	14	56
26	37	36	22	58
27	62	4	55	59
28	90	9	51	60
29	61	32	28	60
30	21	31	32	63
31	57	37	27	64
32	24	14	52	66
33	52	24	42	66
34	87	47	21	68
35	26	43	29	72
36	77	63	15	78
37	56	19	60	79
38	60	55	24	79
39	76	28	53	81
40	14	29	52	81
41	85	40	41	81
42	72	58	23	81
43	66	44	39	83
44	36	20	66	86
45	41	33	54	87
46	69	26	62	88
47	33	41	49	90
48	68	48	43	91
49	12	61	31	92
50	35	60	33	93

Ranked order	Accession no.	Score		Total
		in January 1989	in April 1989	
51	50	50	44	94
52	44	56	39	95
53	64	49	47	96
54	80	64	37	101
55	86	69	35	104
56	32	51	56	107
57	16	45	64	109
58	1	54	57	111
59	88	67	48	115
60	19	39	77	116
61	75	52	65	117
62	7	57	61	118
63	39	.3	45	118
64	55	89	34	123
65	31	46	79	126
66	10	53	73	126
67	63	71	59	130
68	22	80	50	130
69	18	59	72	131
70	19	72	63	135
71	38	77	58	135
72	11	74	68	142
73	82	76	69	145
74	30	62	84	146
75	23	70	76	146
76	65	79	67	146
77	20	66	81	147

Ranked order	Accession no.	Score in January 1989	Score in April 1989	Total
78	83	78	70	148
79	73	75	74	149
80	15	68	82	150
81	17	65	87	152
82	89	84	71	155
83	3	83	78	161
84	28	86	80	166
85	13	81	86	167
86	42	82	85	167
87	9	88	83	171
88	2	85	90	175
89	34	87	88	175
90	27	90	89	179

Table 19 Accumulated Score of Biomass accssions on growth in the container (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Score in July 1989	Score in October1989	Score in December 1989	Total Score
1	90	5	7	6	18
2	75	10	6	5	21
3	46	11	8	8	27
4	71	18	5	4	27
5	84	1	20	9	30
6	51	31	2	2	35
7	74	26	4	7	37
8	78	2	24	21	47
9	72	21	14	18	53
10	62	3	26	26	55
11	41	51	3	3	57
12	69	57	1	1	59
13	39	20	19	22	61
14	66	41	11	13	65
15	81	17	32	17	66
16	67	9	21	31	68
17	80	7	16	48	71
18	37	46	13	15	74
19	21	47	15	16	78
20	70	29	23	27	79
21	43	25	27	28	80
22	87	24	29	29	82
23	82	37	21	24	82
24	47	45	18	19	82
25	77	50	10	25	85
26	68	22	30	34	86

Ranked order	Accession no.	Score in July 1989	Score in October1989	Score in December 1989	Total Score
27	59	13	37	38	88
28	52	70	9	14	93
29	57	71	12	10	93
30	58	8	44	44	96
31	79	35	22	39	96
32	85	34	43	23	100
33	63	63	17	20	100
34	14	36	35	37	108
35	76	27	41	42	110
36	35	42	34	36	112
37	86	61	40	12	113
38	60	53	31	33	117
39	89	68	42	11	121
40	54	6	60	58	124
41	45	69	25	30	124
42	32	59	33	35	127
43	26	16	57	55	128
44	48	4	65	64	133
45	49	33	52	50	135
46	50	14	64	61	139
47	61	64	36	40	140
48	11	15	67	65	147
49	29	65	39	43	147
50	30	32	53	63	148
51	19	54	54	41	149
52	33	28	61	62	151
53	53	12	72	70	154

Ranked order	Accession no.	Score in July 1989	Score in October1989	Score in December 1989	Total Score
54	56	52	51	51	154
55	24	60	47	49	156
56	4	49	59	56	164
57	22	75	45	45	165
58	83	85	49	32	166
59	10	81	46	46	173
60	25	62	58	54	174
61	40	38	71	71	180
62	88	74	38	68	180
63	64	78	50	52	180
64	42	19	82	82	183
65	38	88	48	47	183
66	6	30	78	78	186
67	1	39	74	75	188
68	20	80	55	53	188
69	12	23	83	84	190
70	5	56	69	66	191
71	31	40	76	76	192
72	44	73	62	59	194
73	73	43	75	77	195
74	65	84	56	57	197
75	8	44	81	80	205
76	17	72	66	67	205
77	27	86	68	60	214
78	36	55	80	81	216
79	16	82	63	72	217
80	9	67	77	74	218

Ranked order	Accession no.	Score in July 1989	Score in October1989	Score in December 1989	Total Score
81	55	79	70	69	218
82	7	48	86	86	220
83	13	83	73	73	229
84	3	58	87	87	232
85	15	66	85	85	236
86	18	77	84	83	244
87	34	90	79	79	248
88	28	76	88	88	252
89	2	87	90	90	267
90	23	89	89	89	267

Table 20 Detailed data of grafted plant of sour type accessions with statistical analysis December, 1989 (Duncan's Multiple Range Test, α = 0.01)

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
1	87-1-02-001	145.00 A	86-2-08-028	96.67 A	86-2-13-014	100.00 A
2	87-1-02-005	139.00 B	87-2-09-017	95.33 AB	87-1-02-001	98.33 A
3	87-1-02-002	136.67 B	87-2-17-008	95.00 AB	87-2-17-009	96.00 A
4	87-2-09-017	127.00 C	87-2-17-009	94.67 AB	87-2-17-011	95.00 A
5	87-2-17-009	126.00 CD	87-2-17-026	94.00 AB	87-2-17-008	95.00 A
6	87-2-17-011	126.00 CD	87-2-17-011	93.00 AB	87-2-17-026	89.00 B
7	87-1-02-004	123.00 CDE	87-1-02-001	89.67 BC	87-2-17-002	86.67 B
8	87-2-17-021	120.00 DEF	87-2-01-005	84.67 CD	86-2-13-001	85.33 BC
9	86-2-13-015	118.00 EF	87-2-01-035	84.00 D	87-1-02-005	83.33 BCD
10	87-1-02-003	116.00 FG	87-1-02-005	81.67 D	87-1-02-002	83.33 BCD
11	86-2-08-028	114.00 FGH	87-2-17-016	81.00 D	87-2-17-016	83.00 BCD
12	87-2-17-008	111.00 GH	86-2-13-014	81.00 D	87-1-02-004	80.00 CDE
13	87-3-20-002	108.33 HI	87-1-02-002	80.67 D	87-2-08-025	80.00 CDE
14	87-2-01-005	105.00 IJ	87-2-08-025	80.67 D	87-2-01-005	78.33 DEF
15	87-2-17-002	103.00 IJK	87-1-02-004	75.00 E	86-2-08-028	78.33 DEF
16	87-2-08-025	100.00 JKL	87-3-20-002	74.33 E	87-2-17-021	77.00 DEF
17	87-2-08-014	98.00 KLM	87-1-02-003	72.67 EF	87-2-08-023	75.00 EFG
18	87-2-17-016	94.00 MN	87-2-17-021	70.00 EFG	87-1-02-003	75.00 EFG
19	87-2-01-035	94.00 MN	87-4-13-003	69.67 EFG	87-3-20-002	73.33 FG
20	87-2-08-023	93.00 MN	87-2-08-003	68.03 FG	87-2-08-014	70.00 GH
21	87-2-17-026	91.00 N	86-2-08-083	66.00 GH	86-2-08-183	69.67 GH
22	86-2-13-009	91.00 N	87-2-08-023	65.00 GH	87-2-17-002	66.67 HI
23	86-2-13-001	91.00 N	87-2-17-002	64.33 GH	87-2-01-035	66.00 HIJ
24	86-2-13-005	89.00 NO	86-2-13-002	61.67 H	87-2-07-001	63.00 IJ
25	87-2-08-003	89.00 NO	87-2-08-014	61.67 H	86-2-13-002	61.67 IJ

Ranked order	Accession no.	Height (cm.)	Accession no.	Width (cm.)	Accession no.	length (cm.)
26	87-2-07-001	84.00 OP	86-2-13-001	61.67 H	86-2-13-009	61.00 IJ
27	87-2-07-003	81.00 PQ	87-2-07-001	61.00 H	87-2-08-023	60.00 J
28	86-2-13-002	80.00 PQ	86-2-08-038	51.67 I	86-2-13-004	51.33 K
29	87-4-13-003	80.00 PQ	86-2-08-183	51.00 IJ	87-2-07-003	50.00 KL
30	86-2-13-004	76.33 QR	86-2-13-004	49.00 IJ	86-2-08-183	49.00 KL
31	86-2-08-083	75.33 QR	86-2-13-009	47.33 IJK	86-2-08-083	46.67 KLM
32	86-2-13-008	72.33 R	87-2-07-003	46.67 IJK	87-2-08-027	45.00 LMN
33	87-2-08-027	71.00 R	87-2-08-027	45.00 JKL	86-2-13-008	45.00 LMN
34	86-2-13-017	65.00 S	87-2-07-001	45.00 JKL	87-2-07-001	45.00 LMN
35	87-2-07-001	64.00 S	86-2-13-008	42.67 KL	86-2-08-038	41.00 MNO
36	86-2-08-183	63.00 S	86-2-13-005	40.33 LM	86-2-13-019	40.67 MNO
37	86-2-08-016	61.00 ST	86-2-13-019	39.33 LM	86-2-13-005	40.00 NO
38	86-2-08-038	60.33 ST	86-2-13-001	36.67 M	86-2-13-018	31.67 PQ
39	86-2-13-020	55.00 TU	87-2-08-005	28.67 N	86-2-13-001	31.00 PQ
40	86-2-13-015	55.33 U	86-2-13-017	25.00 NO	87-2-08-005	30.00 Q
41	86-2-13-001	53.00 U	86-2-08-016	25.00 NO	86-2-13-020	30.00 Q
42	86-2-13-018	50.00 U	86-2-13-015	25.00 NO	86-2-13-017	30.00 Q
43	86-2-13-019	50.00 U	86-2-13-020	20.00 O	86-2-08-016	30.00 Q
44	87-2-08-005	49.00 U	86-2-13-018	20.00 O	86-2-13-015	30.00 Q

Table 21 Detailed data of grafted plants of sweet type accessions with statistical analysis on December. 1989
(Duncan's Multiple Range Test, α = 0.01)

Ranked order	Cultivar	Height (cm.)	Cultivar	Width (cm.)	Cultivar	length (cm.)
1	Pakduk	144.33 A	Pakduk	106.67 A	Pakduk	93.33 A
2	Pechkaset	141.67 A	Nualchan	101.67 AB	Nualchan	85.00 AB
3	Nualchan	119.00 B	Pechkaset	93.33 ABC	Muktip	76.67 ABC
4	Taltip	118.00 B	Pannanikom	83.33 BCD	Pechkaset	75.00 ABC
5	Muktip	118.00 B	Chauwnuasethakit	81.67 BCD	Chauwnuasethakit	73.33 ABCD
6	Pramualvit	115.00 BC	Saeng-Ar-tit	80.67 BCD	Pramualvit	71.67 ABCDE
7	Saeng-Ar-tit	113.33 BC	Namphung	80.33 BCD	Taltip	71.67 ABCDE
8	Namphung	113.33 BC	Jae-Home	79.33 BCDE	Namphung	68.00 BCDE
9	Sichompoo	109.67 BCD	Kru Buapan	78.33 CDE	Pra Roj	68.00 BCDE
10	Chauwnuasethakit	109.00 BCD	Pra Roj	71.00 CDE	Pannanikom	66.67 BCDE
11	kru-in	108.67 BCD	Pramualvit	70.00 DE	Nimnuan	61.67 BCDEF
12	Pra Roj	107.00 BCDE	Kru-in	70.00 DE	Jae-Home	61.67 BCDEF
13	Pannanikom	105.00 BCDE	Sichompoo	68.33 DE	Pan-Phai-Yai	60.00 BCDEF
14	Ban-Phai-Yai	103.33 BCDE	Muen-Jong	67.67 DE	Kru Buapan	60.00 BCDEF
15	Kru BuapanG	98.33 CDEF	Muktip	67.33 DE	Muen-Jong	57.00 CDEFG
16	Muen-Jong	98.00 CDEF	Sithong	63.67 DE	Sichompoo	56.00 CDEFG
17	Jae-Home	94.00 DEF	Ban-Phai-Yai	63.00 DE	Kru-in	54.33 CDEFG
18	Khantee	89.67 EF	Nimnuan	61.67 DE	Saeng-Ar-tit	53.33 CDEFG
19	Nimnuan	85.00 FG	Khantee	61.00 DE	Ban-Fakloei	48.33 DEFG
20	Sithong	82.33 FG	Taltip	56.67 E	Khantee	48.33 DEFG
21	Nai-whan	72.67 G	Nai-whan	33.33 F	Sithong	47.33 EFG
22	Nasinuan	56.00 H	Nasinuan	31.67 F	Nai-whan	38.33 FG
23	Ban-Fakloei	55.00 H	Ban-Fakloei	30.00 F	Nasinuan	33.33 G

Table 22 Stomatal number in relation to growth of Biomass Accession in the field at the age of one year old

Ranked Order	Accession No.	Score	Stomatal No.
1	77	4	59.6
2	81	8	50.5
3	30	11	61.0
4	20	16	56.3
5	10	20	54.4
6	11	26	50.0
6	78	26	46.2
8	31	27	46.5
9	76	28	48.4
10	16	29	56.0
81	58	236	50.4
82	46	237	54.9
83	51	249	47.7
84	68	252	40.4
85	55	257	44.3
85	63	257	42.6
87	50	262	45.6
87	66	262	52.0
89	64	263	51.3
90	73	268	45.0

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PART 2 RHIZOBIUM INVESTIGATION

PSTC RESEARCH REPORT (5.243)

PROJECT TITLE : COLLECTION AND UTILIZATION OF TAMARIND GERMPLASM

PRINCIPAL INVESTIGATOR : Dr. Sumrit Feungchan

TASK 1 : RHIZOBIUM STUDY ON TAMARIND ROOT.

COLLABORATIVE INSTITUTION

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Research Period : July, 1988 - December, 1989.

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1. INTRODUCTION :

Rhizobium, the associated bacteria in leguminous crops is known to play significant roles under the poor soil condition, particulary the soil in the northeast region of Thailand. Various crops were reported to be infected by rhizobium through root hairs to form an infectious thread. The thread that contained rhizobium grew into the cortex of the roots and branches releasing the rhizobium into cortical cells that become nodule or remaining as the thread in the nodule (De Faria et al, 1986). The rhizobium association in tamarind was reported by some investigators (Postgate, 1979, Quiniones, 1983). Although the available information is limited compared to those reported in other leguminous species. This study attempts to verify the previous works on the association of rhizobium in tamarind roots.

2. OBJECTIVES :

To verify any rhizobium associated in tamarind root by

1. isolation of rhizobium from the tamarind root
2. differentiating the group of rhizobium
3. inoculating rhizobium to tamarind seedlings

3. MATERIALS AND METHODS :

3.1 Isolation of Rhizobium from tamarind root

Rhizobium associated with tamarind was isolated from the root samples. Forty three tamarind seedlings with various ages were collected from experimental plot. The root specimens were washed five times with sterile distilled water and immersed in 70 % ethanol for 1 minute and 3 % sodium hyperchlorite solution for 1-3 minutes, respectively. After surface sterilization, the root specimens were washed three times with sterile distilled water and chopped 4 cm. in length. Each piece of root was blended with a small amount of sterile water. An aliquot of the solution was streaked over the surface of yeast extract mannintol congo red agar medium (YMCA) (Appendix A-6.1.1) in the sterile petridish for cultivation of RHIZOBIUM, and smeared over the surface of glass slide for staining with carbol fuchsin dye (Appendix B-7.1.1). The morphology of rhizobium cells was observed by light microscope after stainning, and the characteristics of white mucous colonies that did not absorb red colour from mannitol congo red agar medium which was the characteristics of rhizobium cultures were selected after incubation at 30°C or room temperature for 5-7 days

3.2 Differentiation of Rhizobium Groups

Fifty nine isolates of pure bacteria colonies were similar in cultural characteristics to rhizobium cultures were tested for some biochemical characteristics; i.e. utilization of citrate and carbohydrate, to differentiate from close proximity bacteria. Each isolate was streaked on Simmon's citrate agar slant (Appendix A-6.1.4) and incubated at 30°C for 48 hours. The bacterial growth was observed. The test for utilization of carbohydrate; each isolate was inoculated on phenol red broth base (PRBB) with four kinds of carbohydrates contained in separate tubes (Appendix A-6.1.2). Acid and gas production in the media were observed after incubation at 30°C for 48 hours.

3.3 Confirmation of Rhizobium strains

3.3.1 Microorganism preparation

Thirteen strains of the tested *Rhizobium* were cultured on manitol medium (Appendix A-6.1.3) for 36 hours. Then, they were centrifuged to separate cell and supernatant at 5000 rpm for 10 minutes. The supernatant was discarded and the cells obtained at the bottom of the tube was washed three times with phosphate buffer at pH 7. The final cell solution was adjusted to appropiate concentration with the same buffer.

3.3.2 Tamarind seedling preparation

Tamarind seeds were sown in the pots which contained sterile soil. The sterile water without nitrogen was applied to the pot twice a day. After one month, only two seedlings in one pot were maintained.

3.3.3 Rhizobium inoculation

Twenty five millilitres of each Rhizobium inoculum prepared as mentioned above was poured into tamarind seedling pots. Fifteen seedling pots were used per one strain of microorganism. The control was poured by phosphate buffer only. The height of the tamarind seedling was measured at fifteen day intervals after inoculation to observe growth.

3.4 Verification of Rhizobium strain on sterile sand.

3.4.1 Microorganism preparation.

Eight strains of the suspicious Rhizobia were prepared as mentioned above.

3.4.2 Sterile sand preparation.

The clean sand was washed several times against water in order to leach nitrate, nitrite and ammonium compounds. The test of nitrate compound was done by adding 2-3 drops of diphenylamine solution (Appendix B-7.1.2) into 2-3 drops of washed water that passed through the sand. The blue color indicated positive test. The test of nitrite compound was done by adding 2-3 drops of H_2SO_4 (conc) : H_2O = 1:3 and 1-2 drops of Trommsdorf's solution (Appendix B-7.1.3) to the same amount of washed water. The dark blue color indicated positive test. For the test of ammonium compound was done by dropping 2-3 drop of Nessler's reagent (Appendix B-7.1.4) into 2-3 drops of washed water. The positive test was indicated by yellow color. After it was proved that the prepared sand was free from all indogenous compounds then the sand was sterilized by dry heat sterilization (150 C, over night in hot air oven)

3.4.3 Tamarind seedling preparation

Tamarind seeds were washed with ethanol for 0.5 minute, then poured off and soaked in mercuric chloride for 2.5 minuters. After that the tamarind seeds were washed with sterile water six quick washes then left seeds soaking in water overnight. The sterile seeds were sown in the small pot contained 200 grams of sterile sand. Ten millilitres of nitrogen free solution (Appendix B-7.1.5) was applied to the pot once a day. After two weeks, the tamarind seedlings were ready for Rhizobium inocultation.

3.4.4 Bean seedling preparation.

Five species of bean namely; soil bean, mung bean, cowpea, and peanut were sterilized by the same procedure as tamarind seeds. After two days growing in the pot, the bean seedlings were ready for Rhizobium inoculation.

3.4.5 Rhizobium inoculation.

Ten millitres of each tested Rhizobium inoculum was poured into seedling tamarind pots. Eleven seedling pots were used per one strain of microorganism. As for bean seedling, five millilitres of each tested Rhizobium inocolum was poured into one seedling pot. Twenty five pots of bean seedling were used per one tested Rhizobium strain with five pots for each kind of bean. The control was treated by phosphate buffer only. The height of the tamarind seedling was measured at fourteen day intervals after inoculation to observe growth. The nodule formation in bean seedling roots were investigated at appropriate time to confirm the tested Rhizobium strain.

4. RESULTS :

4.1 Isolation of rhizobium from tamarind root

4.1.1 Rhizobium cultivation :

For the isolation of *Rhizobium* from the root by specimens streak plate technique, twenty four among the 43 tamarind seedlings showed the mucous colonies that did not absorb red colour from mannitol congo red agar medium. The number of tamarind specimens from colllection, the number of specimens with rhizobium-like colonies and age of these specimens were shown in table 1.

Table 1. Number of tamarind seedlings with various ages used for isolation of *Rhizobium*. Isolation of Rhizobium-like colonies from different ages of tamarind seedlings.

Age of seedling (month)	Number of Seedling Collected	Number of Rhizobium like colonies
2	5	3
3	10	5
6	10	7
7	9	7
12	8	2

As a result shown in table 1, around 50 % of seedlings collected had the cultures which was similar in cultural characteristics to those rhizobium. The cultures were restreaked several times on the medium to purify and then tested for some biochemical characteristics.

For microscopic determining the rod or bacteroid - shaped of rhizobium cells from the root specimens it was very difficult to differentiate the shape of rhizobial bacteroid. There was a lot of cell debris from the crushed tamarind root which interfered our bacteroid inspection. However, a number of rod shape and ovoid shape bacteria were observed.

4.2 Differentiation of Rhizobium Group

4.2.1 Biochemical characteristics:

The distinction between groups of Rhizobium and close proximity bacteria is likely possible on the basis of biochemical characteristics (Hamdi, 1982). Thus, some biochemical test that refer to the important characteristics of the rhizobia such as sugar utilization and citrate utilization were tested to the suspicious strains.

Fifteen among the 59 isolated bacterial cultures could not utilize citrate but could produce acid without gas in phenol red broth base medium containing glucose, sucrose, lactose or mannitol. These characteristics belong to the genus *Rhizobium* according to Bergey's Manual of Systematic Bacteriology (Krieg and Holt, 1984). From the result, only 25 % of cultures isolated from the root specimens had the biochemical characteristics similar to *Rhizobium* group. It was difficult to say that the tested organism was the rhizobium associating with tamarind roots or not. If the rhizobium associating in the root, the number of rhizobium like bacteria should be higher than this. This groups of bacteria may or may not be the rhizobium staying at the tamarind rhizosphere and contaminated to the root. Thus inoculating the tested strain in the sterile soil lacking or having small amount of nitrogen should be confirmed.

4.3 Confirmation of Rhizobium strain on sterile soil

Thirteen strains of the tested rhizobium were inoculated to the one month old tamarind seedlings. It was found that the increasing height of the tamarind seedlings of the thirteen tested *Rhizobium* strains and the control was not significantly different as shown in table 2.

Table 2. The average height of tamarind seedlings inocolated with tested *Rhizobium*

Microorganism	Average height of tamarind seedlings 0 day (cm)	41 day (cm)	The increasing height (cm)
1	15.41	23.05	7.64
2	16.00	23.26	7.26
3	15.82	22.89	7.07
4	16.44	23.02	6.58
5	16.24	23.82	7.58
6	15.33	22.17	6.84
7	16.09	23.26	7.14
8	17.02	23.80	6.78
9	16.70	22.45	5.75
10	16.32	23.22	6.90
11	15.50	21.72	6.22
12	16.12	23.44	7.32
13	14.89	21.93	7.04
Control	16.12	22.81	6.69

some strains showed the higher increasing growth than the control but not significantly different. From this result, it might due to the trace amount of nitrogen left in the sterile soil. The seedlings could utilize this element for growth which could observe from the control that were green and healthy.

4.4 Verification of Rhizobium strain

4.4.1 confirmation of Rhizobium strain of tamarind seedling :

The tamarind seedling growth rate in sterile sand was very low. After fifteen days of inoculation, there was no significant difference in tamarind seedling height which treated by the tested strains and the control as shown in table 3. After thirty days of inoculation and the control began to wilt and dry. There was no growth anymore after forty-five days of inoculation. There was only one strain of K-1-1 Rhizobium which seemed to show well growth longer than the control but after sixty days of inoculation the seedling began to die. No nodule formation was observed.

Table 3 The average height of tamrind seedlings sown on sterile sand and inoculated with tested Rhizobium.

Microorganism strains	Average height at fifteen days (cm)
1	12.34
2	11.78
3	12.27
4	9.25
5	9.40
6	10.73
7	12.48
8	13.49
Control	14.35

4.4.2 Confirmation of Rhizobium strain on bean seedling :

The growth of bean seedling in the sterile sand was quite high as compare to tamarind seedling. The result was slightly different from each others. After inoculation for 1-2 weeks, the symptom of nitrogen deficiency was observed with the four species of bean seedlings. All seedlings, including control began to wilt and completely died.

5. DISCUSSION

There was some reports on Rhizobium associated in the tamarind root (Postgate, 1979), but in this investigation we could not find the Rhizobium strain from tamarind root isolations, even though some of the isolated specimens showed close proximity characteristics in biochemical tests of Rhizobium. It was noted that there were nodule formation in the tamarind root. However, if there were any Rhizobium associated to tamarind root, the population of microorganism should be abundant to the extent that there is a clue of rhizobium association. The expressed characteristics of the Rhizobium on tamarind and bean seedlings should be clearly observed than this. Since there were some Rhizobium survived freely in the rhizosphere, the tested strains might be those microorganisms which was closely related to Rhizobium. It needs further investigation on the relationship between tamarind root and this microorganism.

6. APPENDIX A:

6.1 Media

6.1.1 yeast extract mannitol congo red agar medium (YMCA)

constituents

Yeast extract	3.0 g. (Dehydrated)
$MgSo_4$ $7H_2o$	0.2 g.
K_2HPO_4	0.5 g.
Mannitol	10.0 g.
NaCl	0.1 g
$CaCo_3$ (if used)	3.0 g
Agar	15.0 g
Congo red (1:400 aqueous solution)	10.0 ml.
Distilled water (Adjusted to pH 6.8)	1000.0 ml.

6.1.2 Phenol red broth base (PRBB) with carbohydrate.

Constituents

Beef extract	1.0 g.
proteose peptone No.3	10.0 g.
NaCl	5.0 g.
Phenol red	0.013 g.
Carbohydrate	5.0 g.
Distilled water	1000.0 ml.

(Adjusted to pH 7.4)

Carbohydrate : glucose, sucrose, lactose or manitol

6.1.3 **Mannitol Medium**

constituents

Yeast extract	30.0 g. (Dehydrated)
$MgSO_4$ $7H_2O$	0.2 g.
K_2HPO_4	0.5 g.
Mannitol	10.0 g.
Distilled water	1000.0 ml.

(Adjusted to pH 6.8)

6.1.4 **Simmon's citrate agar**

constituents

$MgSO_4$ $7H_2O$	0.2 g.
$NH_4H_2PO_4$	1.0 g.
K_2HPO_4	1.0 g.
Sodium citrate (dehydrate)	2.0 g.
NaCl	5.0 g
Agar	15.0 g
Bromthymol blue	0.08 g.
Distilled water	1000.0 ml.

(Adjusted to pH 6.9)

7. APPENDIX B.

7.1 Chemical

7.1.1 **Carbol Fuchsin dye**

Constituents

Basic Fuchsin	0.3 g.
95% Ethanol	10.0 ml.
Mixed together and then added :	
Phenol (5% aqueous solution)	100.0 ml.

7.1.2 **Diphenylamine reagent**

Dissolve 50 milligrams of diphenylamine in 25 millilitres of H_2SO_4 (conc). Keep in dark place.

7.1.3 Trommsdorf's solution

1.) Pour 20 percent of aqeous zinc chloride solution dropwise into small aqueous of starch solution (4 grams of starch and small amount of water) until the volume reach 100 millilitres.

2.) Add distilled water until the volume up to 500 millilitres then add 2 grams of potassium iodide.

3.) Add distilled water until the volume up to 1000 millilitres.

4.) Filtrate the solution and keep in dark cool places.

7.1.4 Nessler's reagent

Dissolve 50 grams of KI in 35 millilitres of distilled water then add saturated solution of $HgCl_2$ until some precipitation occur add 400 millilitres of 50 percent KOH. until precipitate disappear then step up the volume to 1000 millilitres by distilled water.

7.1.5 Nitrogen free solution

Constituents:

$CaHPO_4$	1 g.
K_2HPO_4	0.2 g.
$MgSO_4$ $7H_2O$	0.2 g.
NaCl	0.7 g.
$FeCl_3$	0.1 g.
Water	1000 ml.

other salts added as required eg. trace elements.

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PSTC RESEARCH REPORT (5.243)

PROJECT TITLE : COLLECTION AND UTILIZATION OF TAMARIND GERMPLASMS

PRINCIPAL INVESTIGATOR : Dr.Sumrit Feungchan

TASK 2 : MICROSCOPIC STUDIES ON ASSOCIATION OF MICROORGANISMS WITH TAMARIND ROOTS AND ITS RHIZOSPHERE

COLLABORATIVE INSTITUTION

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Research Period : July 1988 - December 1989

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1. INTRODUCTION

Tamarind (Tamarindus indica Linn.), is a perennial tree of medium to large size of about 60 feet high. The tamarind had its origin in Africa and distributed to South India, Burma, Thailand, Laos and Vietnam (Thieng-buranatham, 1988). It is classified in the family of Caesalpiniaceae (Leguminosae).

Tamarind can be used as a medicinal plants for particular therapy. However, special feature of tamarind as viewed by botanist and agriculturist is its ability to grow well in various soil conditions under hot climate. It is interesting to investigate on factors involved in this special character. The nitrogen fixation is one of the characteristic to explore since tamarind is a variety of legume.

This research is the first investigation on rhizosphere microorganisms of a sour type tamarind growing in Thailand. The work has been focused on the association of microorganisms with tamarind roots by examination of root surfaces and internal structures using microscopic techniques.

2. OBJECTIVES

The overall aim is to use microscopic techniques for investigation of tamarind roots whether there is any association with the nitrogen fixing bacteria or other microorganisms. The objectives of this research work therefore includes:

2.1 To examine the presence of nitrogen fixing bacteria in tamarind roots similar to those of Rhizobium found in nodules of other leguminous plants.

2.2 To determine what kind of microorganisms present in tamarind roots or in the rhizosphere.

3. METHODOLOGY

3.1 Roots of tamarind seedlings were examined for the presence of nodules or nodule-like structures under compound microscope.

3.2 Surface and internal structures of root cells were examined for the presence of nodule bacteria such as *Rhizobium spp.* or other microorganisms by scanning electron microscope.

3.3 Ultrastructure of root cells were examined under a trans-mission electron microscope.

4. MATERIALS AND METHODS

4.1 Tamarind Roots

Tamarind seedlings were sown and then planted in polyethylene bags for maintaining as source of plant materials in all experiments. For observation of roots and nodules, seedlings were transferred to clay pots (8 inches diameter) containing planting soil to initiate growth of new roots. Otherwise, seedlings were transferred to the field for 3 months and freshly growing roots were used for experiments (Fig. 1, 2).

4.2 Light Microscopy Examination

Free-hand sections of fresh young roots and nodule-like structure were observed under compound microscope. The materials were thinly sliced both longitudinally and transversely. The sections were mounted in water and observed unstained.

4.3 Scanning Electron Microscopy Examination

Surface structure of root cells and internal structure of freeze-fractured root cells were investigated. Roots or segments of root were cut to the size of 0.5 cm in length and fixed in 2.5 % glutaraldehyde for 1-2 h with mild suction. Tissues were washed 3 times (10 min each) with 0.1 M phosphate buffer, pH 7.0, and dehydrated with graded ethanol from 30-100 % for 10 min each. The tissues were then transferred into solution of amyl acetate for 7-10 min and subjected to critical point drying. Dried samples were gold-coated before observation. For nodule-like appendages of roots, the tissues were fixed, and dehydrated as above. They were then freeze-fractured in liquid nitrogen for observation of the internal structures. After that, the tissues were critical point dried and coated with gold ions.

4.4 Transmission Electron Microscopy Examination

Young roots of Tamarind plants maintained in the pot and in the field were processed for ultrathin sectioning. Roots were excised into small pieces about 1-2 x 10 mm^2 and p fixed .n 5 % glutaraldehyde solution for 3 h at 4 . After washing with 0.1 M phosphate buffer, pH 7.0 , the tissues were post-fixed in 1 % osmium tetroxide for 3 h at 4 C. They were then dehydrated in a series of ethanol (30-100 %) followed by substitution with glycidyl n-butyl ether and embedded in

Spurr's resin. The tissues were sectioned transversely and tangentially with ultra microtome to the thickness of about 700-1500 angstroms, stained with uranyl acetate and lead citrate, and viewed under transmission electron microscope.

4.5 Assay for Nitrogen Fixing Activity

Tamarind roots and the planting soil were determined for nitrogen fixing activity by using the acetylene-ethylene assay method (Hardy et al., 1968). Roots or segments of roots were placed in 10 ml test tubes and the tubes were sealed with rubber serum stoppers. Ten percent of air in each sealed tube was replaced with pure acetylene by withdrawing one ml of air from the tube and injecting acethylene gas for one ml into the tube using a plastic disposable syringe. Ethylene levels were determined after 1, 24 and 72 h by withdrawing one ml gas samples from the tubes and injecting the sample into a gas chromatograph (Shimadzu GC 9A) equipped with a hydrogen flame detector and a 3-m Porpak N column. Peaks corresponding to ethylene were measured, and average value of ethylene formation were calculated.

Roots of the following plants were used as controls in this experiment:

a) Manila grass, Zoysia matrella Willd.

b) Wild bean, Phaseolus lathyroides.

c) Papaya, Carica papaya.

5. RESULTS

5.1 Overall Structures of Young Roots The examined young roots (Fig.3) were composed of three distinct regions; a) a root cap to which soil clinged, b) next to this, a glistening white or pale brown region with averaged length of 3-20 mm without emerged branches, c) a region of mature root, dark brown region, very branchy through its length, connecting to the root base. **Structure of nodule like those found associated with leguminous plants was not detected.** Other structures observed were clusters of branchy roots (Fig. 4a), gall-like structures on mature root (Fig.4b, 4c, 4d), the end point of branching root (root tip ; Fig.4e, 4f). The appearances of these structures were not the same as that of rhizobial nodule. They were round-shaped knobs with rigid cell wall and glistening light brown or ge color. These structures are called 'nodule-like structures' in this report. Further observation for the existence of microorganisms in these structures were carried out by electron microscopy.

5.2 Light Microscopy Observation

Longitudinal sections of young roots showed the regions of root cap, meristem region, central cylinder, continuosly with epidermal and cortex cell layers (Fig.5). There are sloughed root cap cells covering the root cap and extending some distances back over the root surface (Fig.6). The epidermis is composed of a single layer of cells with flat shape and brown color (Fig.7).

The mature roots were observed under light microscope after processing for paraffin embedding sections (Fig.8-11). Coating materials frequently appeared around the roots. The structure of nodule-like tissues revealed similar appearance to the structure of normal root (Fig.12-13).

5.3 Scanning Electron Microscopy Observation

a) Surface and Internal Structures of Roots.

The exterior of root consisted of aggregated sand grains (Fig.14). Root cap was distinctly observed as well as were sloughed cells and coating materials resembling mucilages (Vermeer and McCully,1982., Wullstein and Pratt, 1981, Miki et al., 1980) (Fig.15). Microorganisms were oftenly observed buried in the coated surfaces in the zone next to root cap of potted plant. Most organisms found were rod formed bacteria appearing as single cells (Fig.16), clusters (Fig.17), or chains (Fig.18). Roots of field-grown plants revealed similar surface structure (Fig.19-21). In both cases, bacteria may be obscured by surface coatings. Definite conclusion for site or type of bacterial colonization need to be investigated in more details which is not in the scope of this proposal.

Fungal hyphae occurred on root surface (Fig.22,23) but found less often than bacteria. Some sculptures on root surfaces were unable to identify whether they were fungal hyphae or not (Fig.24,25).

The most striking feature found on cell surface and in some of epidermal cells is a finger-like projection, named 'Microvilli' by the authors (Fig.26-32). The microvilli had one end stuck into cell wall with another end projected out freely (Fig.29). The stalk which stuck into the cell seem to be narrower than its round head (Fig.32). The width was about 0.50-0.65 microns and the length was 1.8-2.2 microns as measured from cell base through another end. Bacteria were also observed together with microvilli but showed no relations by structure (Fig.30-31). These microvilli structures were abundantly found on the outer layer of root cells such as epidermis and cortical cells, but not the inner cell layers (Fig.33-36). Fibrillar materials were abundantly seen connecting around (Fig.37, 39). Microvilli were detected only on meristemic region of root, but not on old brown root region. Appearances of root surfaces were the same for both roots from potted plant and field-grown plant. It is interesting to note that microorganisms were observed only on the active region of roots.

Our examination could not confirm for the presence of mychorrhizae or actinomycetes since the methods for identifying their presence such as histochemical or biochemical techniques were not performed.

b) Nodule-like Structures

In this study Rhizobium nodules of a legume plant <u>Phaseolus lathyroides</u>, were used for comparison. Nodules were processed for freeze-fracturing and for ultrathin sectioning as described above for tamarind roots. Rhizobium were abundantly seen enclosed in nodule cell cavities (Fig.39). The long rod bacteria clumped together by fibrillar connections (Fig.40) as reported for legume nodules (Klucas and Pederson, 1980, Pelczar et al., 1986). On the contrary, all of the nodule-like structures reported here showed different features to those of legume nodule. First, they were very rigid and had distinct brown color like meristem tip of young root. Second, they contained no pinky or gelly substances like those found in nodules. Third, the internal structure of these nodule-like structures had empty cell cavity in contrast to the nodule cells which Rhizobium exist (Fig.41,42). Surface structures were similar to those of young roots. Microvilli were always seen together with rod shape bacteria and fungal hyphae. The result from this observation indicated that these nodule-like structures of tamarind roots were not symbiotic nodules like those of Rhizobium. They were just common parts of the root or root tip.

c) Young Branchy Roots

Tamarind plant had clusters of young branchy roots emerging from the root which were just under the soil surface (Fig.43, 44). These tiny branched roots were attached by gelatinous materials in orange color. To see if there was an association of microorganisms with these roots, the roots were processed for observation under scanning electron microscopy. Unfortunately, most of the roots and gelatinous materials were lost during tissue processing. The remainings showed a structure of short branchy root (Fig.45), containing very fragile and tiny cells (Fig.46). Thick layer of coatings were observed on the outer surface of roots (Fig.47). Some bacteria were detected on cell surface (Fig.48). Their internal structures were similar to those of common roots explained before.

5.4 Transmission Electron Microscopy Observation

a) Ultrastructures of Roots

Ultrathin cross-sectioning of roots revealed an association of bacteria with young roots. In the outer layers of roots, there were detached cells (Vermeer and McCully,1982) containing fibrillar matrix including cellular components which were mostly degenerated (Fig.49,50). There were some bacteria embedded in the mucilage coatings around these epidermal detached cells. Most of the bacteria appeared as a single cell surrounded by an electron-lucent shell. No bacteria were observed in the epidermal cells, neither in the cortical layer. No occurrence of other microorganisms inserted in root cells.

The bacteria found on root surface were of limited numbers, and not forming as colonies (Fig.51-56). They were seen oftenly on root surfaces (Fig. 51, 52, 53, 54) and in the intercellular matrix connecting between cells of the outer layers (Fig. 55, 56).

The cortical cells of root (Fig. 57) had prominent vacuoles within the cytoplasm. Nucleus, mitochondria and golgi bodies were also observed (Fig. 57-60). There were electron-dense materials in cells (Fig. 58, 59, The rhizospheres of root also revealed attachment of soil to roots (Fig. 63, 64). The sites on cell surfaces to which microvilli clung were also demonstrated (Fig.65-69).

b) Ultrastructure of Nodule-like Structures

All of nodule-like structures showed similar ultrastructure appearances as those of common roots. Microorganisms could not be found associated within the cells. This is in contrast to the features of nodule cells which were fully assorted by Rhizobium rods (Fig. 61, 62). The result supported the observation of cells by scanning electron microscope that such structures of tamarind root had no association with bacteria or Rhizobium as the legume-nodule did.

5.5 Acethylene-ethylene Assay for Nitrogen Fixing Activity

In the first experiment, roots and soils were collected only from planting pots and assay for nitrogen fixation compared to the nodulating roots of wild bean. The result was shown in Table 1. There was a little amount (27 ppm) of ethylene produced by samples from tamarind trees (growing naturally near our laboratory), but this was negligible as compared to the amount of ethylene produced by bean nodules (529 ppm). In the second experiments, it was expected that during three-month growing period, newly developed root may have some activity including nitrogen fixation if it was their nature. Roots and soils collected from field and pots were tested for ethylene production and the result was shown in Table 2. Negative results were obtained for the whole sample of tamarind plants.

6. DISCUSSION

The results from the experiments conducted in this research work implies that the roots of tamarind plant had no structure like a nodule of leguminous plant which is the site of Rhizobium association. Presence of bacteria and fungal hyphae found on root surface and in the coatings as interpreted by electron micrographs suggested for the relationship between roots and microorganisms in tamarind rhizosphere. We were unable to demonstrate any symbiotic nitrogen fixation in tamarind roots neither from microscopic observation of nitrogen fixing bacteria nor from an assay for nitrogen fixation activity of tamarind roots.

It is interesting to note that the 'microvilli' reported herein was an unknown structure. It may be a kind of projection helping in minerals or water absorption of root, or has other activities. We could not find any report concerning this structure so far.

It should be investigated further, in detail, about tamarind rhizosphere, the possibility of microbial association in the rhizosphere, the role of such a microvilli structure, and also about fundamental factors underlying the ability of tamarind plant to effectively survive under various soil conditions. These topics were not in the scope of the workplan of this project.

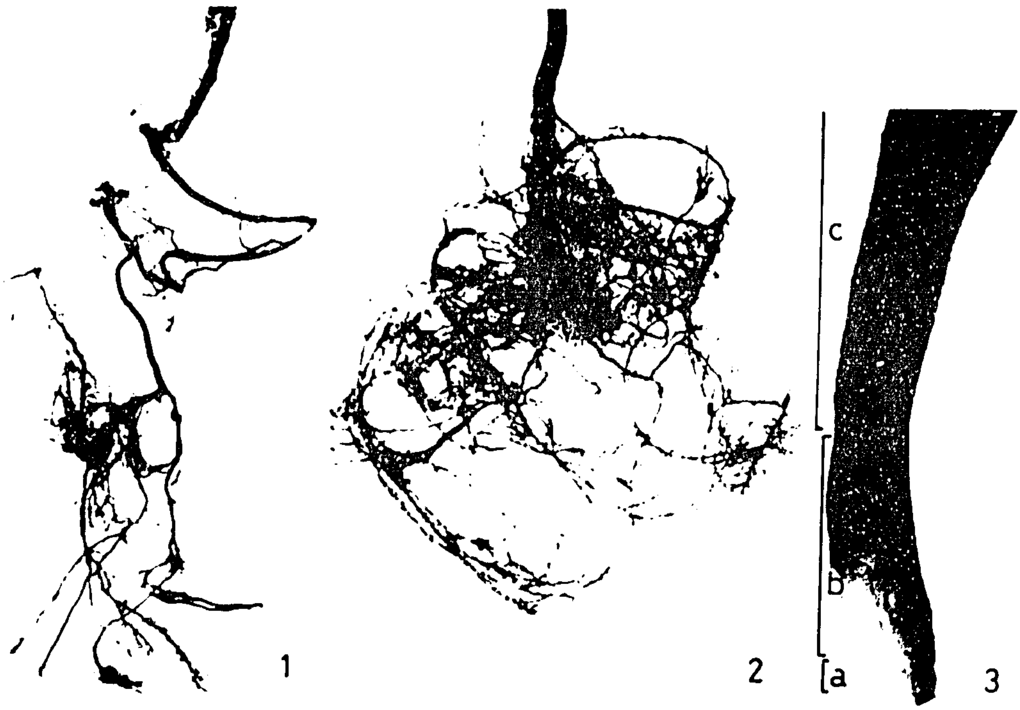

Fig. 1-3 Tamarind roots used in the experiment were collected from potted plant (Fig.1) and field-grown plant (Fig.2). Young root (Fig.3) was divided into three regions: a) root cap, b) root meristem, and c) mature root.

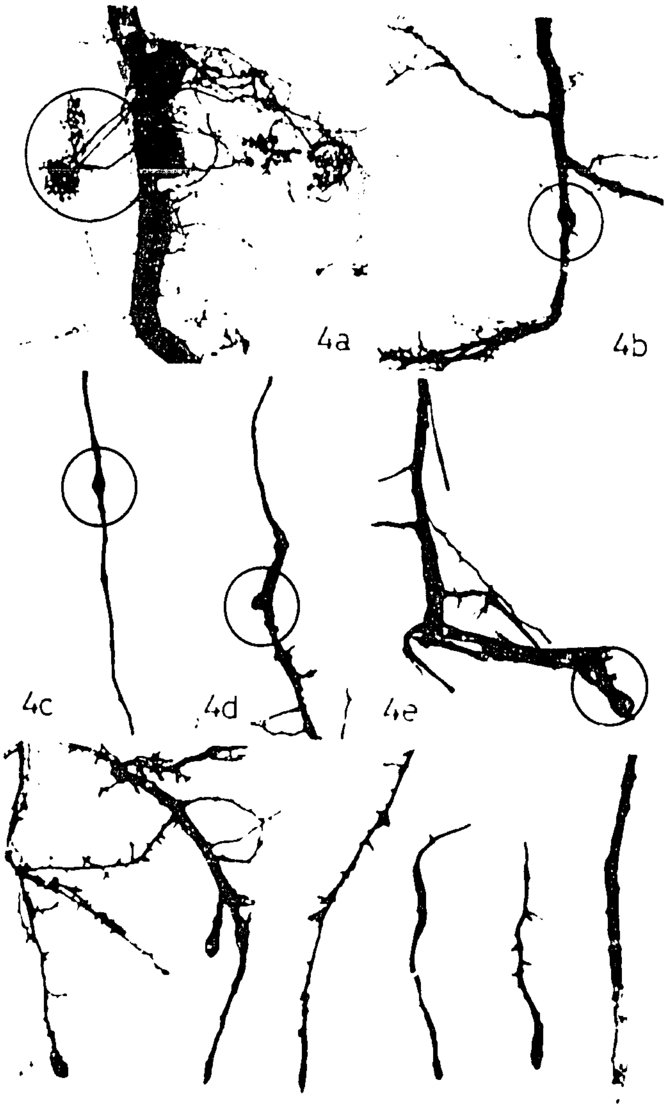

Fig. 4. Morphology of roots and parts of root which were examined;
a: Branchy root in the root region next to the stem.
b-d: Gall-like structures on mature roots.
e: Round root tips.
f: Young roots.

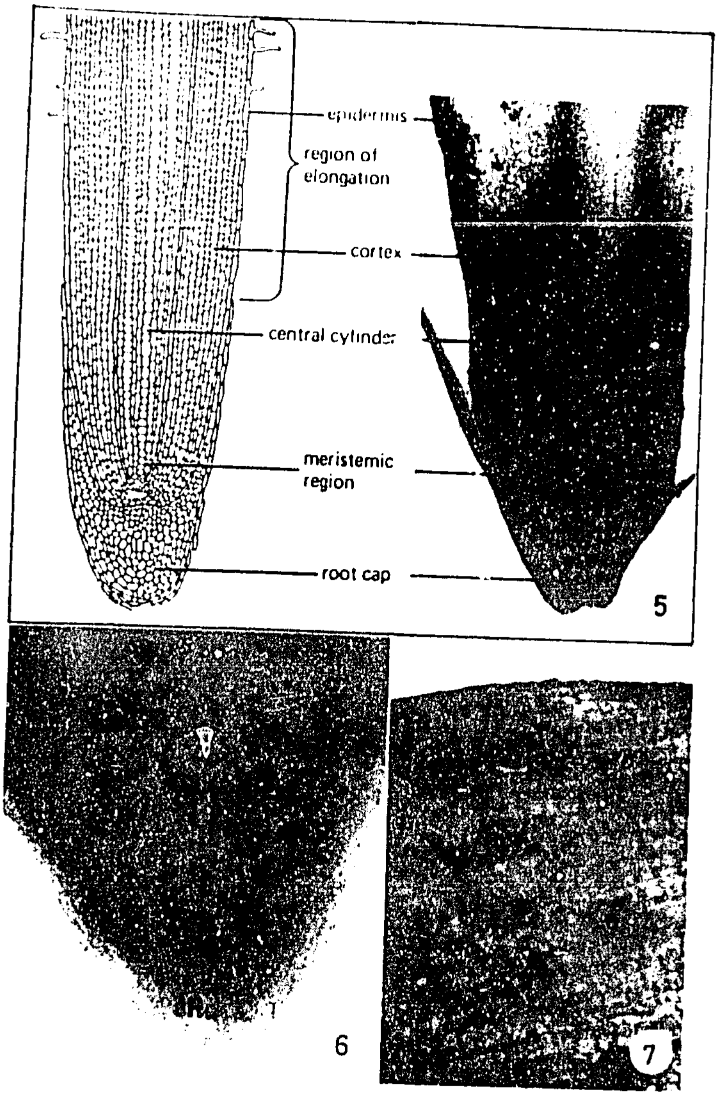

Fig. 5. Longitudinal sections of a root tip.

Fig. 6. Root cap (Rc) with slough root cap cells (sRc) covered the meristem root region (mR)

Fig. 7. Epidermal cells (Ep)

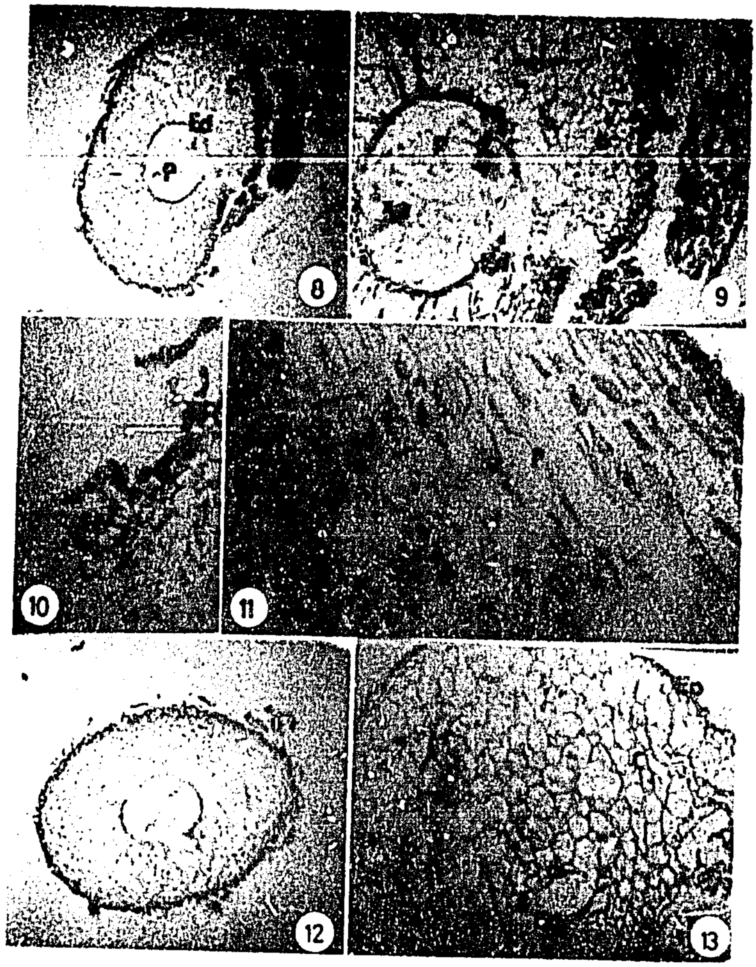

Fig. 8-10. Transverse sections of paraffin embedding roots showing epidermal cells (Ep), cortex (C), endodermis (Ed), xylem (X), phloem (P), including mucilage coatings (M) and root hairs (Rh).

Fig. 11. Longitudinal section of root meristem

Fig. 12-13. Transverse sections of paraffin embedding root parts which looked like nodules (see Fig. 4b, c, d).

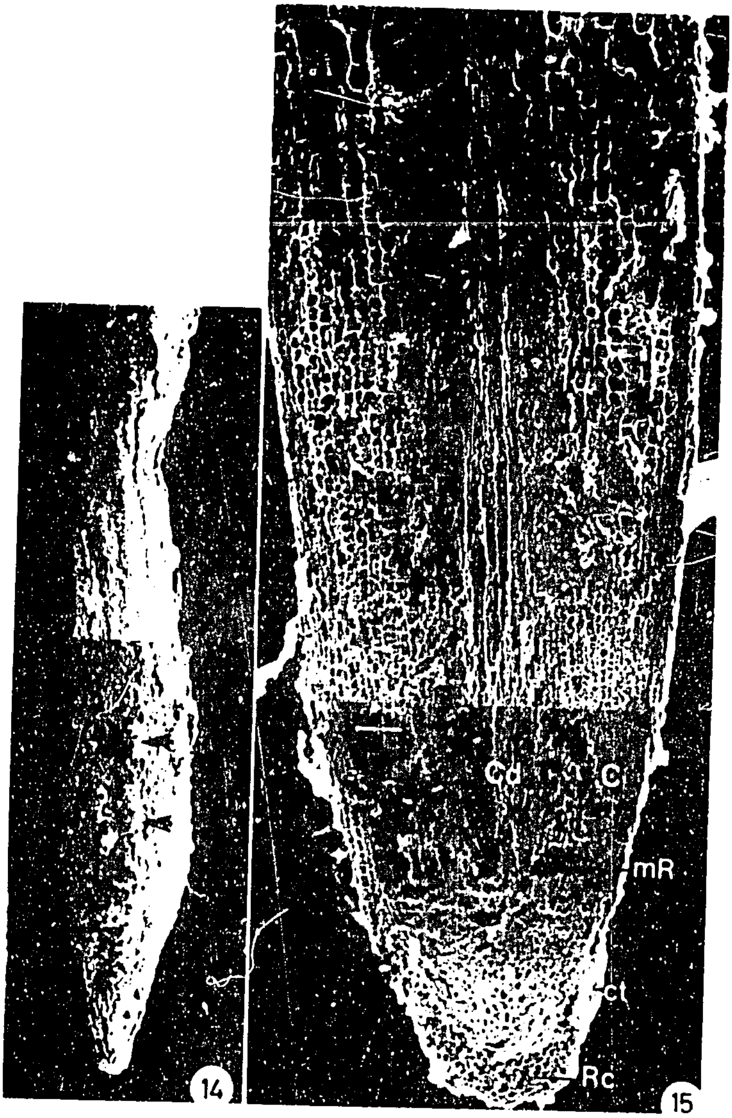

Fig. 14. The exterior of a young root. (arrows indicate soil grains)

Fig. 15 Interior of a young root showing root coatings (ct), root cap (Rc), meristem region (mR), cortex (C) and central cylinder (cd).

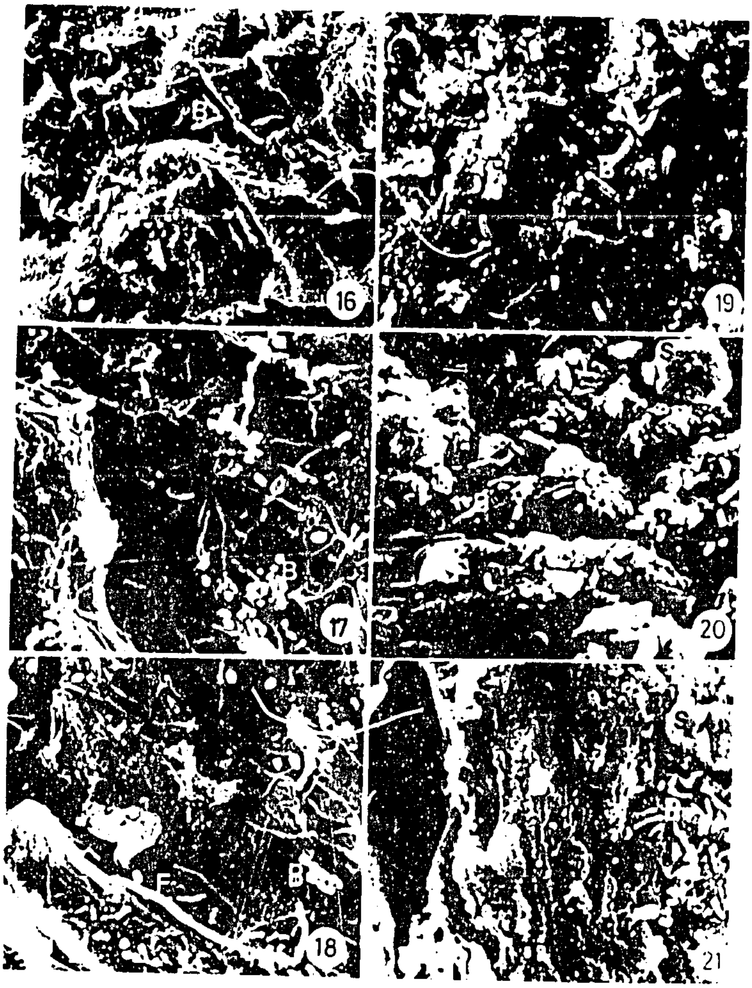

Fig. 16-21. Surface structures of roots from potted plant (Fig. 16-18) and field-grown plant (Fig. 19-21) showing the association of microorganisms.

B : Bacteria, F : Fungal hyphae, S : Soil grains

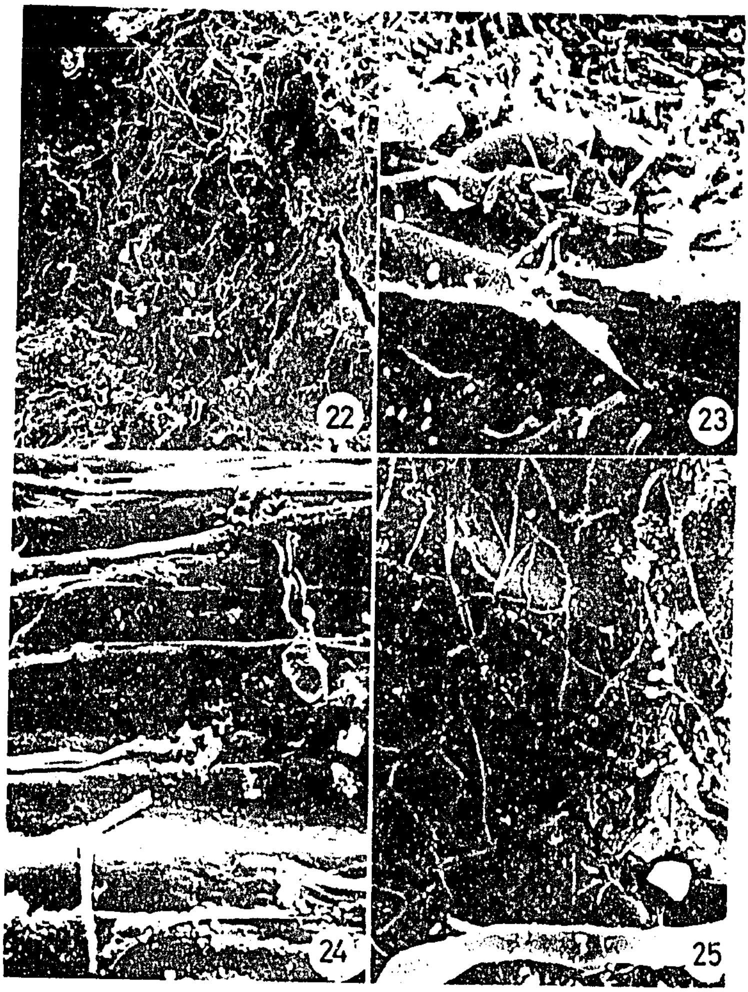

Fig. 22, 23 Fungal hyphae (arrows) found on root surfaces.

Fig. 24, 25 Unidentified root sculptures.

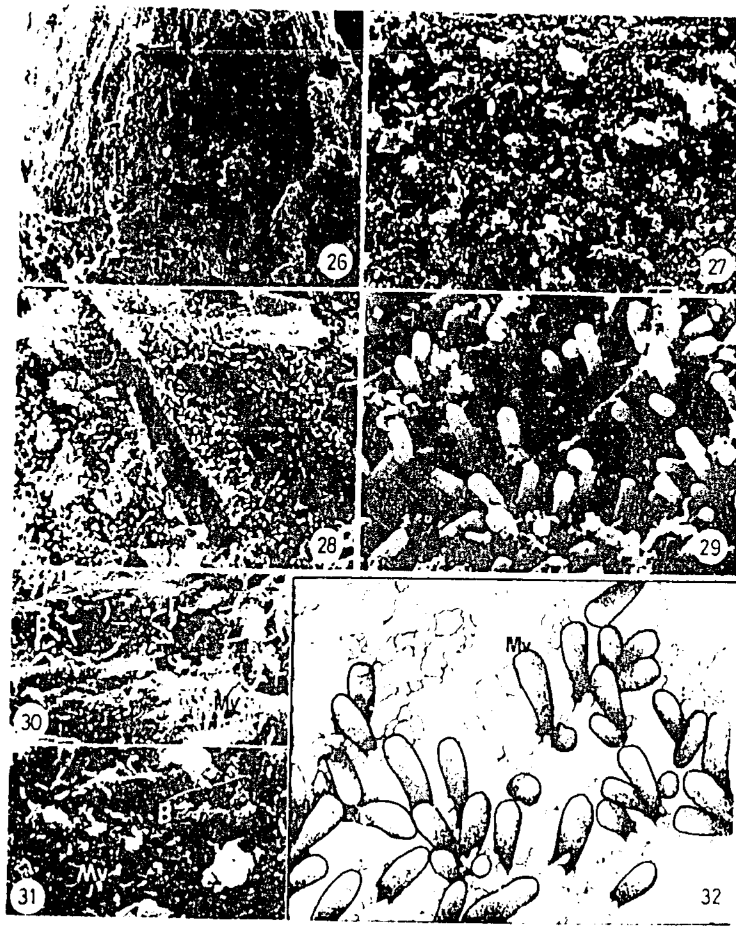

Fig. 26-31. The appearance of 'microvilli' structures found on root surfaces at meristem root zone of potted (Fig. 26, 27) and field-grown plants(Fig.28). The microvilli have one end stuck into the cell (Fig. 29), and its size is about the size of bacteria that occurred together (Fig. 30, 31).

Fig. 32. An illustration of the 'microvilli'.

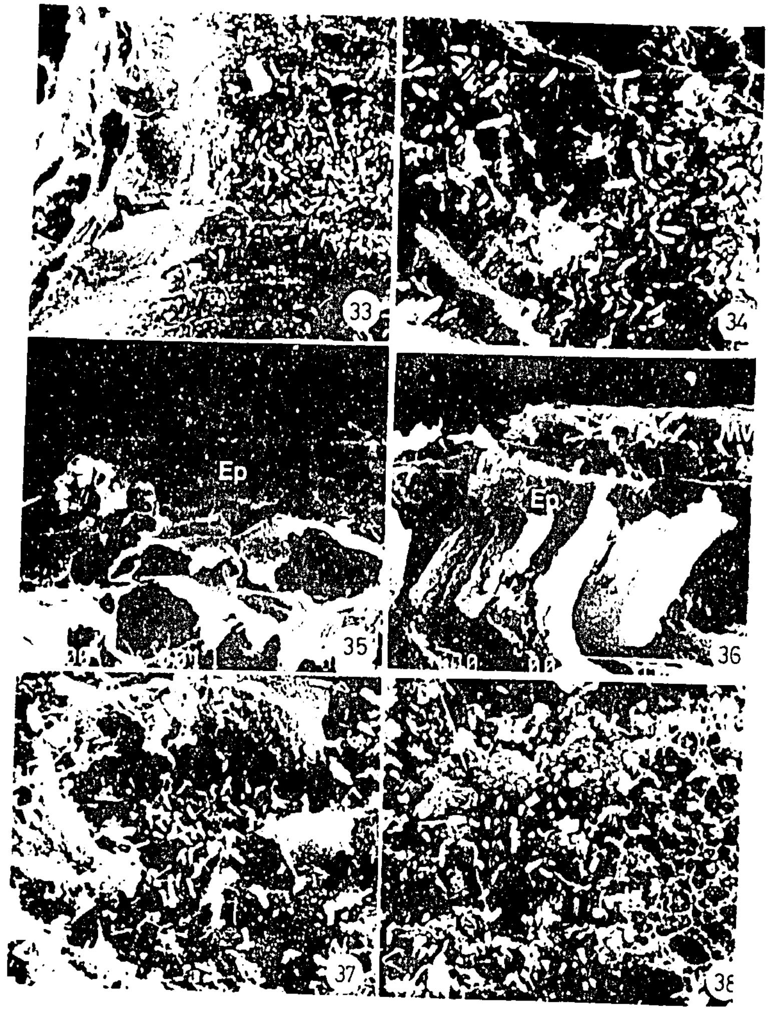

Fig. 33-36 The microvilli were found on cell surfaces (Fig.33,34) and in the outer cell layers (Fig.35,36) of either a young root or a nodule like structure.

Fig. 37, 38 Numerous fibrillar materials were observed together with the microvilli.

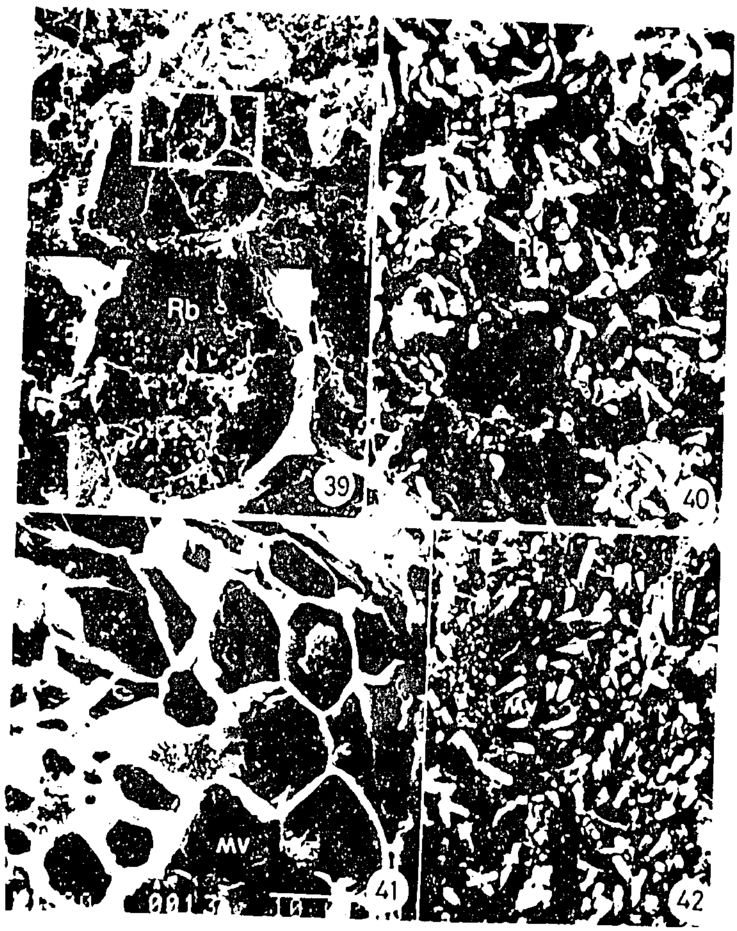

Fig.39,40 The internal structure of a nodule of wild bean, Phaseolus lathyroides Willd. Cells were inserted by plenty of rod-shaped Rhizobium(Rb).

Fig.41,42 The internal structure of a nodule-like structure of tamarind roots(Fig.41). No bacteria was observed. Microvilli were frequently found(Fig.42).

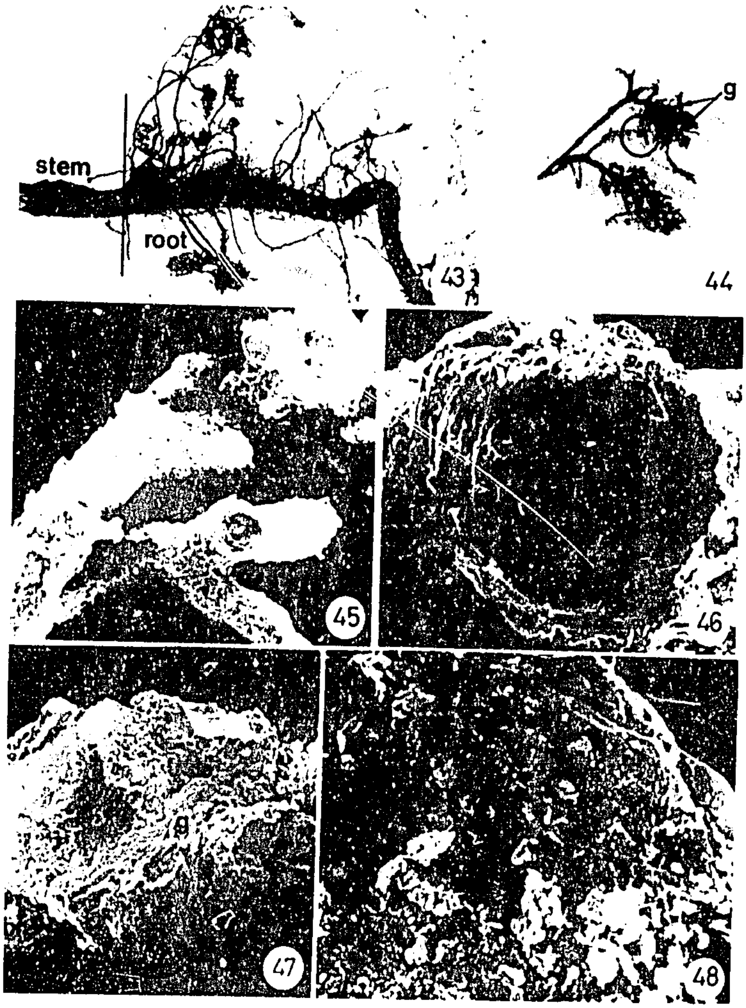

Fig.43,44 Clusters of branchy roots of tamarind plant with gelatinous materials (g).

Fig.45 A scanning electron micrograph of branchy root circled in Fig.44.

Fig.46 Freeze fractured root of Fig.45.

Fig.47 Gelatinous materials on branchy roots.

Fig.48 Some bacteria found on branchy root surfaces.

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Fig.49 Ultrastructure of root cells revealed detached (slough) cells(dc) and mucilage coatings(M) on root surface. Bacteria(B) were found embedding in the coatings.

Fig.50 An illustration of ultrastructure of root cell outer layers.

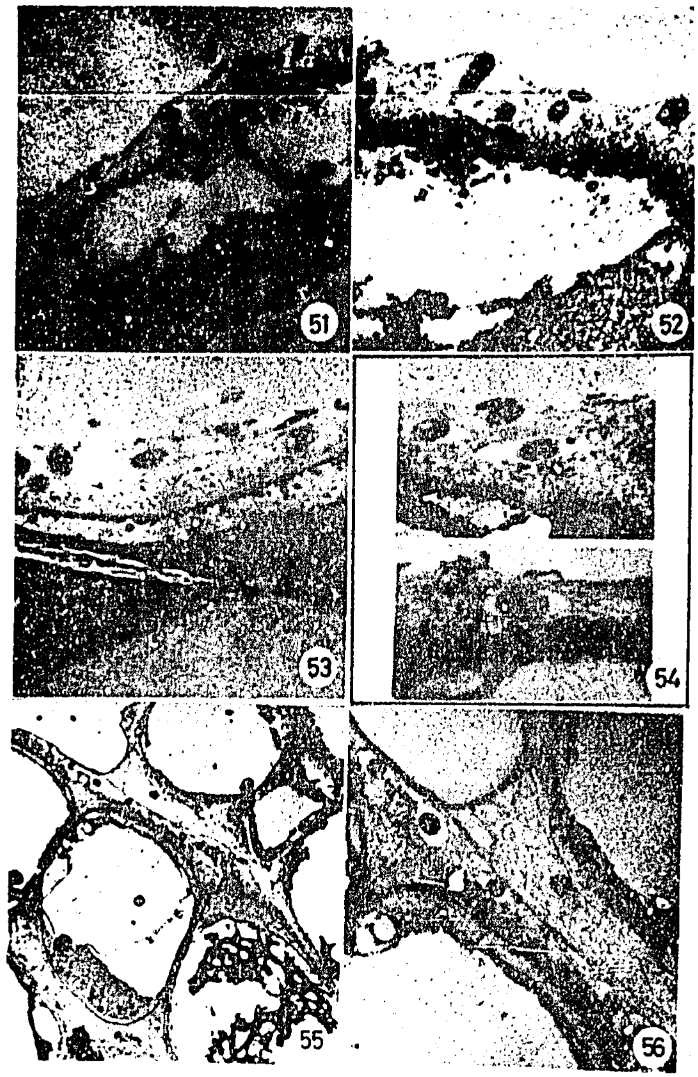

Fig.51-54 Most of bacterial rod found in mucilage coatings(M) were surrounded by electron-translucent capsules(Cs).

Fig.55,56 Some bacteria were found embedding intercellularly in the inner layer of epidermal cells next to cortical cells.

Fig.57-60 Ultrastructure of cortical cells of roots showing cell contents including unknown dense materials(Un).

N : Nucleus Cw : Cell wall

Chr : Chromoplast V : Vacuole

Fig.61-62 Cells of wild bean nodules containing Rhizobium rod (Rb). The bacteria had electron translucent capsules (Cs).

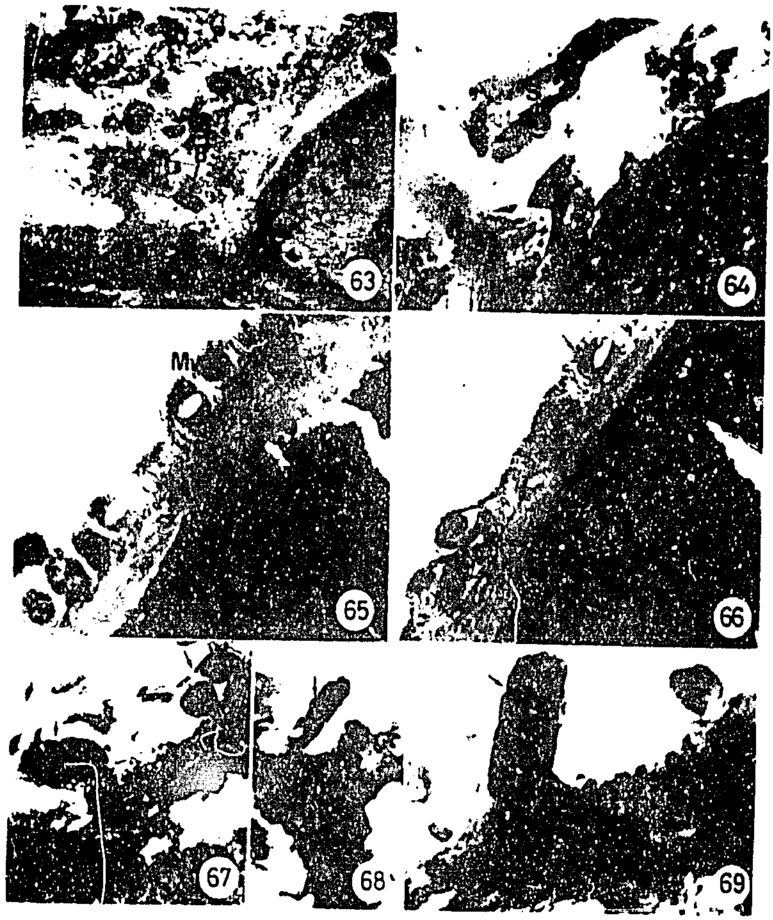

Fig.63,64 The appearance of rhizosphere of tamarind roots. Soil grains(S) and some bacteria(B) were observed.

Fig.65-69 Ultrathin sections of microvilli(Mv, arrows) showing attachment sites on the root cell wall(Cw).

Table 1. Results on the test for nitrogen fixation activity of plant root by acetylene-ethylene assay. (Experiment 1)

Root sample (20 g wt.)	ethylene formation(ppm)[a] by root or soil at 1	24	72 hr
control(blank)	3.5	3.5	3.4
wild bean(root & nodule)	340	516	529
Manila grass(root)	3.9	-	3.3
papaya	3.6	-	4.7
tamarind (potted root)	3.5	3.3	7.0
tamarind tree-1[b]	3.6	3.9	5.1
tamarind tree-2[b]	3.9	-	27.8
natural soil	3.6	-	9.0

[a] Averaged from 3 replicates.
[b] Tamarind tree naturally grows near our laboratory.

Table 2. Results on the test for nitrogen fixation activity of plant roots by acetylene-ethylene assay. (Experiment 2)

Root sample (1 g wt.)	ethylene formation(ppm)[a] by root or soil at 24	72 hr
control (blank)	0.17	0.13
wild bean (root & nodule)	420.00	386.00
Manila grass (root)	0.85	0.63
papaya (root)	1.37	1.10
tamarind (potted root)	0.26	0.27
tamarind (field-grown root)	0.46	0.59
potted soil	4.20	4.20
natural soil	7.30	7.30

[a] Averaged from 3 replicates.

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