



**REGIONAL TRAINING PROGRAMME
ON
VEGETABLE PRODUCTION
TECHNOLOGIES**



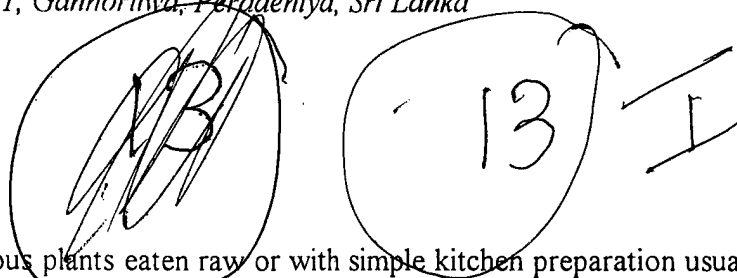
**TRAINING MANUAL
MODULE - 1**

**Horticultural Crop Research & Development Institute
Gannoruwa, Peradeniya, Sri Lanka**

VEGETABLE PRODUCTION, RESEARCH AND DEVELOPMENT IN ASIA

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INTRODUCTION



Vegetables are parts of herbaceous plants eaten raw or with simple kitchen preparation usually as the principal supplement to foods which supply the major parts of calories and protein.

Vegetables play an important role in human diet as providers of wide range of nutrients which supply energy, promote growth and sustain the metabolic function essential for life. Apart from providing food and required fiber, vegetables also play important role in fighting diet-related non-communicable diseases like obesity, cardio-vascular diseases, strokes, anemia, diabetes some forms of cancer etc.

Vegetables make several important contribution to tropical diets,

1. They enrich the diet with nutrients
2. They render the staple food more palatable and hence improve intake
3. They improve digestion
4. They sometimes have curative action

The addition of vitamins, minerals and other nutrients to the diet is the most important contribution of vegetable in human nutrition. (Table 1 & Table 2) At least 65% of dietary vitamin A in Asia comes from vegetables. The nutrition status of vitamin A in Asia has a strong linkage to the consumption rate of vegetables. A high price elasticity coefficient (-0.3408) for vitamin A from leafy vegetables was observed for Taiwan and -0.527 for Pakistan. It means that a price reduction of 10% for leafy vegetable will lead to a 3.4% and 5.3% increase in the availability of vitamin A in Taiwan and Pakistan. Iron deficiency anemia is common in many Asian countries. The main reason is insufficient intake of iron which can be prevented by consumption of vegetables. Vegetables are not only rich in iron, some vegetables are also rich in promoters of iron availability. Studies have demonstrated that availability of iron in legumes can be enhanced if cooked with vegetables rich in enhancing factors. Besides the nutritional value of vegetables increased interest is given to functional benefits of vegetables and their therapeutic benefits to human health. Vegetables are rich source of anti cancer compounds such as lycopene. Increasing chemical evidence supports the role of lycopene as a natural antioxidant with important health benefit since it offers to provide protection against a broad range of epithelial cancer.

PRODUCTION

The Asian region encompasses all the 3 types of major climatic zones. Eg : Tropical, Sub tropical and temperate, the former being the predominant. Likewise, all the 3 types of vegetables, tropical, sub tropical and temperate are grown in the region. Some of the vegetables due to its genetic plasticity and selection/breeding of distinct types with diverse adaptation are grown under all the 3 types of climatic conditions. For instance in the case of tomatoes, cabbages, pepper, etc. There are varieties which are separately tolerant to cold and hot conditions and where these crops could be grown under diverse climatic conditions.

More than 100 species of vegetables are grown. However, about 30 species are predominant. The most important vegetables in the region are tomato, cabbage, egg plant, Chinese cabbage, cucumber, chili, pepper, onions and beans.

Total production of vegetables plus water melons in selected countries in Asia Pacific is given in table 3. Asia produce about 70% of the world vegetable production. In 1995 the total vegetable production in Asia was 367,288 thousand tons where this figure in 2001 increased to 541,523 thousand tons. During these 7 years mean annual growth rate in vegetable production in Asia is 7% and it performed better than the world which had a growth rate of only 5%.

Performance of individual countries varied considerably. In 2001, China with 350,372 thousand tons accounts for 64% of the regions production. India second largest producer of vegetables with an annual production of 53,476 thousand tons accounts for about 12% of the regional production in 2001.

As regards to rate of growth of vegetable production in different countries, Laos showed the highest growth rate. China, Mongolia, Myanmar, Nepal, Vietnam showed more than 5% growth rate. Growth rate in Malaysia is negative while Bhutan, Sri Lanka and Thailand showed zero growth rate.

The highest productivity of vegetables is found in Republic of Korea followed by Iran and China (Table 4). Bhutan, Bangladesh, Fiji, Indonesia, Mongolia, Nepal, Philippines, Sri Lanka, Thailand recorded less than 10 t/ha productivity.

Table 5 presents per capita production of vegetables in different countries of the region. Per capita production has increased from 95.9 kg to 116.2 kg in 2000. An annual consumption of 125 kg of vegetables per capita is recommended for Asian countries. Considering this china, Iran, Democratic Peoples Republic of Korea, Republic of Korea has met the recommended level of production/ consumption.

With the exception of Indonesia, Malaysia, Philippines and Thailand other countries showed growth of per capita production in the last 7 years. The highest growth rate were shown by Laos followed by Mongolia and China.

Seventy percent world's cabbage production is in Asia. The highest production is found in China followed by Republic of Korea. The productivity of cabbage in the region is generally high, Republic of Korea recording the highest yield per ha (Tables 6&7)

Asia produces about 50% of world Tomato. China, India and Iran being dominant countries. The productivity of Tomato is high in Republic of Korea, Iran and Thailand. (Tables 6&7).

Sixty five percent world production of Pumpkin and squashes are in the Asia Pacific region. India is the leading producer followed by China. The productivity of pumpkin and squashes in Malaysia is high followed by Republic of Korea (Table 6 & 7).

The regions production of cucumbers and Gherkins accounted for 80% of the world's production. China produces the largest amount of cucumbers and Gherkins. Republic of Korea recorded the highest per ha yield of Gherkins (Tables 6&7).

The region accounted for 92 of the worlds production of eggplant. The largest producers are China and India. Iran, Republic of Korea and China recorded the highest per ha yield (Tables 6 & 7).

The production of chilies and peppers in Asia is only 4% of the worlds production. China and Indonesia being the largest producers (Tables 6 & 7).

The region with an annual production of 3274 thousand tons accounts for 64% of the worlds' production of beans. The leading producers are China, India and Indonesia (Table 6 & 7).

The region accounts for 40% of world's carrot production. The leading producers are China, India and Indonesia. The productivity of carrots is high in Republic of Korea followed by Iran and China (Table 6 & 7).

Trade of Vegetables

Data on import and export of vegetable as a whole are not readily available. In most of the countries only small quantity of the production is exported. However, from Thailand and Malaysia substantial quantities of the produce is exported (Table 8).

Seasonality

Vegetable production not only varies form year to year but also from season to season. During the season, the prices are low and farmers get the prices for their product. In Sri Lanka prices are normally low in January-April and August-October and high in November-December and May-July. However, the peaks and low prices periods do not overlap in different countries of Asia. This provides an opportunity to reduce seasonality by strengthening to regional and cross country trade (Figure 1&2).

MAJOR CONSTRAINTS TO IMPROVE PRODUCTION OF VEGETABLES

1. *Climatological*

Hot and humid habitats with little differences in day and night temperatures, characterize most vegetable areas in the Asia-Pacific region. These areas are usually in monsoonal zones which are often subjected to uncertainties of rainfall and monsoonal vagaries such as floods, droughts, typhoons and hurricanes. Moreover, hot and humid conditions are highly conducive to proliferation of pests and diseases.

2. *Narrow spectrum of improved varieties*

Improved varieties possessing high yield, wide adoptability, resistance / tolerance to biotic and abiotic stresses and desired quality are the pivotal component of any crop improvement programme. Except in major vegetable crops there is a dearth of suitable high yielding varieties. Several countries in the region lack appropriate breeding infrastructures to develop locally adopted varieties. Introduced varieties often succumb to local pests and diseases. Further, vegetable breeders are handicapped due to limited availability of germplasm. Moreover, indigenous variability is eroding fast, and if not adequately conserved will be out for ever.

3. *Inadequate supply of quality seeds*

In most developing countries usually not more than 5% to 10% belong to quality seed category. The cost of seeds, particularly imported hybrids are very high and is beyond buying power of resource poor farmers. Lack of suitable man power and research support for producing quality seed is the major constraint. There is general lack of synergistic interaction between private sector and public sector in seed production. In some of the countries there is no seed act and regulations. In some countries, even where rules and acts exists, they are not enforced effectively.

4. *Lack of appropriate package of vegetable production technology*

Generally lacking are appropriate packages of technologies which encompassed appropriate varieties, seeding and seedling management, fertilizer and water management, pest management and post harvest operations. These are needed for different agro ecological and socio-economic setting such as rain fed vs irrigated, low-input vs high - input and home gardening vs commercial. Research has not being integrated and covers only one or other component without taking a holistic approach.

5. *Lack of extension support*

There is wide gap between yields recorded in demonstration fields and average farmers yields. Among the several factors responsible for the gap, poor linkage between research and extension and poor technology transfer are important. There is acute shortage of extension staff trained for scientific production of vegetables.

6. *Problems associated with Pest Management*

The problems associated with miss and overuse of pesticide in vegetable production remain serious and acute. Extensive use of pesticide in vegetable results in unsustainable production practices arising from undesirable externalities such as pesticide resistance in pest organisms wide spread environmental pollution, health hazard to farmers and their families, toxic residues in food for consumers and negative international trade implications

7. *Poor post harvest handling*

The post harvest losses of vegetables accounts for about 10-30%. Appropriate techniques for harvesting, cleaning, precooling, cooling, packaging, storage, transport and processing can reduce the post harvest losses.

8. *Marketing Problem*

Limited and inadequate market support and infrastructure and facilities for transport, processing and storage results in high prices to consumer and low prices to producer. Market intelligence for vegetable products hardly exists in most of the developing countries.

VEGETABLE RESEARCH AND DEVELOPMENT

Crop Improvement

Advances have been made in breeding for high yield, quality and resistance to biotic and abiotic stress. Varieties of Tomato resistant to bacterial wilt and heat stress have been developed. Breeders have paid attention to quality characters such as high lycopene content in tomato and high capsicin content in Chili. Heterosis has been exploited in crops like tomato, brinjal and cruciferous vegetables.

Bio Technology

Biotechnology offers vast potential in vegetable research. Genetic transformation, micro propagation, invitro conservation of germplasm, production of virus free planting material,

biofertilizer and biopesticides and post harvest biotechnology are important areas of biotechnology in horticultural crops.

Molecular markers offer diverse uses such as analysis of genetic diversity, rapid screening of germplasm to locate desirable traits and pyramiding of genes conferring resistance to more than one biotype of a pathogen.

Pest and disease resistance vegetable varieties have been developed through the utilization of genetic transformation using Bt genes and coat protein genes. Meristem culture is used to propagate virus free seed potato within short time.

Genetic manipulation through bio-technology to develop more efficient strains of N fixing and phosphorous solubilizing micro organism is likely to increase bio fertilizer efficacy. Horticultural crops require high quantities of N and P which can be considerably replaced through the use of nitrogen fixing organisms like Rhizobium, Azotobacter and Azospirilla and Phosphate solubilizing bacteria *Pseudomonas* and fungi *Penicillium* and *Aspergillus*.

Production Technology

Multiple stress caused by biotic factors and abiotic factors results low productivity. In the race to increase productivity farmers resort to the excessive use and mis use of inputs such as fertilizer and pesticides and also irrigation water. These practices lead to soil and ground water pollution among the other constraints of vegetable production are gluts during the season leading to lower prices to growers and shortages during lean periods.

Fertilizer efficiency of crops can be enhanced by several ways. Soil test based fertilizer recommendation can reduce the unwanted fertilizer use. Balance between application of inorganic and organic manure are essential for better plant growth. Inoculation of seed with various N fixing bacteria such as Azotobacter and Azospirillum is found to increase the nitrogen efficiency. Fertigation is an effective means of controlling timing and placement of fertilizer and of improving fertilizer use efficiency and yield.

Water use efficiency of crops can be improved by various means. Mycorrhizal association with plants have found to mitigate drought tolerance. Mulching with organic wastes materials, black polythene and other plastic material reduces water evaporation and delays drying of soil. Micro – irrigation also improves water use efficiency by placing required quantity of water at the root zone.

The main purpose of protected cultivation is to create a favourable micro-climate for the sustained growth of plants so as to realize its maximum potential even in adverse climate conditions. Advances have been made on the selection of high value crops suitable for green house culture, selection of suitable low cost growing media, training and pruning methods and other crop management technologies.

Crop Protection

Protecting vegetable crops from the pests without causing environmental harm and endangering lives of producers and consumers remains one of the most daunting challenges facing the vegetable industry today. Vegetable production consumes tremendous amounts of chemical pesticides and there are often used irresponsibly and often pose unnecessary risks to the environment and human health. Additionally, this mis-use increasingly results in the development of pesticide resistance in target pest species leading into greater control difficulties and the presence of even greater amount of toxic chemicals in the environment. In the past few years, however much has been learned about how to minimize the risks associated with pest control of vegetables and other crop productions. Collectively these environmental friendly pest control tactics are components of the integrated pest management (IPM) approach. Several methods such as host resistance, cultural control, biological control and use of botanicals are employed as components of IPM.

Neem in its crude form and various formulation are used for the control of wide range of vegetable pests. Apart from neem leaf extract of *Adathoda* is effective for management of color rot of brinjal caused by *Scelerotium rolfsi*.

Antagonistic micro organisms are now widely used as bio-control agents particularly for the control of root diseases. Soil application of *Trichoderma varidae* is found to be effective for the management of root rot in cassava while seed treatment with some fungi lowered the incidence of damping off.

Various components of IPM are now successfully packaged to devise pest management programmes with rational use of insecticides. In potato adoption of seed plot techniques comprising use of healthy seeds, adjustment of planting and harvesting dates, haulms cutting, crop rotation, hot weather cultivation has reduced excessive use of pesticides. Methods of forecasting appearance of late blight have been standardized making prophylactic treatment at the appropriate time.

For sweet weevil management, re-ridging organic mulching, encouraging natural parasitoids, removal of alternate hosts and burning of sweet potato weevil infested crop residue has found to be effective.

It was found that no single method was found to be effective in management of nematodes in vegetables on any crop on a sustainable basis. Bio-intensive nematode management of economically important nematodes of vegetable crops were developed by integrating bio-control agents (*Paecilomyces lilacinus*, *T. hazainum* *Verticillium lecani* all fungi, *Pasturia penetrans* (bacteria), botanicals (Neem and castor cake and *Calotropis procera*) and endomycorrhiza (*Glomus mosseae*).

Post Harvest Management

The post harvest losses of vegetables accounts for about 10% - 30%. Various concepts have evolved over the years for extending shelf life improving safety and for diversify product utilization of perishable produce. Major post harvest technological applications include controlled and modified atmosphere storage and packaging, irradiation for maintaining the produce in the fresh state, thermal processing, freezing, drying, fermentation etc.

In developed countries harvest from the field are bulk transported to pack houses where they are washed, sorted graded and different other treatments like fungicidal dip, surface coating, degreasing, ripening, conditioning and vapour. Heat treatment are given. Farmers co-operative can operate pack houses at nodal points to argument marketing of horticultural produce both for internal trade and export.

Packaging individual fruits of brinjal, capsicum etc. using high density seal shrink polythene film can considerably increase storage life. The film wrapping reduces weight loss and maintain firmness of the produce. Polymeric film give good results in packaging of fresh produce due to their high gas permeability and impervious nature to bacteria.

Various packaging material like bamboo baskets, gunny bags, wooden boxes and plastic crates are used for packaging. There is constant search for newer and effective and cost effective packaging material. A ventilated corrugated fiber board (CFB) box has been developed with ventilated partition for packaging.

Pre cooling is the process of rapidly removing the heat from commodities. Packaging followed by pre cooling considerably enhances the shelf life of horticultural produce by reducing the physiological and biochemical changes. The environmentally friendly low cost evaporative cool chamber developed can be gainfully used for pre cooling horticultural produce.

Modified atmosphere (MA) essentially means any deviation from the normal atmosphereric gas composition, if this deviation is strictly controlled with certain specific gaseous concentration of N₂, CO₂ and O₂ then it is termed controlled atmosphere (CA). The beneficial effects of CA/MA are retardation of ripening senescence and physiological changes. A gas blending system has been designed and fabricated at Indian Agriculture Research Institute, New Delhi for the generation of CA for the post harvest treatment of horticulture produce.

Processing of vegetables for both food and non food uses will open up marketing alternatives to the sales of fresh produces, reduces post harvest losses, regulate prices during peak production and lean period. The value added products include freshcut vegetables, dried vegetables, caned and pickled products. Many industrial and pharmaceutically important products can be prepared particularly from processed root and tubers.

Table 1 : Composition of some vegetables, compared with pulses and starch foods (Per 100 grams of Edible Portion).

Product	Dry matter	Kcal	Protein g	Fibre g	Calcium mg	Iron mg	Carotene mg	Thiamine mg	Riboflavin mg	Niacin mg	Vitamin C mg
Starchy basic food											
Maize	88	362	9.5	1.5	12	2.5	0.00	0.35	0.13	2.0	0
Rice	88	354	8.0	0.5	10	2.5	0.00	0.25	0.05	2.0	0
Cassava	40	153	0.7	1.0	25	1.0	0.00	0.07	0.03	0.7	30
Sweet potato	30	114	1.5	1.0	25	1.0	0.06	0.10	0.04	0.7	30
Pulses											
Ground nut	55	332	15.0	1.5	30	1.5	0.00	0.50	0.10	10.0	10
Cowpea	90	340	22.0	4.0	90	5.0	0.01	0.90	0.15	2.0	0
Vegetables											
Dark green leaves	15	48	5.0	1.5	250	4.0	1.80	0.10	0.30	1.5	100
Tomato	6	20	1.0	0.6	5	0.4	0.15	0.06	0.04	0.7	25
Okra	10	33	2.0	1.0	70	1.0	0.09	0.10	0.10	1.0	25
Green beans in pod	10	34	2.0	1.0	50	1.4	0.12	0.08	0.12	0.5	20
Daily requirements		2530	46.0	-	500	9.0	1.50	1.00	1.50	17.5	30

Table 2 : Average nutritive value of vegetables. Data from food composition table for use in East Asia (FAO, 1972)

Per 100g edible portion														
Type of Produce	Waste %	DM %	Energy Kcal	Protein	Fibre	Ca mg	Iron mg	Carotene mg	Thiamine mg	Ribo-Flavin mg	Niacin mg	Vit.C Mg	ANV	ANV per 100g dry matter
Fruit-Vegetables														
Tomato	5	6.2	20	1.2	0.7	7	0.5	0.5	0.06	0.04	0.6	23	2.39	38.5
Eggplant	4	8.0	26	1.6	1.0	22	0.9	0.0	0.08	0.07	0.7	6	2.14	26.8
Sweet peppers	13	8.0	26	1.3	1.4	12	0.9	1.8	0.07	0.08	0.8	103	6.61	82.6
Peper.hot	13	34.6	116	6.3	15.0	86	3.6	6.6	0.37	0.51	2.5	96	27.92	80.7
Okra	10	1.04	31	1.8	0.9	90	1.0	0.1	0.07	0.08	0.8	18	3.21	30.9
Cucumber	20	3.8	12	0.6	0.5	21	0.4	0.1	0.03	0.04	0.2	11	1.69	44.5
Pumpkin	17	8.1	27	0.7	0.8	24	0.7	0.8	0.03	0.04	0.5	14	2.68	33.1
Watermelon	37	6.8	21	0.6	0.2	8	0.2	0.1	0.03	0.03	0.2	6	0.90	13.2
Melon (white-green)	22	7.6	26	1.0	0.5	18	0.5	0.0	0.05	0.02	0.4	25	2.33	30.7
Bittergourd	20	6.0	19	0.8	1.0	26	2.3	0.1	0.06	0.04	0.3	57	4.10	68.3
Leafy Vegetables														
Amaranth	40	10.7	26	3.6	1.3	154	2.9	6.5	0.04	0.22	0.7	23	11.32	105.8
Kangkong	28	10.0	30	2.7	1.1	60	2.5	2.9	0.09	0.16	1.1	47	7.57	75.7
Chinese cabbage, leaf type	14	5.8	17	1.7	0.7	102	2.6	2.3	0.07	0.13	0.8	53	6.99	120.5
Lettuce	25	6.4	20	1.4	0.6	56	2.1	2.0	0.06	0.12	0.5	17	5.35	83.6
White cabbage	15	7.0	22	1.6	0.8	55	0.8	0.3	0.06	0.06	0.3	46	3.52	50.3
Cassava leaves	13	19.0	50	6.9	2.1	144	2.8	8.3	0.16	0.32	1.8	82	16.67	87.7
Leguminous vegetables														
Hyacinth bean (dry)	0	87.9	334	21.5	6.8	98	3.9	0.0	0.40	0.12	1.8	0	14.03	16.0
Lima bean (fresh)	43	31.5	119	8.4	1.0	25	2.2	0.1	0.16	0.16	1.5	30	4.88	17.9
Mungbean (sprouted)	7	9.9	30	4.2	0.9	15	1.2	0.0	0.11	0.10	0.8	18	2.94	34.2
Sprout, Bulbs, Tubers, etc. ,														
Onion (dry)	6	11.4	38	1.6	0.7	30	1.0	0.0	0.06	0.04	0.2	9	2.05	20.0
Carrot	15	10.4	37	1.1	0.9	36	1.2	4.2	0.06	0.05	0.7	8	6.48	64.2
Bambooshoots	44	9.0	28	2.5	1.2	17	0.9	0.0	0.11	0.09	0.6	9	2.55	30.9
Mushroom	9	11.3	37	2.7	0.9	8	1.0	0.0	0.10	0.42	4.8	3	2.10	19.3
Taro (as vegetable)	16	24.6	94	2.2	0.8	34	1.2	0.0	0.12	0.04	1.0	8	2.38	9.7

Table 3 : Total vegetable productions (Including melons) (in 1000 tons) in different years

Production (Mt)	Year							Avg. Ann. Gr. Rate
	1995	1996	1997	1998	1999	2000	2001	
China	202,569	226,276	242,570	251,340	280,069	328,702	350,372	10
Bangladesh	1,486	1,507	1,559	1,572	1,785	1,802	1,795	3
Bhutan	10	10	10	10	10	10	10	0
Fiji Islands	17	16	16	18	20	21	22	4
India	56,275	56,660	57,778	63,164	65,617	67,880	68,059	3
Indonesia	6,464	6,590	5,576	5,958	6,322	6,166	6,738	1
Iran, Islamic Rep of	7,875	10,217	10,543	12,254	12,711	11,499	11,514	7
Korea, Dem People's Rep	3,374	3,324	3,334	3,583	3,595	3,811	3,831	2
Korea, Republic of	11,325	11,087	10,743	10,906	11,185	12,255	12,413	2
Laos	87	118	132	150	269	671	665	48
Malaysia	510	459	502	559	488	461	466	-1
Maldives	24	24	25	26	28	30	30	4
Mongolia	27	24	36	46	47	45	48	12
Myanmar	2,475	2,658	2,738	2,978	3,279	3,343	3,475	6
Nepal	1,257	1,327	1,357	1,417	1,348	1,500	1,669	5
Pakistan	4,186	4,457	4,482	4,467	4,541	5,065	4,967	3
Papua New Guinea	389	400	420	436	461	474	474	3
Philippines	4,432	4,935	4,466	4,597	4,716	4,808	4,910	2
Sri Lanka	627	599	606	590	657	628	607	0
Thailand	2,946	2,864	2,775	2,848	2,897	2,903	2,899	0
Viet Nam	4,645	4,723	5,465	5,680	6,323	6,487	7,212	8
Asia	367,288	394,276	409,486	430,100	465,691	518,398	541,523	7
World	560,519	594,001	609,631	634,713	683,430	733,874	753,263	5

Source : FAOSTAT Database

Table 4 : Productivity of vegetables in different countries in varies years.

Yield (Mt/Ha)	Year						
	1995	1996	1997	1998	1999	2000	2001
China	18.77	19.07	19.13	18.22	18.41	19.02	18.84
Bangladesh	6.10	6.04	6.19	6.11	5.64	6.00	5.95
Bhutan	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Fiji Islands	7.88	7.63	7.82	7.18	6.91	6.96	7.53
India	10.19	11.24	11.31	11.49	11.32	11.32	11.25
Indonesia	7.57	7.60	6.76	7.13	7.44	7.36	8.04
Iran, Islamic Rep of	18.00	19.23	19.14	19.42	20.93	20.94	21.56
Korea, Dem People's Rep	11.56	11.43	11.47	11.91	11.87	12.32	12.35
Korea, Republic of	26.31	25.80	27.30	28.05	27.12	29.51	30.93
Laos	7.95	7.36	4.75	4.51	6.18	6.26	5.93
Malaysia	17.35	17.33	17.14	18.30	17.16	17.11	17.30
Maldives	14.56	14.56	14.55	14.69	14.75	14.47	14.86
Mongolia	8.41	7.46	7.88	7.98	8.19	7.54	7.97
Myanmar	12.12	12.19	12.27	12.31	12.32	11.83	12.23
Nepal	8.95	9.19	9.27	9.41	9.56	9.93	10.25
Pakistan	13.37	13.53	13.37	13.21	13.21	13.84	13.76
Papua New Guinea	12.27	12.18	12.30	12.31	12.38	12.40	12.40
Philippines	8.34	8.34	8.16	8.36	8.47	8.43	8.42
Sri Lanka	6.96	7.15	7.38	7.59	7.95	7.92	7.95
Thailand	8.90	9.01	8.80	8.89	8.86	8.77	8.78
Viet Nam	11.24	11.37	11.87	11.62	11.57	11.99	12.37
Asia	15.64	16.27	16.34	16.01	16.18	16.66	16.64
World	15.53	16.04	16.07	15.87	16.12	16.40	16.40

Source : FAOSTAT Database

Table 5: Percapita vegetable production in different countries

<i>Supply/Cap/Yr (Kg)</i>	Year						Av. Annul Gr. Rate
	1995	1996	1997	1998	1999	2000	
China	148	163.8	173.7	178.2	189	203.5	6.14
Bangladesh	11	11.1	11.2	11.2	12.2	12.1	1.83
Fiji Islands	33.7	33.3	31.9	31.9	39.9	39.2	2.53
India	56.4	55.8	55.9	60.2	61.4	62.5	1.99
Indonesia	30	30.2	25.6	27.3	29.5	27.6	-2.10
Iran, Islamic Rep of	105.2	135.7	124.6	142.7	144.6	131.3	3.49
Korea, Dem People's Rep	140.2	136.8	136	145.1	144.6	152.3	1.58
Korea, Republic of	220.8	215.1	208.3	207.5	213.2	232.2	0.91
Laos	17.6	23.3	25.6	28.4	49.6	52.2	18.21
Malaysia	33.3	39.1	32.1	33.1	35.9	28	-4.87
Maldives	120.2	116.7	125.9	122.9	122.8	123.4	0.45
Mongolia	8.5	11.3	16.3	21.7	21.1	21.2	15.59
Myanmar	50.4	53.3	56.4	58	63.2	63.6	4.51
Nepal	55.8	57.3	57.5	62	55.2	58.3	0.64
Pakistan	32.8	34.3	33.4	32.5	32.1	34.3	0.82
Papua New Guinea	82.1	82.8	85.1	86	89	89.3	1.66
Philippines	61.6	68	60.2	61.1	62	61.6	-0.25
Sri Lanka	32.2	32.5	34.3	32.5	34.6	34.9	1.51
Thailand	39.8	38.3	36.3	36.6	37.2	37.1	-1.45
Viet Nam	57.4	57.4	65.9	67.2	73.7	74.9	5.05
Asia	95.9	101.4	103.6	106.9	111.4	116.2	3.76

Source : FAOSTAT Database

Table 6 : Production of selected vegetables in year 2001 in different countries. (in 1000 mt)

<i>Production (Mt)</i>	Cabbages	Tomatoes	Pumpkins, Squash, Gourds	Cucumbers and Gherkins	<i>Eggplants</i>	Chillies&Pepp ers, Green	Beans, Green	Carrots
China	25,348	24,116	3,796	21,674	14,030	533	1,800	6,112
Bhutan						3		
Bangladesh	115	100	206	21			50	
Fiji Islands	0.7	3	2	1	4	0.14		
India	4,300	8,500	3,900	119	6,400	6	420	350
Indonesia	1,750	320	290	480	300	185	175	320
Iran, Islamic Rep of	260	3,009	500	1,300	100	4	15	40
Korea, Dem People's Rep	650	62	85	64	43	23		
Korea, Republic of	3,420	260	240	454	5	76		150
Maldives						0.013		
Malaysia	47	10	14	50				
Nepal						3		
Pakistan	67	270	250	14	76		18	188
Papua New Guinea		0.38	0.14				0	
Philippines	90	146	63	6	165	5	12	
Sri Lanka	54	40	170	28	69	17	31	28
Thailand	205	236	210	210	66	1	87	
Viet Nam	107							
Asia	41,759	52,526	10,743	28,833	23,270	951	3,274	8,742
World	59,267	105,070	16,392	35,018	25,076	21,273	5,067	20,840

Source : FAOSTAT Database

Table 7 : Productivity of selected vegetables in year 2001 in different countries

<i>Yield (Mt/Ha)</i>	Cabbages	Tomatoes	Pumpkins, Squash, Gourds	Cucumbers and Gherkins	Eggplants	Chillies& Peppers, Green	Beans, Green	Carrots
China	18.89	25.81	15.51	18.06	17.95	18.54	10.91	17.82
Bangladesh	9.79	6.67	7.49	4.32			4.57	
Bhutan						3.40		
Fiji Islands	9.33	9.33	8.00	13.75	5.00	5.00		
India	17.92	17.00	9.75	6.61	13.91	9.09	2.80	14.58
Indonesia	17.50	7.08	11.15	9.80	7.50	2.97	6.03	16.01
Iran, Islamic Rep of	24.76	27.30	13.16	21.67	22.22	25.00	10.00	25.00
Korea, Dem People's Rep	19.12	7.38	10.00	11.64	10.00	2.39		
Korea, Republic of	61.59	77.66	28.51	62.39	16.67	4.98		34.90
Maldives						3.38		
Malaysia	36.15	17.54	29.79	31.25				
Pakistan	14.91	9.67	10.42	12.73	10.56			17.78
Papua New Guinea		4.75	1.87					
Philippines	11.52	8.77	7.00	4.00	9.17	3.49		
Sri Lanka	13.69	7.57	14.17	9.33	6.86	2.83		11.14
Thailand	11.02	23.79	11.86	7.72	6.00	14.00	4.00	
Viet Nam	22.77							
Asia	20.75	24.03	12.16	18.03	16.38	13.76	7.00	18.28

Table 5 Vegetable export in absolute values (000 tons) as well as in terms of percentage to the domestic production.

Country	1995	% of total production	1996	% of total production	1997	% of total production	1998	% of total production	1999	% of total production	2000	% of total production	2001	% of total production
Asia	2 433 666	0 663	4 759 608	1 207	2 566 840	0 627	2 718 114	0 632	2 659 997	0 571	2 764 764	0 533	3 081 521	0 569
China	1 395 090	0 689	1 496 082	0 661	1 532 266	0 632	1 681 790	0 669	1 673 733	0 598	1 713 094	0 521	1 926 156	0 550
Fiji Islands	346	2 023	502	3 080	392	2 463	511	2 849	538	2 690	956	4 618	1 402	6 521
India	91 541	0 163	75 732	0 134	108 939	0 189	105 986	0 168	114 712	0 175	156 447	0 230	203 871	0 300
Indonesia	18 384	0 284	15 696	0 238	6 919	0 124	3 316	0 056	20 902	0 331	41 791	0 678	26 160	0 388
Iran, Islamic Rep of	72 018	0 915	7 222	0 071	18 838	0 179	19 460	0 159	25 362	0 200	8 043	0 070	27 726	0 241
Korea, Dem People's Rep	17 807	0 528	18 068	0 544	15 531	0 466	21 922	0 612	29 284	0 815	27 350	0 718	29 331	0 766
Malaysia	73 211	14 366	32 008	6 973	77 227	15 384	51 018	9 127	56 057	11 487	59 435	12 893	63 328	13 590
Pakistan	3 678	0 088	8 344	0 187	2 160	0 048	1 205	0 027	2 330	0 051	6 401	0 126	13 261	0 267
Philippines	5 316	0 120	6 547	0 133	7 947	0 178	13 211	0 287	12 506	0 265	10 873	0 226	10 232	0 208
Sri Lanka	6 691	1 067	7 075	1 180	8 844	1 458	10 798	1 829	8 337	1 269	9 080	1 445	9 141	1 506
Tailand	296 316	10 058	289 283	10 100	291 649	10 509	305 748	10 737	268 841	9 280	260 446	8 972	305 640	10 544
Tet Nam	1 259	0 027	3 540	0 075	836	0 015	1 320	0 023	5 934	0 094	5 000	0 077	1 700	0 024
Bangladesh	3 200	0 215	3 500	0 232	3 565	0 229	12 103	0 770	6 489	0 364	9 489	0 527	11 489	0 640
Jepal	187	0 015	19	0 001	19	0 000	309	0 022	363	0 027	660	0 044	636	0 038
Bhutan	253	2 456	483	4 689	1 766	17 146	1 079	10 476	1 079	10 476	1 079	10 476	1 079	10 476

Source : FAOSTAT Database

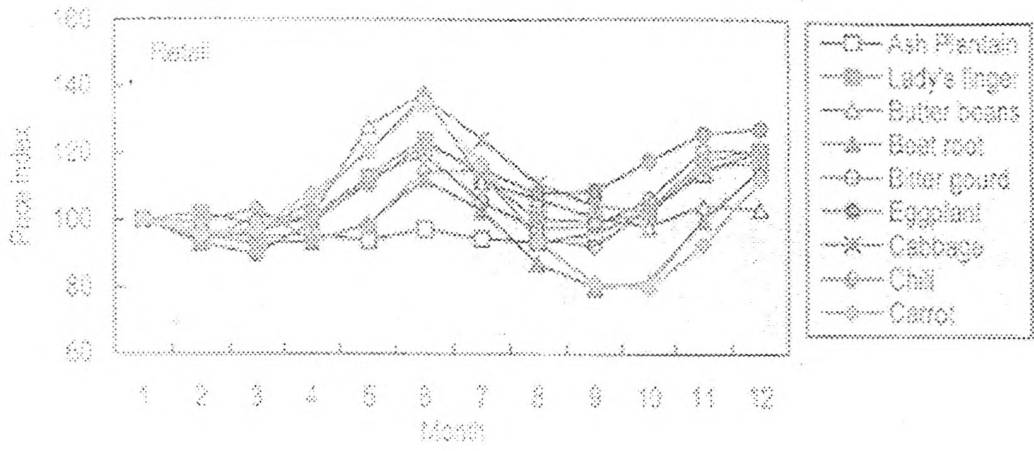


Figure 1: Seasonal indices of retail prices of vegetable

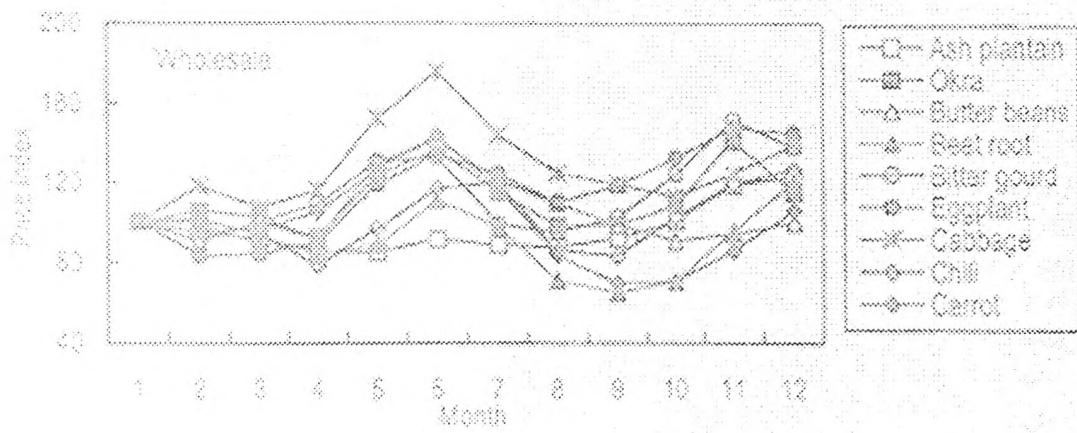


Figure 2 : Seasonal indices of wholesale prices of vegetables

Nutritive Value of Vegetables

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Vegetables may be classified as edible parts of plants, such as, leaves, stalks, flowers and roots and in some instances fruits too. Vegetables are generally eaten with the principal part of the meal, as opposed to fruits, which are eaten as desert.

Principal source of fresh vegetables is the home garden produce. Other types of vegetables are purchased from markets close to home or distant places, on a daily or weekly basis. The latter is a typical village oriented sales center, where village grown produce is sold.

Vegetables add colour, texture, flavor and aroma to meals and contain 70 to 95% of moisture. The latter makes long-term storage difficult and requires cold storage or processing for preservation.

Fiber and anti-oxidants are two outstanding dietary constituents that are added to the diet by vegetables and fruits, in addition to minerals and vitamins that they contribute. The anti-oxidants constitute vitamins C & E, carotene, Se, tannin etc. The former constituents are now in great demand to counteract the ill effects of 'fad food', poor life style and polluted environment. Therefore vegetables have a special role to play in the diet of 'modern society'.

Leafy Vegetables

Some are fleshy and juicy, whilst others are fibrous and leathery. The juicy ones include spinach (nivithi), *Centella asiatica* (gotukola), amaranth (thampala), *Ipomia aquatica* (kankun) etc. The fibrous ones include drumstick leaves (murunga), *Alternanthera* (mukunuwenna), manihot leaves (manioc), *Sesbania grandiflora* (kathurumurunga) etc.

The dark green leaves are generally rich in iron, calcium, carotene, B-vitamins and vitamin C, whilst those of lighter shade are relatively poor. Fibrous leaves being coarse may cause diarrhoea if eaten excess. In the old, it may lead to flatulence due to undigestible polysaccharides.

They contain anti-nutrients, such as phytate, oxalate and phosphate that make micro-minerals unavailable. Further, labile nutrients, such as, vitamin C and folate may be lost during food preparation, cooking and storage. Using the correct procedures the losses could be minimized.

Nutritive values given in this paper are for 100g of edible portion.

Leaves are poor in energy and range from 15 to 93 kcal per 100g. The protein content varies from 1.3 to 8.4%, with drumstick, manioc and kathurumurunga registering more than 5%. Therefore they could contribute some protein to a cereal diet, and in fact balance the lysine deficiency that is seen among cereals.

The calcium content varies from 25 to 1130 mg per 100 g, with kathurumurunga registering the highest and mukunuwenna registering the next highest at 510 mg.

The iron content ranges from 1 to 68.8 mg, with thampala, thora, wattakka and passion fruit leaves each having 25 mg and gotukola having 68.8 mg.

Except for a few, most leaves are rich in carotene, ranging from 1500 to 5400 ug, with mukunuwenna, thampala, beetroot, manioc, spinach and kathurumurunga all registering higher than 5000 ug. Vitamin C content ranges from 10 to 220 mg, with drumstick leaves having the highest and cabbage and kathurumurunga leaves, each having over 120 mg.

Stalk Vegetables

These include celery, onion, leeks, asparagus etc. Their main function is to add flavor and aroma to food. They contribute 20 to 40 kcal energy, 1 to 2 % protein, 10 to 50 mg vitamin C and valuable fiber to the diet.

Flowers

They include cauliflower, plantain flower, kathurumurunga flower etc. They add variety and flavor to the diet. Their nutritional contribution is similar to that of stalk vegetables.

Root Vegetables

These are eaten as vegetables with the staple diet. They include carrot, beetroot, knolkhol, radish, turnip etc. These contain less than 10% carbohydrate and don't contribute much towards energy of the diet. They add flavor and variety to the diet. They also add soluble fiber. Carrot is a rich source of carotene.

Fruit Vegetables

They include beans, tomato, eggplant, okra, chili, pumpkin, gourd etc. Tomato is a rich source of B vitamins, whilst yellow pumpkin is a rich source of carotene. They add lot of soluble fiber, especially pectin, which is well known for its blood cholesterol and glucose lowering activity. In addition, bitter gourd well recognized for its anti-diabetic effect is in big demand, especially by the diabetics.

Nutritive Values of Vegetables

Leafy Vegetables

Name of foodstuff	Moisture (g)	Energy (kcal)	Protein (g)	Fats (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)	Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vit. C (mg)
Dark green vegetables		28	2.1	0.2		166	2.9	3.6	0.09	0.19	0.8	21
Light green vegetables		25	2.1	0.2		56	1.1	0.546	0.06	0.80	0.4	27
Agathi	73.1	93	8.4	1.4	11.8	1130	3.9	5.4	0.21	0.09	1.2	169
Amaranth tender	85.7	45	4.0	0.5	6.1	397	25.5	5.5	0.03	0.3	1.2	99
Beet, greens	86.4	46	3.4	0.8	6.5	380	16.2	5.8	0.26	0.56	3.3	70
Cabbage	91.9	27	1.8	0.1	4.6	39	0.8	1.2	0.06	0.09	0.4	124
Carrot, leaves	76.6	77	5.1	0.5	13.1	340	8.8	5.7	0.04	0.37	2.1	79
Chilies, leaves	82.1	53	5.8	1.0	8.5	246	1.4	6.21	0.4	0.33	1.9	68
Colocasia, black	78.8	77	6.8	2.0	8.1	460	38.7	12	0.06	0.45	1.9	63
Colocasia, green	82.7	56	3.9	1.5	6.8	227	10	10.27	0.22	0.26	1.1	12
Curry leaves	63.8	108	6.1	1.0	18.7	830	7.0	7.56	0.08	0.21	2.3	4
Drumstick leaves	75.9	92	6.7	1.7	12.5	440	7.0	6.78	0.06	0.05	0.8	220
Gotukola	84.5	37	2.10.5	6.0	224	68.8	-	-	-	-	-	-
Kankun	90.3	28	2.9	0.4	3.1	110	3.9	1.98	0.05	0.13	0.6	137
Kola Gova, rape leaves	84.9	48	5.1	0.4	5.9	370	12.5	1.38	0.01	0.03	0.9	65
Leek	85	52	2	0	11	50	1	0.015	0.1	0.1	0.5	20
Lettuce	93.4	21	2.1	0.3	2.5	50	2.4	0.99	0.09	0.13	0.5	10
Manioc leaves	91	28	2	0.3	4	80	2.5	0.3	0.01	0.2	0.5	50
Mint	84.9	48	4.8	0.6	5.8	200	15.6	1.62	0.05	0.26	1	27
Mukunuwenna	77.4	73	5	0.7	11.6	510	16.7	1.926	0	0.14	1.2	17
Mustard leaves	89.8	34	4.0	0.6	3.2	155	16.3	2.622	0.03	-	-	33
Onion leaves	87.6	41	0.9	0.2	8.9	50	7.5	0.595	0	0.03	0.3	17
Penela	83.3	61	4.7	4.6	9.1	-	-	-	-	-	-	-
Pumpkin leaves	81.9	57	4.6	0.8	7.9	392	-	-	-	-	-	-
Sarana	91.3	24	2.0	0.4	3.2	100	38.5	-	-	-	-	70
Spinach	92.9	26	2	0.7	2.9	78	10.9	5.58	0.03	0.26	0.5	28
Sweet potato greens	80.7	63	4.2	0.8	9.7	360	10	0.75	0.07	0.24	1.7	27
Radish leaves	89.1	38	3.9	0.6	4.2	310	18.0	5.72	0.58	0.35	5.5	106
Tampala	90	26	3	0.7	2	200	-	-	-	-	-	-
Turnip greens	81.9	67	4	1.5	9.4	710	20.4	9.396	0.31	0.57	5.4	180

Fruits vegetables

Name of foodstuff	Moisture (g)	Energy (kcal)	Protein (g)	Fats (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)	Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vit. C (mg)
Ash gourd	96.5	10	0.4	0.1	1.9	30	30.8	0	0.06	0.01	0.4	1
Bitter gourd	92.5	25	1.6	0.2	4.2	20	1.8	0.126	0.07	0.09	0.5	88
Brinjal	92.7	24	1.4	0.3	4	18	0.9	0.074	0.04	0.11	0.9	12
Chilly, green	85.7	29	2.9	0.6	3	30	1.2	0.17	0.19	0.39	0.9	111
Cucumber	96.3	13	0.4	0.1	2.5	10	1.5	0	0.03	0	0.2	7
Drumstick	86.9	26	2.5	0.1	3.7	30	5.3	0.11	0.05	70	0.2	120
Elabatu	75.5	39	3.1	0.8	4.8	100	1.2	-	-	-	-	-
Ladies fingers	89.6	35	1.9	0.2	6.4	65	1.5	52	0.07	0.1	0.6	13
Mango green	87.5	44	0.7	0.1	10.1	10	19	5.4	0.09	0.04	0.2	3
Papaya green	92	27	0.7	0.2	5.7	28	0.9	0	0.01	0.01	0.1	12
Plantain green	83.2	64	1.4	0.2	14	10	0.6	0.03	0.05	0.02	0.3	24
Pumpkin	92.6	25	1.4	0.1	4.6	10	0.7	0.05	0.06	0.04	0.5	2
Snake gourd	94.6	18	0.5	0.3	3.3	26	0.3	0.096	0.04	0.06	0.3	0
Tomato green	93.1	23	1.9	0.1	3.6	20	1.8	0.192	0.07	0.01	0.4	31
Tomato ripe	94	20	0.9	0.2	3.6	48	0.4	0.351	0.12	0.06	0.4	27

Stem vegetables

Name of foodstuff	Moisture (g)	Energy (kcal)	Protein (g)	Fats (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)	Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vit. C (mg)
Colocasia (Kohila)	94	18	0.3	0.3	3.6	60	0.5	0.104	0.07	0.07	0.1	3
Lotus stem (dry)	9.5	234	4.1	1.3	51.4	405	60.6	0	0.82	1.21	1.9	3
Rhubarb stem	92.7	26	1.1	0.5	4.3	120	2.2	-	-	-	-	37

Flower vegetables

Name of foodstuff	Moisture (g)	Energy (kcal)	Protein (g)	Fats (g)	Carbohydrates (g)	Calcium (mg)	Iron (mg)	Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vit. C (mg)
Agathi	92.9	26	1	0.5	4.4	9	-	-	-	-	-	-
Cauliflower	90.8	30	2.6	0.4	4	33	1.5	0.03	0.04	0.1	1	56
Plantain	89.9	34	1.7	0.7	5.1	32	1.6	0.027	0.05	0.02	0.4	16

Medicinal values of Vegetables

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Ayurveda, describes a balanced diet consisting of the following Varga (categories)

- | | |
|------------------|---------------------------|
| 1. Dhanya varga | - Seeds. |
| 2. Kanda varga | - Tubers |
| 3. Shaka varga | - Vegetables |
| 4. Mamsa varga | - Fish, meat etc., |
| 5. Phala varga | - Fruits and |
| 6. Ksheera varga | - Milk and milk products. |

A person who intends to lead a healthy life should take a balanced diet and Shaka varga (vegetables) is one of the most important components. The vegetables should suit your age, your body constitution (prakriti) and they should be fresh. If a person is suffering from a disease, the vegetables taken should agree with his disease condition. Ayurveda describes two types of food according to their effect ie Sheeta food (gives a cooling effect) and Ushna food (gives a heaty effect). For example a person suffering with a cold, cough or asthma are advised to avoid food that has a cooling effect, such as Nelumala², Labu⁴⁰, Nivithi¹⁴ etc. A person suffering with a skin rash (Eczema) should avoid food having a heaty effect such as Del⁴⁷, Murunga⁴² etc. Food are also classified in to 2 categories according to digestion ie. Lagu (food that are digested easily) and Guru (food that are not digested easily).

The Vegetables that we ingest daily not only give nourishment to the body, but they also possess medicinal values and certain vegetables such as Pathola²⁶ and Vetakolu²² are found to contain immune enhancing properties too.

The following description gives the medicinal values of the common vegetables and related items according to Ayurveda, and traditional medicine, in Sri Lanka.

01. Innala - Coleus rotundifolius
This is cooked with rice and is given for haemorrhoids. It is anthelmintic . This is given as a food during fractures.
02. Nelum ala - Nelumbo nucifera
The rhizome is cooling, reduces Pitta, increases breast milk and appetite, reduces cough, thirst and burning sensation in the body.

03. Garlic - Ushna, suitable for the heart and hair ; increases the appetite, suitable for patients with Asthma, Peenasa (sinusitis), skin diseases and worm infestations.
04. Onion - Allium cepa L.
It is effective for pain , peenasa (sinusitis), cough, asthma, bronchitis, whooping cough, tuberculosis, increases appetite, digestion, effective in hemorrhoids (for bleeding from nose/rectum) stimulates liver, it is diuretic, it increases semen, is an aphrodisiac and germicide.
05. Kohila - Lassia spinosa
The rhizome & the leaves are taken as food. Effective for Piles, liver diseases, constipation. bleeding, increases appetite and body weight. The rhizome & leaves are used to prepare kunji.
06. Kekatiya - Sheeta (Cooling), increases breast milk and reduces blood disorders.
07. Flowers of Diyahabarala - Reduces burning sensation in urine & increases appetite.
08. Carrot - Ushna , increases appetite, suitable as a curry , salad and drink.
09. Potato - Cooling , suitable for constipation, increases body strength and breast milk.
10. Manioc - Manihot esculenta
The rhizome is anthelmintic ; the leaves (mallum) reduces poison & worms, specially for thread worms. It contains starch, calcium and iron.
11. Gahala - Colocasia esculenta L.
The varieties are Desha ala, Kiriala, Habarala, Val habarala and Kalu habarala. The corm is a laxative and diuretic.
12. Kidaram - Amrophophallus campanulatus
The rhizome is eaten after boiling. It increases appetite, effective in abdominal distension, liver and spleen diseases, worms, non bleeding piles. Not suitable in skin diseases.
13. Flowers of Thanpala - Nothosaerva brachiata L.
Increases appetite and body weight, reduces kapha & pitta , purifies blood reduces bleeding eg. in haemorrhoids.

14. Nivithi - *Basella alba* L.
Cooling, increases Kapha and elevates Pitta and Vata, increases sleep, semen, strength and body weight, unsuitable for throat, gives a good sleep, reduces burning sensation, bleeding and anorexia, cardiac and diuretic.
15. Kura - *Amaranthus viridis* L.
Light, suitable for blood disorders and poisoning, increases stools and urine.
16. Kankun - *Ipomoea aquatica*
It increases breast milk and semen. It purifies breast milk too. Effective for blood poisoning, worms and haemorrhoids & gives a good motion.
17. Genda - *Portulaca olercea*
It elevates Pitta & Kapha. Stimulates liver, increases appetite, digestion, reduces constipation, haemorrhoids, bleeding, oedema, dysuria, oedema due to kidney disease, cystitis and haematuria. Used as a curry in fever.
18. Embul embiliya - *Oxalis corniculata* L.
Increases appetite & digestive power and is suitable for irritable bowels.
The small variety (whole plant) acts in the liver, increases blood. Effective in indigestion, diarrhoea, mal absorption & haemorrhoids. This cooked with meat increases the appetite and reduces constipation.
19. Leaves of Rabu - *Raphanus sativus* L.
Light & increases appetite.
20. Getathumba - *Leucas zeylanica* L.
It elevates Kapha & Vata, wormicidal, reduces poison, increases the appetite, purgative, purifies blood, reduces swelling and fever, common cold, headache, jaundice, abdominal distension, mal absorption, chronic diarrhoeas, cough, asthma, dysmenorrhoea, skin diseases and snake bite poisoning. It increases the menstrual flow.
21. Mukunuvenna - *Alternanthera sessilis*
Suitable in eye diseases, improves vision, suitable for burning sensation & for skin rashes and mental diseases. Can be given to asthma patients.
22. Vetakolu - *Luffa acutangula* Roxb
Cooling, increases appetite, effective in fever, cough and asthma & worms.
23. Bandakka - *Hibiscus esculentus* L.
Increases appetite, cooling, digested after some time and is a diuretic. Increases sex ability, and body strength, not suitable in kidney diseases, contains proteins, calcium, phosphorous & ammonia.

24. Bilin - Averrhoa bilimbi L.
Increases appetite digestion & suitable for hemorrhoids, fever, scurvy and is a laxative. The fruits are cooked after squeezing (and removing the juice). The fruits are cut, put in hot water, dried with salt.
25. Undupiyaliya - Desmodium triflorum
The whole plant & juice are used as medicine, Grind with Iriveriya, add lime juice & bees honey and give for diarrhoea ; for abdominal distension the powder is used as tea; useful for thirst during diabetes. In angular stomatitis this is chewed as bites and the juice is swallowed.
26. Pathola - Trichosanthes angunina L.
It is Ushna; elevates all 3 doshes. It increases the appetite and digestion, is a laxative; the seeds are anthelmintic, purifies blood, suitable in skin diseases fever, eye diseases, burning sensation in the body and poison.
27. Pipinna - Cucumis sativus L.
There are 2 varieties the large & small. Effective for thirst, constipation, is a diuretic, the seeds too are diuretic, cooling, effective for diseases caused by pitta & blood.
The fruits are used as a salad or in preparing a curry, suitable as a food for children's diarrhoea.
28. Leaves of Thora - Cassia thora
Heavy in digestion; suitable for constipation.
The mullum gives a good motion. Effective for cough, skin rashes, vata & kapha, poison, liver diseases, purifies blood, increases ojas, worms, can be given to patients with asthma.
29. Penithora - Cassia occidentalis L.
Can be given to patients with urinary disorders and diabetes.
30. Ratathora - Cassia alata L.(Cajanus)
The leaves increase vata, effective for skin diseases, poison and haemorrhoids
The leaf kunji is effective for jaundice
The seeds reduce kapha & pitta and the urine output effective for oedema, poison, diseases of blood, piles, worms, cooling, gives skin colour, produce, constipation and abdominal distension; if taken with ghee reduces Vata. The soup increases body strength.
31. Eththora - Cassia alata
The leaf mullum is prepared along with other leaves. It is cardiac, purifies blood, effective for skin diseases, reduces vata & kapha, itching, cough and asthma. If taken in excess causes purgation and abdominal pain. The leaf mullum prepared with ghee is effective for thread worm infestation.

32. Gotukola - *Centella asiatica*
There are 2 varieties the larger one and the smaller one. It increases the brain capacity, sex power, (sheeta) cooling, rasayana (rejuvenating), suitable in sinusitis, cough and asthma.
33. Katurumurunga leaves- *Sesbania grandiflora*
It alleviates pitta & kapha. The leaves increase body strength, appetite, vision, reduce constipation, effective for sinusitis, angular stomatitis, jaundice, dry cough, increases brain power and is anthelmintic. The leaves are cooling effective in vaginal discharges, nocturnal emissions, burning sensation in the body and bleeding.
34. Katurumurunga flowers -
Cooling, effective for night blindness, sinusitis, reduces pitta & kapha & Vata and increases appetite.
35. Kesel - *Musa sapientum L*
Reduces constipation. The ash plantain is cooling, effective in bleeding diseases, burning sensation, diabetes, increases semen and ova, body strength and body weight. The flower is cooked and used in haemorrhoids and malabsorption.
36. Sarana - *Boerhavia diffusa L.*
Increases blood and gives a good motion.
37. Lunuvila - *Bacopa monnieri L.*
Cooling, Rasayana, increases voice, blood and mental capacity.
Gives strength to brain, nerves, reduces fits, mental disorders and fever, increases appetite digestion, laxative, purifies blood, produces sweat, effective for skin rashes and itching, kills poison, gives strength to the body and rejuvenating.
38. Jak - *Artocarpus heterophyllus lam.*
Increases strength and fat, heavy in digestion, causes constipation.
This is eaten instead of rice, contains starch. The raw fruits are cooling & hence increases kapha & increases semen, strength & body weight.
In seeds the starch content is high, It is an aphrodisiac and increases production of urine.
39. Diyalabu - *Lagenaria siceraria*
Cooling, reduces constipation.
Reduces pitta, increases Vata, growth of foetus, semen, body tissues, body strength, appetite. Sedates brain & gives a good sleep, cardiac, diuretic, can be given during bleeding in T.B & in chronic fever, if taken in excess increases kapha, reduces thirst, gastritis, bleeding and fever.

40. Kekiri - Cucumis melo
The fruits are cooling and increase appetite.
The ripe fruits reduce thirst and constipation, diuretic, effective for urinary calculi, exhaustion and burning sensation.
41. Murunga - Moringa oleifera
The flowers of Murunga is hot, wormicidal, reduces vata & kapha
The leaves are used while cooking crabs/ prawns to reduce heaty effect. The fingers are rich in protein, calcium, iron, and phosphorus.
42. Elabatu - Solanum melongena L
Suitable for the heart and conditions with increased phlegm.
The fruits alleviates the 3 doshas. Helps in digestion and increases appetite, useful as a food during cough, asthma and sore-throat . The seeds stimulates the heart. The Kola kenda made out of leaves is effective in cough and asthma. Fruits are diuretic.
43. Thibbatu - Solanum indicum Linn.
Reduces Pitta, anorexia & eye diseases.
44. Brinjals - Solanum melongena L.(Vambatu)
Ushna (heaty), Decreases vata & kapha and fever. Increases appetite, body weight & semen.
45. Kekatiya - Apanogeton crispus
Cooling, diuretic and useful in bleeding diseases.
Flowers of Kekatiya - Cooling, reduces vata & pitta, increases bone marrow and semen and clears urine.
46. Del - Artocarpus incisus
Causes blood disorders, constipation and eye diseases.
Nutritious, vitiate 3 doshas & semen , heaty & hence not suitable in skin diseases.
47. Coconut - Increases body weight, strength and is heavy in digestion.
48. Thumba - Momordica dioica Roxb
Purifies blood ,Increases appetite, light in digestion.
Reduces all 3 doshas.
Effective for pain, skin & urinary diseases, fever, bleeding, loss of appetite, worms, cough, asthma, hiccup, T.B. and increases body weight.
49. Yellow pumpkin (Vattakka) -
Increases body weight & tissues and strength; diuretic, reduces vata & pitta and is sheetha (cooling).

50. Thiyambara - Increases appetite, vata & kapha, Diuretic effective for dysuria & urinary calculi.
51. Karavila - Momordica charantia
Increases appetite, digestion, uhsna, reduces vata , pitta & kapha, oedema, effective for diseases of blood, fever, worms,skin rashes, urinary disorders, asthma,abdominal distension , anaemia ,ulcers, haemorrhoids and diabetes mellitus. It is a diuretic.
52. Tomato - Increases appetite & pitta and bleeding , reduces vata & kapha.
53. Karamkoku - Acrostichum aureus L.
Cooling, effective in bleeding piles, gastritis, gastric ulcer, poisoning, burning sensation in abdomen and bleeding diseases.
54. Puhul - Benincasa hispida (Thunb)
Effective for dysuria, renal calculi, thirst, bleeding, increases body weight & body tissues and kills poison.
55. Alupuhul - Benincasa hispida
The fruit eleviates pitta and increase kapha,diuretic,effective for bleeding and burning sensation in the body. The fruit juice reduces poison in stomach & poisoning, suitable for patients with T.B ,increases body strength and weight. The fruit increases the mental capacity and reduces anaemia, the seeds are anthelmintic.
56. Anguna - Wattakaka volubilis
There are 2 varieties 1) Tiththa anguna and 2) Kirianguna.
The first purifies blood and eleviates pitta. Hence it is given to mothers during lactation in order to purify the breast milk, Kirianguna increases breast milk, reduces constipation during pregnancy and kills poison.
57. Attikka - Ficus racemosa L.
The syrup made out of the fruits increases body weight and mental capacity. It is effective in cough and asthma.
58. Kurinnan - Gymnema lectiterum L.
The leaves are given in cancer and haemorrhoids to increase the appetite. Used as mullum and salad.
59. Rabu - Raphanus sativus L.
Heaty, Increases appetite, digestion, reduces vata, enlargement of spleen, urinary calculi & liver diseases and jaundice), effective for haemorrhoids, heart disease, asthma, cough,eye diseases,sinusitis and cleans urine .

The dried rhizome is light in digestion reduces all 3 doshas, poison, effective for oedema, TB, bleeding, cough, urinary disorders, urticaria, oedema, anaemia, skin rashes & gastritis.

The leaves increase kapha & pitta and digestion but if fried with oil it elevates all 3 doshas.

60. Dambala - Phaseolus lunatus L.
Rich in proteins (in seeds 29-37% & in leaves 5-7% and gives body strength.

Vegetable Farming Systems in Sri Lanka

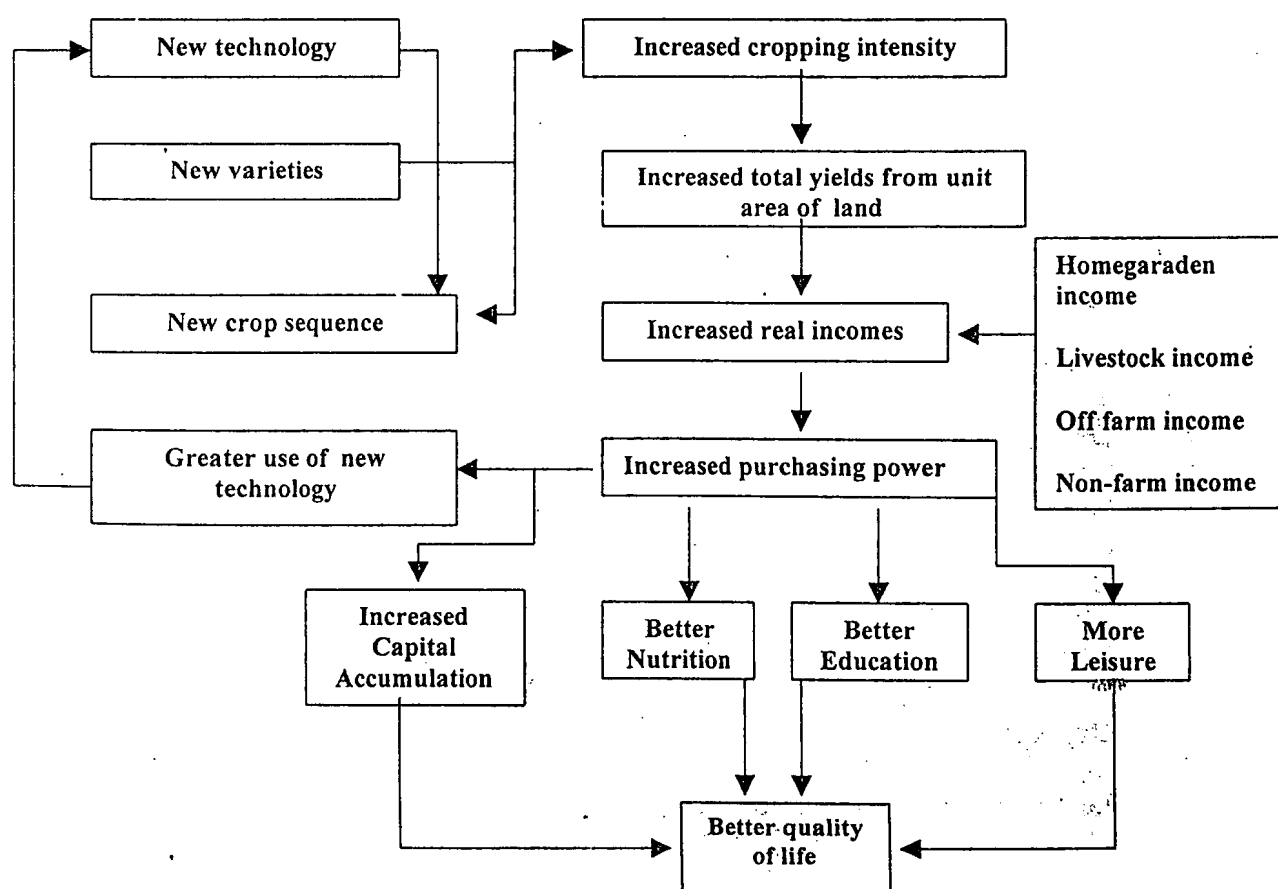
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Farming Systems Definition and Approach

Farming system is a set of components interacting with each other with a view to achieve increased resource productivity, enhanced agricultural production and farmer income leading to higher standards of living. An important aspect in this approach is that attention is focussed not only to improve the income generated through farm land but also towards all the components the his farm, namely household crop land (low land, high land etc.), home-garden, livestock, off-farm as well as non farm activities (Figure 1). Therefore, farming systems practiced in different countries and regions vary from one to another depending on the agro-climatic conditions, resource availability and socio-economic considerations of the farm-household systems.

Figure 1 - Farming Systems Approach



Source : Ranaweera, 1988

Vegetable Farming Systems in Sri Lanka

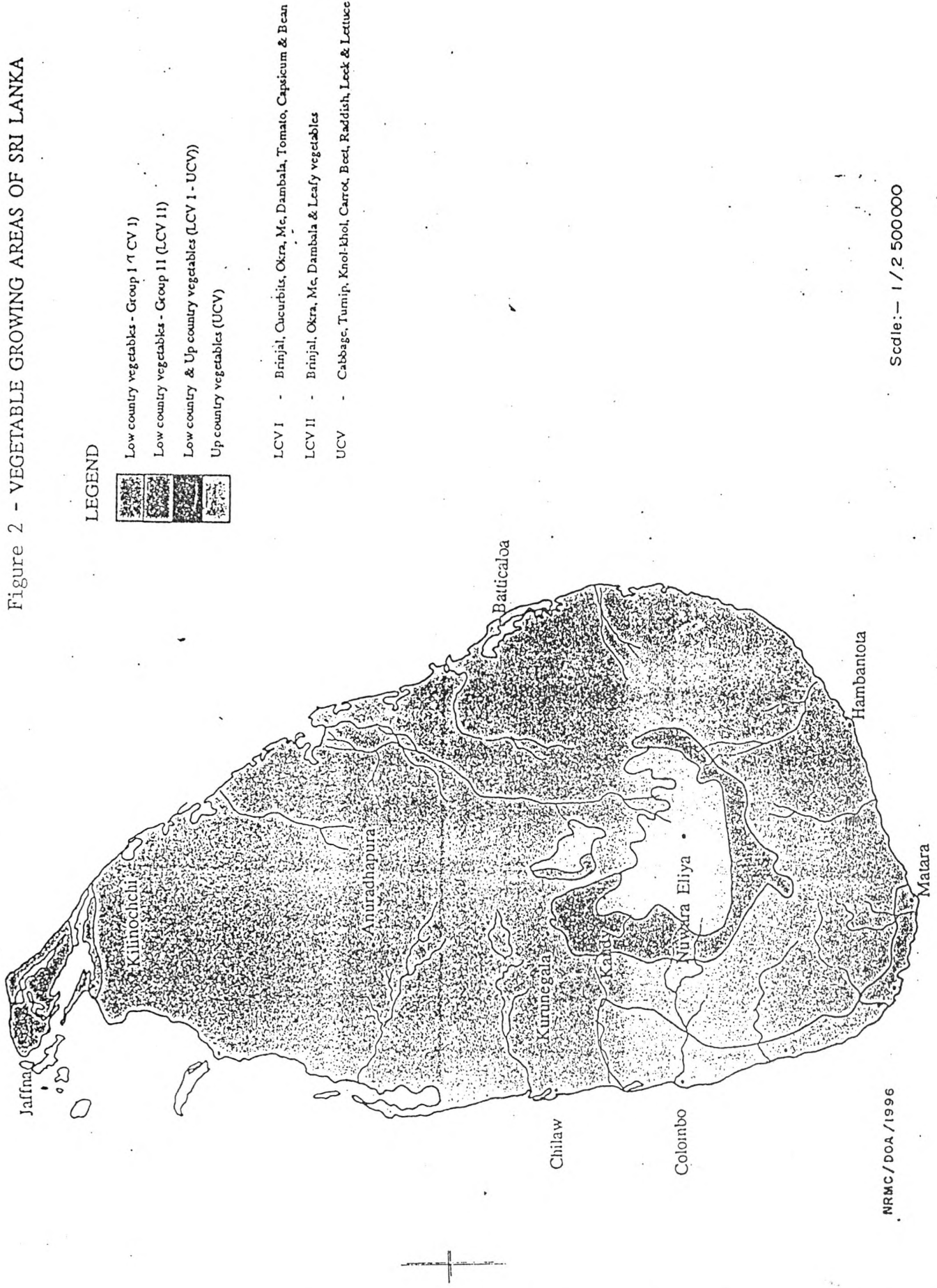
The rainfall pattern of Sri Lanka represents a bimodal distribution leading to two distinct cultivation seasons in most parts of the country. The major cultivation season identified as Maha (wet season) and extends from September to January. The rainfall during this season flows mainly from convention, depressions and North-East monsoon. The minor season Yala (dry season) begins from March, extends up to August and receive rainfall through conventional rains followed by South-West monsoon.

On the basis of rainfall regime, the country is divided in to three climatic zones namely wet, dry and intermediate zones. These three climatic zones in turn are classified into seven agro-ecological zones based on the altitude, temperature and landform (Table 1). The seven zones are further sub-divided into 24 well-defined agro-ecological regions based on soil type, elevation, land from, temperature and rainfall pattern. The wide variation in agro-ecological conditions favours the cultivation of temperate and tropical vegetables in the country.

Table 1. Environmental Parameters of Major Agro-Ecological Zones in Sri Lanka

Zone/region	Elevation (m)	Temperature (c ^o)	Mean rainfall (mm)
Wet zone			
Up-country	1000-2400	10-15	2500-5000
Mid country	500-1000	15-20	2000-3000
Low-country	0-500	20-25	2000-3000
Intermediate zone			
Up-country	1000-1500	15-22	1500-2250
Mid country	350-500	24-26	1500-2250
Low-country	0-350	25-29	2000-2200
Dry Zone			
Low-country	0-300	28-30	900-1000

Figure 2 - VEGETABLE GROWING AREAS OF SRI LANKA



Although vegetables are grown within almost all agro-ecological regions of the country, there are four distinct vegetable producing regions identified in Sri Lanka (Figure 2). The traditional indigenous types of vegetables are categorized as tropical type, popularly known as "low-country" vegetable is cultivated generally in lowland and midland peneplains. The vegetable introduced from other countries are known as "exotic" vegetables or "up-country" vegetables and they are usually cultivated in the cooler climates of the up-country peneplains.

The production data indicates a considerable gap between the potential research yields of vegetables and actual yields obtained by farmers (Table 2). This shows that farmer's resources are not being utilized efficiently under the existing cropping patterns and farming systems adapted by farmers.

Table 2. Average Farmer Yield & Potential yields of Major Vegetables Grown in Sri Lanka - 2001/2002

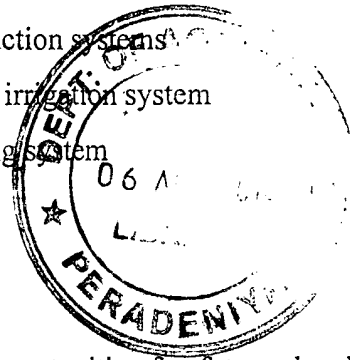
Crop	Extent (ha)		Production (mt)		Farmer's Yield (mt/ha)		Potential Yield (mt/ha)	
	Maha	Yala	Maha	Yala	Maha	Yala	Maha	Yala
<i>Low-Country Vegetables</i>								
Brinjal	5999	3640	42879	25109	7.15	6.90	20.0	18.0
Okra	3860	2775	21733	14261	5.63	5.14	9.0	11.0
Snake gourd	1525	1140	10327	7402	6.77	6.49	16.0	14.0
Red Pumpkin	4402	2222	40198	19466	9.13	8.76	20.0	20.0
Cucumber	1459	941	11322	7312	7.76	7.77	16.0	18.0
<i>Up-Country Vegetables</i>								
Bean	3482	3087	17620	15281	5.06	4.95	20.0	18.0
Tomato	2708	2396	19146	19955	7.07	8.33	24.0	33.0
Capsicum	1458	1240	5968	5280	4.09	4.26	6.5	15.0
Beetroot	907	892	8612	8045	9.50	9.02	13.0	17.0
Cabbage	1945	1770	29372	22090	15.10	11.81	40.0	20.0
Carrot	1299	1335	13402	15954	10.32	11.95	30.0	25.0
Leeks	840	775	12256	11180	14.59	14.43	23.0	19.0
Raddish	1359	1241	13160	10964	9.68	8.83	17.0	15.0

Source : Department of Census & Statistics

The cropping patterns vary from mono cropping to different degree of multiple cropping, mixed cropping, inter-cropping, crop rotations and ratoon cropping.

The major vegetables farming systems practiced by the Sri Lankan farmers are indicated below:

- ✓ 1. Bush-fallow system of shifting cultivation (Chena)
2. Rain-fed highland farming system
3. Rice based farming systems
- ✓ 4. Potato based farming systems
5. Home gardens
6. Kandyan Forest gardens
7. Peri-urban leafy vegetable production systems
8. Commercial farming with micro irrigation system
9. Crop-livestock integrated farming system
11. Organic farming
12. Protected Agriculture



The advantages, limitations and anticipated opportunities for future development of the aforesaid farming systems are discussed in this paper on consideration of the relevant physical, biological economic and social determinates.

Bush-Fallow System of Shifting Cultivation (Chena)

This is the most ancient and traditional system practiced in dry zone high lands mainly during maha season. The clearing of land begins usually during the dry months in July and August. Once the bushes are being cut down and firewood is extracted, all weeds and other vegetation's are spread and burnt with the intention of incorporating ash in to the soil. The land clearing process is generally done manually by both men and women and the operations extend up to September to October when seeds are sown. The size of land holding varies from 0.5 to 2 hectares depending on the availability of state land and family labour. Most of the low country vegetables (chilli, brinjal, cucumber, pumpkin, okra, cowpea etc.) are cultivated as mono crop or mixed crop under this system. Fallow period is observed to be generally about one to two years.

to mixed cropping. Relatively large holding size and poor technology adoption are the main characteristics of the vegetable production in the dry zone lowland peneplain. The application of fertilizer and the use of improved cultivars are not widespread. The exception, however, is mainly the northern-most part of the country where adoption of new technologies in vegetable cultivation is comparatively advanced.

In the mid-and up-country regions, terraced paddy fields located around 1500 m asl are cultivated with a mixture of both up-country and low-country vegetables during the Yala season. The crops include potato, beans, tomato, beet-root and cabbage. Vegetables cannot be cultivated in paddy fields during the Maha season without a proper drainage system due to stagnant water. Paddy-tomato cropping system is popular in Matale and Kandy districts. Paddy-potato-vegetable cropping system is common in Badulla district, which is one of the major vegetables producing districts in the country. Studies indicate that higher profits are being obtained by farmers through potato and vegetable cultivation in these districts (Table 3).

Table 3. Costs and Returns of Vegetable Cultivation in Badulla and Matale Districts -Yala 2001

District	Crop	Total Cost of Cultivation (Rs/ha)	Net Returns (Rs/ha)	Average Yield (Kg/ha)	Labour Requirement (Man days/ha)
Matale	Tomato	67870.22	20994.85	9765	246
Badulla	Potato	270772.16	252129.37	13425	317
Badulla	Pole Bean	113313.56	54541.20	7811	333

Source : Socio Economics & Planning Centre, Department of Agriculture.

Potato Based Farming Systems

Potato is cultivated in the cool highlands of Nuwara Eliya and Badulla districts where the climate is favorable for vegetable cultivation throughout the year. Potato-potato-vegetable system and Potato-vegetable -vegetable system are the cropping systems that have gained

popularity among farmers in these areas. Up-country vegetables such as beans, carrot, leeks, cabbage, beetroot, knolkhol and raddish are grown as monocrop and mixed crop. The average holding size is small ranging 0.2 to 1 hectares and cultivation is undertaken continuously with intensive labour, application of organic and chemical fertilizers, and high levels of agro-chemicals. The cropping intensity and the level of technology adoption is high, more often with overuse of inputs. Vegetable cultivation is highly commercialized and vegetable growers are competent in marketing of inputs and their farm produce. The extent cultivated under potato and vegetables vary depending on price structure, availability of seeds and the degree of state protection to potato cultivation. Excessive use of agro-chemicals and degradation of soils are the major issues concerned with this farming system.

Home Gardens

Another common and traditional form of vegetable production is the home garden. Most home gardens, in both rural and urban areas, have at least a few popular vegetables, especially in areas where both monsoons prevail. Home gardens also have permanent vegetable trees, such as jack-fruit and breadfruit in the wet and intermediate zones and drumstick in the dry zone. Ash plantain and Kathurumurunga are also common in wet and intermediate zone home gardens. Many leafy vegetables grow wild in backyards. The production is mainly used for home consumption. Vegetable cultivation in home-gardens is the easiest way of obtaining the vegetable requirements of the family.

Kandyan Forest Gardens

These home gardens are more prominent in the wet zone regions of the country, where wide range of crops are grown in a mixed garden. Home garden are dominated by perennial trees, with multistoried canopy structure where coconut, arecanut, bread-fruit and forest trees dominate the upper layer as the canopy, fruit trees and spices at upper middle layer and vegetables as lower and ground layer. Low country vegetables and root and tubers are mainly grown as vegetables. Produce of these crops is mainly used for home consumption.

Peri-urban Leafy Vegetable Production Systems

The peri-urban leafy vegetable production system is a specialized form of market gardening near major cities (especially Colombo and Gampaha) which consists of very intensive cultivation of leafy vegetables to supply the needs of the urban and semi-urban populations. Both organic and inorganic fertilizers are used in large quantities. As green leaves are an important component of the Sri Lankan rice and curry-based diet, there is a year-round demand for these vegetables. The most popular leafy vegetables are gotukola (*Centella asiatica*), thampala (*Amaranthus sp.*), mukunuwenna (*Atternananthera Sessilis*), kangkong (*Ipomea aquatica*), sarana (*Trianthema decandra*) and kathurumurunga (*Sesbania grandiflora*).

Crop intensity is high and farmers annual profits ranges from Rs. 200,000 to 300,000 per hectare depending on the level of management. Studies indicate that area under leafy vegetables around Colombo is declining due to expansion of the city while expansion is reported from other districts. Excessive use of pesticides and agro-chemicals are the other issues concerned related to leafy vegetable production.

Agro-well based Farming Systems

In dry and intermediate zones water deficit is the main limiting factor for year-round production of vegetables. However, in northern region of the dry zone abundance of ground water in Miocene limestone aquifer has enabled year-round cultivation of vegetables by means of well irrigation as an intensive system. Cultivation of low-country vegetables such as chilli, brinjal and gourds are popular under agro-well system. Few farmers in the northern peninsula even cultivate up-country vegetables such as cabbage, carrot, beetroot and leeks successfully during the dry months of June to August with well water irrigation. Similarly, underlying fresh water of sand dunes (Gyben-Heizberg lens) in Puttalam area (Kalpitiya peninsula) is also widely used for vegetable cultivation, mainly for chilli and onion cultivation. Year-round cultivation of vegetable could be promoted under agro-wells in both dry and intermediate zones. However, precautions are

needed to avoid any environmental problems that could arise due to excessive use of ground water.

Commercial Farming with Micro Irrigation Systems

Modern irrigation methods such as sprinkler and drip systems are becoming popular in commercial vegetable production. There are many advantages of using these systems. It saves water and labour. More land could be cultivated using this saving. The crop yield increases and hence reduces unit cost of production. Crop grows consistently, healthier and mature fast hence faster, returns to investment. Fertilizer use efficiency increases up to 30 percent. Cost of fertilizer and cultural practices like weeding could be reduced. Land development costs could be reduced because it does need to leveling of land. There is no drudgery while operation is easy for workers and crop failures could be minimized.

There are some disadvantages also in operation of these systems. It needs high capital cost for installation. Operation of these systems requires technological knowledge and skilled labour. If water is of poor quality there may be blocks in the nozzles with calcium and algae deposits, which need clearing operations.

Year- round production of high quality vegetables can be produced through this system, for local and export markets. There are many government organizations now supporting in various ways such as technical advice and credit for micro irrigation systems in Sri Lanka.

Organic farming

Organic farming is becoming popular as there is increasing market opportunities in both domestic and export markets. Several non governmental organizations are promoting this programme in different parts of the country.

Addition of organic manure improve the soil fertility and increase the water use efficiency. However, the crop yields are low at years during the conversion period. The certification production of the organic production are costly and few exports are currently involved in of organic products from Sri Lanka.

certification procedures of the organic produce are costly and only few exports are currently involved in the marketing of organic products from Sri Lanka.

Crop-Livestock Integrated Farming Systems

Crop-Livestock farming system has the advantages of increasing the farm productivity and profitability of small-scale farmers, while sustaining the environment. This system is widely adapted by vegetable farmers in the wet and intermediate zones and in the northern regions of Sri Lanka. There is potential for expansion of this system in the country.

Protected Agriculture

Protected Agriculture or Controlled Environment Agriculture (CEA) for vegetable production has recently been attracting a great deal of interest from the farmers in Sri Lanka in recent years. Protected agriculture is the modification of the natural environment to achieve optimum plant growth with less use of land, labor water and other inputs such as agro-chemicals. The main forms of protected agriculture include the use of mulches row covers and polytunnels.

Polytunnels with drip irrigation and hydroponics are commonly practiced and demonstrations have been established at the research and training institutes of Sri Lanka. Hydroponics culture facilitates growing of plants in areas with marginal condition for crop production, such as adverse climate, soil, disease and pest occurrences. Tomato, bell pepper, cucumber, lettuce and capsicum are the popular crops grown under hydroponics system in Sri Lanka.

The controlled system with soil less culture could be used to obtain high yields but requires good management skills for successful crop production. Investors using this modern technological process face many problems in production and marketing of their produce. High capital investment, pests and diseases, difficulties in control of physical conditions and optimization of nutrient management are the main problems encountered by farmers in production. Lack of market facilities, fluctuation of prices and improper post harvest-handling are the main marketing problems affecting the stability of

farmer income. However, there is great potential for this technology to expand, because yields per unit area could be doubled compared to open field production and economic returns could be increased significantly. The government as well as private sector institutes have encouraged growers to take part in protected agriculture production by providing capital, input, technical know how and marketing facilities at varying degrees.

Summary

Vegetables in Sri Lanka are grown in various farming systems ranging from rice-based farming system to capital intensive protected agriculture system. Income and population growth and fast urbanization have generated additional scope for expanding the year-round production of vegetables. Improvements to the existing farming systems could enhance year-round vegetable production and farmer income, leading to higher standards of living.

**INTRODUCTION TO BREEDING METHODS & GENETIC
IMPROVEMENT OF VEGETABLE CROPS**
*Prepared for Regional Training Programme on Vegetable Production
Technologies (11 Feb -13 March 2003)*

By

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Plant breeding is an applied science that based mainly on genetics. Although simple selection by farmer is sometimes effective, well-arranged breeding program supported with genetics is more effective and minimize required labor and time.

Definitions: is an applied science that is mainly based on genetics

is a genetic adjustment of plant to the social, cultural, economic and technological aspects of environment

is manipulation of genetic system to design a more desirable product

Goals of plant Breeding

1. High productivity/High yield/Annual bearing
2. Resistance/tolerance (P&D, Flood, cold, heat, drought)
3. Quality of the product
4. Adaptive ability/ Improved plant characters/type
5. Suitability for new crop husbandry

Peculiarity of Vegetables:

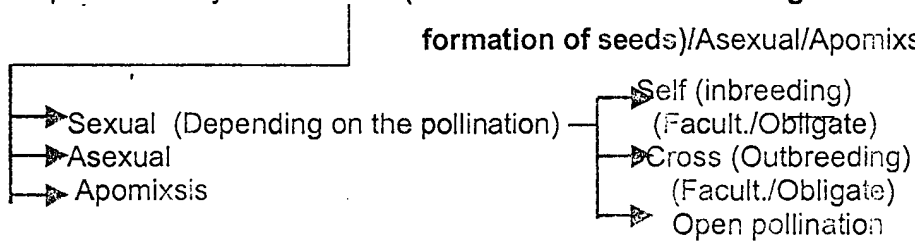
- Often edible part is not a seed/seed production capacity has to be consider
- Consumed in different forms (fresh/processed)
- Consumer preference differ greatly (size, color and shape)
- Perishable nature demand varieties with better keeping quality and suitability for long distance transportation
- Vary widely in mode of reproduction necessitating appropriate choice of breeding method

Classification

1. Reproductive Cycle: Annual / Semi perennial/ Perennial
 - a. Annuals - most of the vegetables

- b. Biennials - Some vegetables and some fruits
- c. Perennials - most of the fruits

2. Reproductive System: Sexual (Involves the fusion of M&F gametes and formation of seeds)/Asexual/Apomixis



Propagation can be done sexually or asexually, but improvement is only by sexual means

Pollination: Transfer of pollen from anther to stigma

Fertilization: The union of male and female gametes

Pollination does not always assure fertilization

Types of Pollination: Open-pollination (Free): Pollination with themselves or other plants

Self-pollination: Pollination between the same flower or flower on the same plant

Cross-pollination: Pollen from one plant pollinate a different plant

No clear demarcation between in-breeders and out-breeders.

Depending on the insect activity some crops behave differently.

Facultative breeding systems —> act as in breeders/out breeders

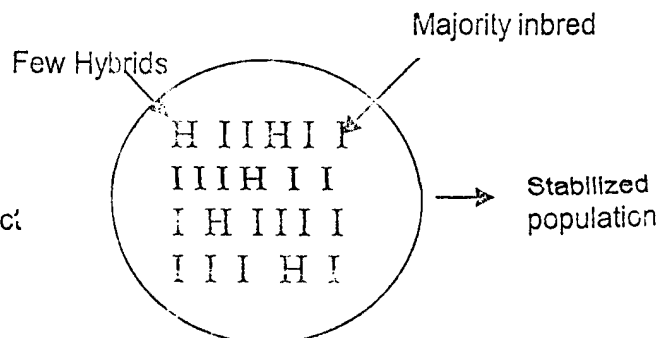
- In nature the majority tend to be Fac. Out breeders

Depending on the nature of pollination two major breeding systems are identified

1. Inbreeding system/Self-pollination
2. Outbreeding System/Cross-pollination

1. Inbreeding system:

- Preferred horticulturally
- Tend to be annuals
- Extremely uniform/pure lines
- Obligate in breeders are easy to predict



- Fac. In breeders show slightly less uniformity
- There are Mechanisms to restrict the out crossing in self-pollinated crops (Cleistogamy)

2. Out Breeding Systems:

- Obligate out breeders are rare in horticultural crops
- These crops show variability in flower formation
- Bisexual flowers (Hermaphrodite) can be found in most of the crops

Eg. Carrot/Cabbage/radish/Brinjal/papaya

- **Dioecious**- Female and male flowers are on different plants. They are obligate out breeders e.g. Rambutan/Spinach/Asparagus.
- **Monoecious**- Male and female flowers born separately on the same plant eg. Cucumber/Bitter gourd
- **Hermaphrodite plants** - Can be found in most of the crops thus increasing the chances of self pollination e.g. brinjal, tomato

Out breeders tend to possess floral modification to encourage cross pollination

Classification of Common Vegetables and their Mode of Reproduction

Crop	Reprod. Cycle	Mode of Reprod.	Flower type	Special features
Bean/tomato/eggplant Capsicum/Lettuce	annual	self	Hermaprodite	Cleistogamy in lettuce, heterostyle in brinjal
Okra	annual	Often cross	do	-
Cucumber/Gourds/ Pumpkin	annual	cross	Monoecious	entomophillous
Amaranth	annual	do	do	anemophillous
Spinach	annual	do	Dioecious	do
Cabbage/ Cauliflower/raddish	biennial	do	Hermaphrodite	Entomophillous Self incompatible
Carrot/Onion/Leek	biennial	do	Hermaphrodite	Entomophillous

Clonal Reproduction

- Not genetic breeding
- Results extremely uniform crops

Inheritance: The sources

Chromosomes

Plasma genes

Genes -If there is no marked cytoplasmic influence the behavior of the gene is quite predictable.

Genes are of two kinds

1. Major Genes
(Qualitative effects)
Simply inherited

2. Minor Genes/Poly genes
(Quantitative effects)
Complex inheritance

Impact of self and cross-fertilization on plants

Characteristic	Self-fertilization	Cross-fertilization
Natural population	Homozygous	Heterogeneous
Single plant from population	Do	Heterozygous
2n genotype	Do	Heterozygous
Genotype of haploid gamete	All the same	All different
Inbreeding Dipression	None	Expected
Self-incompatibility	None	Common

Breeding Methodology/Genetic improvement

Variation is the basis of Plant Breeding

Variations within a crop Spp. are of two kinds

Environmental variation

Hereditary variation → *essential to the plant breeder, without them there could be no heritable plant improvements*

The Breeding of any crop Spp. Regardless of its mode of reproduction involves

1. Creation of genetic variability
2. Selection among the genotypes

Creation of Genetic Variability + Systems of Selection = Methods of Breeding

1. Introduction of exotic germplasm
2. Hybridization
3. Mutation breeding

4. Ploidy manipulation
5. Plant cell and Tissue culture techniques (Somoclonal variation)
6. Gene recombination/Bio technology

1. Plant/germplasm introduction Centers of Origin (see map)

It is the process of introducing plants from their growing locality to a new locality.

It is a dynamic process

It may be deliberate or accidental, traded or freely given, legal or illegal

Introduction within the country —> Indigenous Introduction

Introduction to foreign country —> Foreign Introduction/Exotic Intr.

- Introduction of genetic diversity from the centers of origin (Refer to world Map)
- Introduction of exotic commercial cultivars
- **Germplasm exchange programs with international institutes e.g. (IRRI, ICRISAT, IITA), AVRDC, IPRBG, CIP, INIBAP (Refer to world map for exact localities)**
- Easiest/low cost/less time consuming

Purpose of Introduction

1. Use in agriculture as new crops
2. New germplasm sources for hybridizing with established crops
3. For studying origin, distribution etc.
4. For aesthetic interest
5. For germplasm conservation

Hints for successful introduction

- introduce to areas with soil/climate similarities
- areas with similar photoperiodic conditions
- introductions having broad gene base/wide adaptation

In Sri Lanka nearly

- 40 different crops are used as vegetables
- 55 tropical, sub-tropical and temperate fruits are accommodated
 - Promising varieties were released after evaluation

Vegetables;

Bw 11,MI2, SM 164,Tinnevalley purple Tinnevalley white, Tinnevalley long, all leafy Vegetables,kappetipola Nil (bean)

Local varieties

- Indigenous/introduced/

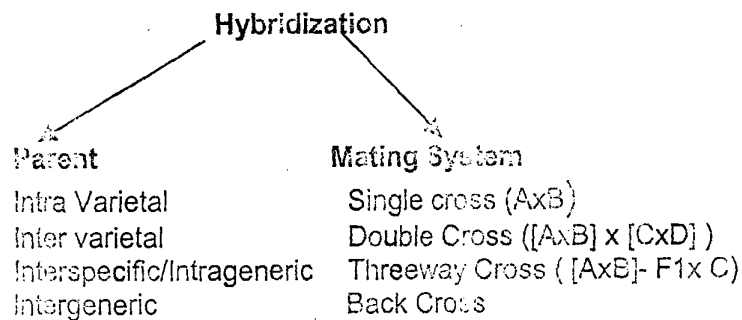
- Subjected to Natural selection
- Well adapted to local environment
- Good level of P/D resistance

Selection and Hybridization in Self Pollinated Crops

Hybridization: is the crossing of genetically dissimilar individuals

Goals of Hybridization:

1. to create a new reservoir of genetic variation to effect further selection
2. to combine the desired characters from various parents in to single variety
3. To exploit heterosis and use hybrid varieties



Selection: Sorting out and propagating individual genotypes or groups of genotypes from mixed population or from segregating populations

Two selection methods are adopted

1. Mass selection \longrightarrow since the object is to select visibly superior genotypes, plants are chosen on the basis of phenotype and the harvested seeds are composite without progeny test.
2. Single plant/Pure line selection

Pure line?

A progeny dependent by self-pollination from a single homozygous plant

Hybridization in self- pollinated crop is enforced/artificial cross-pollination of parents having desirable characteristics.

- Male non functional system is essential (male sterility, emasculation etc)
- Controlled pollination has to be performed
- Production of F1
- Selection of segregating materials from F2
- Pedigree-selection
- Bulk-population method selection practiced at F5 or F6
- Single seed descent F2 seeds and their progenies are advanced by single seed

Choice in selection method will depend upon the –particular crop, objectives and resources.

Plant Cell and Tissue culture Applications in Breeding

1. Clonal propagation

- a. The rapid multiplication of genetic stocks, isolation of pathogen-free planting material, freeze preservation of germplasm
- b. Applications: Potato/Banana/Strawberry/Orchids

2. Embryo Culture

The rescue and propagation of immature embryos following wide hybridization (Application - to over come seed dormancy)

3. Anther Culture

For isolation and production of haploids and doubled haploid plants (homozygous diploid plants) Application: Self-pollinated crops/hybrid production

4. Somoclonal variation

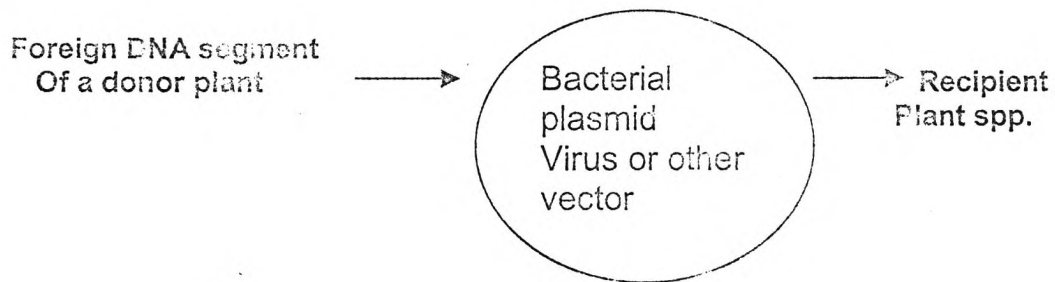
Genetic variation occurring in somatic cell cultured *in vitro* Application- tomato/potato/carrots

5. Somatic cell hybridization/protoplast fusion/somatic cell fusion

Application- hybrids from wide crosses

6. Plant genetic engineering

Cellular transformation or gene splicing through recombinant DNA technology



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Subscribe maillserv@mailserv.iao.org to get plant-breeding news regularly

Use of Induced Mutations in Vegetable Crop Improvement Work

Ranjani Peiris,
Research Officer, HORDI

INTRODUCTION

Induced mutations have been known to scientists since about 1920. However, its use in plant breeding work was made only since 1950. Increasing interest in utilizing induced mutations in breeding programmes began from mid 60's. Recent reports indicate that 1603 mutants in seed propagated crops and 97 vegetatively propagated crops have been developed through mutation induction. Sixty six vegetable mutants are included in the total of 1700 mutants. The desired characteristics that have been obtained by induction of mutations in agricultural crops are mainly those that have not been favoured by natural selection in evolution or derived in previous plant breeding efforts, but are of value in domesticated plants.

MUTAGENS AND USAGE

- Physical agents

Eg. X rays, gamma rays, neutrons, α , β rays, UV

- Chemical agents

Alkylating agents are the most suitable chemical mutagens for plant mutagenesis.

Groups : Sulphur and nitrogen mustards, epoxides, ethylene imines

Alkyl - Sulphates and sulphonates

Diazoalkanes and nitro so compounds

Recommended chemo mutagens for mutation breeding of crop cultivars :

dES	-	diethyl sulphate		
EMS	-	Ethyl methane sulphonate	}	direct
EI	-	Ethyl eneimine		mutagens
NEH	-	N-ethlye - N - nitro so urea		
NMH	-	N - methlye - N - nitro so urea		

Azides → indirect mutagens

Must be enzymetically activated to exhibit a mutagenic potential

Active mutagnic compound → azido alanine

Use of induced mutations in Plant Breeding

The basic requirement in any breeding programme is the clear identification of plant breeding objectives. In mutation breeding too, this approach is the same. First, the breeder studies the available genetic resources the nature of inheritance (dominance, recessiveness, gene complexes etc.) available sources and the efficiency of the selection that could be applied in a breeding programme. After considering the above mentioned factors breeders can decide the breeding method to be adopted such as either by hybridization or inducing mutation.

The most important pre-requisites for a successful breeding programmes are the effective method of mutagen treatment (physical or chemical mutagens) and appropriate selection procedure. The mutations can be used in plant breeding work in different ways as shown in Table 1.

Table - 1 : Methods of using mutations in plant breeding

I. Use of point mutations

1. Autogamous species :
 - (a) Direct use of mutations : mutants used directly as improved varieties
 - (b) Cross-breeding with mutations
 - (i) Crossing the mutants with the original parent variety or line
 - (ii) Crossing different mutants from the same parent line.
 - (iii) Crossing different mutants from different parent lines.
 - (iv) Crossing the mutant with a different variety or line
 - (v) Crossing two varieties apparent carrying the same mutant.
2. Allogamous species : induction of mutation to increase variability
3. Heterosis breeding: induction of mutations to inbred lines. Induction of male sterility (allogamous and autogamous).
4. Asexual plants : induction of "sports"

II. Use of chromosome mutations

1. Use of translocations : for transferring characters from other species and genera.
2. Use of translocations (with known breakage points) for productions of "directed" duplications.
3. Diploidization of polyploids

III. Use of mutagenic agents for special breeding problems

1. Use of radiation to produce haploids.
2. Use of mutagens to increase or lower the frequency of chiasma.
3. Use of radiation for production of transitory sexuality in apomicts.
4. Use of radiation to reduce incompatibility in wide crosses.
5. Use of induced mutations for special studies of genetics or physiological morphological, and biochemical processes in crop plants.

Self and Cross Fertilizing Species of Vegetable

It is generally expressed that induced mutations have less scope for the improvement of cross fertilizing species. The problems here arise in selecting, incorporating and maintaining recessive mutation in the population. Heterozygosity is the main constraint in the selection of desirable mutants. Therefore, use of induced mutations are not much accepted by breeders of cross pollinating species. However, by understanding the floral biology (self incompatible, monoecious, dioecious etc.) and method of breeding, new prospects in mutation in breeding of these crops could be established. Induction of male sterility is a useful application of mutagenic agents on these crops.

In self pollinating annual crop plants, mutation breeding is not a problem. Mutation induction and in vitro culture technique offer the same prospects for the both cross and self-pollinated crops.

Vegetatively propagated species of vegetables

Cross breeding is often limited by specific difficulties (cross barriers, incompatibility, sterility) in most vegetatively propagated plants. Plant improvement in these species mainly depend on the selection of naturally occurring mutants (sports). Therefore, the

use of induced mutations have a high potential for further genetic improvement in these species.

The main advantage of mutation in vegetatively propagated species is the ability to change, one or few characters without disturbing the established genotype. In vegetatively propagated species the most commonly used plant parts are tubers, bulbs, corms, dormant cutting, stolons and rhizomes. Both chemical and physical mutagens have been used in mutation induction. But it has been reported that the physical mutagens are more effective than chemical mutagens due to limited penetration of chemical mutagens into the plant tissues. For vegetatively propagated species irradiation exposures over long periods of time has no advantage over exposures delivered over a short period.

Special merits and disadvantages of mutation breeding

Mutation breeding provides a novel approach to plant breeder for raising the productivity of crop plants thus complimenting conventional plant breeding methods. It is very useful to rectify one or two undesirable traits found in a well adapted variety.

A desired mutant can be recovered in a homozygous stage already in M2 or M3 as compared with the F6, F7 generation in the case of hybridization. Therefore the time required to breed the improved variety can be shorter than when hybridization is used to achieve the same result.

Hybridization is the basic method of creating variability that the breeder needs for his selection. But when genetic variability is limited or lacking, mutation breeding methods are the tools available to the breeder, to create further genetic variability.

The disadvantages of mutation breeding are largely associated with the necessity for testing large second generation (M2) population. The field work required to achieve some particular improvement is often substantially greater with mutation breeding than

the conventional breeding methods. Cell culture techniques may solve the problem in the future. Powerful mutagens are available but the genetic alterations produced cannot be easily detected. Selection techniques should be refined to solve this problem.

Steps involved in development of mutant varieties

e.g. Tomato

- Selection of a variety for mutation induction
 - Choice of mutagen
 - Prediction of desirable dose rate
 - Treatment of planting material with desired dose rate of mutagen
 - Establishment and management of M1 generation - No selection*
 - Establishment and management of M2 generation - Large population* screen for mutants.
 - Establishment of progenies of mutants as M3 generation.
- * Establishment of M4 progenies of mutants to confirm whether these mutants are true to type
- Testing of mutants in preliminary and Advanced Yield trials. Screening of mutants for pest and diseases and fruit quality characters.
 - Testing of mutants in multilocational yield trials.
 - Testing of mutants in varietal adaptability trials in farmer fields

Release of mutants

POTENTIAL FOR HYBRID SEED PRODUCTION IN VEGETABLES

Prepared for Regional Training Programme on Vegetable Production Technologies
(11 Feb-13 March 2003)

By

Dr. Hemal Fonseka

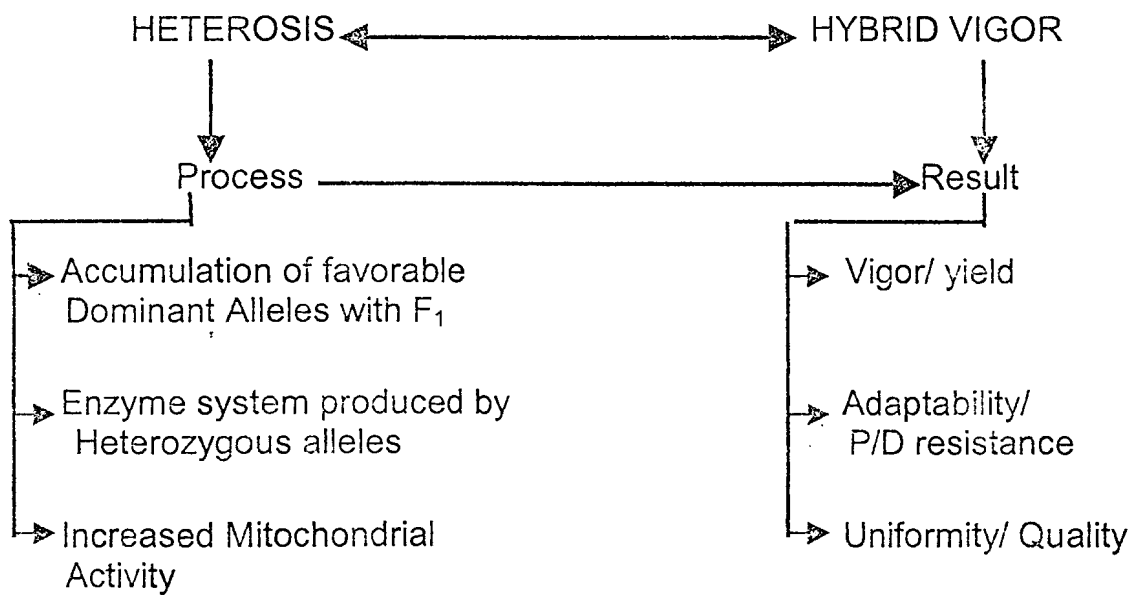
(Horticultural Crop Research & Development Institute, Gannoruwa, Peradeniya, Sri Lanka)

HYBRID..... WHAT???

Is the progeny of a cross between two homozygous (but genetically distinct) parents or es.

breeders regularly witnessed that F_1 's often had an increase level of vigor and performance compared with parents.

WHY?

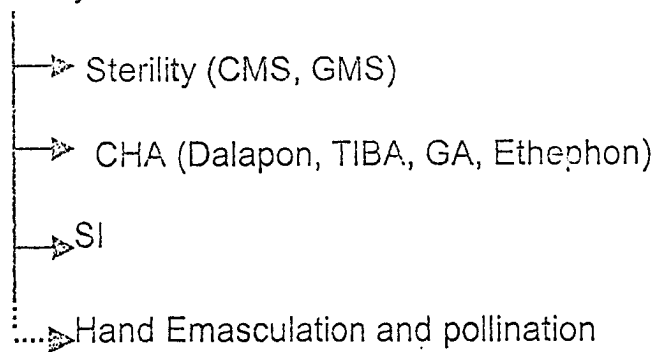


HOW?

- Hybrids are the result of controlled pollination.
- Therefore, male non-functional system is mandatory

vegetables three basic systems have been used.

Male non-functional system



Procedure

1. Selection of parents

- The secret of success in the hybrid business lies in the ability to find the correct combination of inbreds to produce competitive hybrids for the market.
- Characterization and evaluation of parents.
- Parents should be vigorous, early fruit set plants.
- Parental seed should be produced by artificial self-pollination.
- Evaluate them for Combining ability (GCA, SCA)

2. Hybridization

- Emasculation and pollination

3. Get F_1 seeds

Local Vegetable Production System; Features

- High input crops with over optimum adoption of new technology in contrast to OFC's.
- Most of them are grown over wide range of agro-climatic zones.
- Local selections and land races are widely grown.
- Faces lot of biotic and abiotic constraints.
- Lack of high yielding, P/D resistance varieties.

Wide gap between national average yields and potential yield.

POTENTIAL AND ADVANTAGES

Technical:

From plant breeding viewpoint the success of commercial hybrid seed production is influenced by three factors.

Breeding method efficiency

Negative or positive effects of male sterility

Multiplier effect

- The seed multiplication rate and the commercial seeding rate together make up this effect.
- $\text{Multiplication Ratio} = \text{Seed Produced ha}^{-1} / \text{Seed Rate}$
- This will decide the feasibility of hand hybridization on a commercial basis.
- Crops with low multiplication ratio require a large area to produce hybrid seed.

Most of the vegetables i.e., tomato, brinjal, cucumber etc, have higher multiplication ratios. Therefore, hand hybridization is feasible.

Hybrid vigor is pronounced in all vegetables except few and is now used so widely.

The technique of producing hybrid seed is not difficult in many vegetables.

Can obtain greater adaptability to varying environmental conditions.

Greater vigor express as yield, P/D resistance, early maturity, superior quality, greater degree of uniformity for color and size

Early vegetative vigor and strong root system should make them adapted to rainfed areas.

Economic:

From Economic viewpoint adoption of F_1 hybrids in any crop will ultimately depend on

the magnitude of yield advantage

2. the cost/benefit ratio using hybrids Vs pure lines
3. the efficiency of seed production, certification and distribution
 - A. Use of CMS, GMS would drastically reduce the cost of production relative to the hand hybridization
 - B. The disadvantage of extra cost of F₁ hybrids is nearly always out weighed by superior performance
 - C. Both returns/cost ratio and return/input ratio of hybrids are higher than non-hybrids.
 - D. Can be utilized the potential for Fresh vegetable export
 - E. Hybrid varieties could fetch higher market price due to their uniformity and improved quality.
 - F. Tourist industry in the country demands quality vegetables
 - G. Greater adaptability, resistance to P/D and higher yield leads to cut down cost of production.
 - H. Can use to improve productivity of areas where normal cultivars reached a yield plateau.
 - I. Proprietary nature of hybrid seed business attracts private sector and would offer sound economic possibilities for investment in agricultural sector.
 - J. Under the New World order/new economic policies among countries (SAFTA etc.) it would be possible to have joint ventures with other countries to develop the hybrid seed industry in Sri Lanka.

CONSTRAINTS

- High cost involved in manual hybridization
- Labour is expensive compared with India, Pakistan etc.
- Domestic market is limited
- Farmers have to use new seed each season
- Lack of expertise

FUTURE

Acceptance of hybrid seeds by farmers usually depends on the relative cost of hybrid seed compared with the economic gain obtained by the cultivation of the hybrid over non-hybrid variety.

Introduction of CMS, CHA, SI would be useful to cut down the labour cost.

Basic information about hybrids should be generated by public agencies. Later private sector should be given the responsibility to handle the economic framework.

Conventional breeding and hybrid breeding should be complementary and competitive

BUT !!!!

HYBRIDS ARE NOT GENETIC MIRACLE TO SOLVE ALL AGRICULTURAL PRODUCTION PROBLEMS!

Genetically Modified Organisms

Ban or Boon?

- Athula Perera
- Professor of Agricultural Biology
 - Director, Agricultural Biotechnology centre
 - Faculty of Agriculture
 - University of Peradeniya

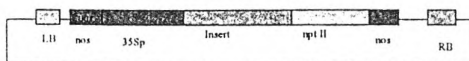
GMOs - Definitions

- Sri Lanka – Genetically Engineered Organism, Genetically Engineered Food Additive, Genetically Engineered Material, Genetically Engineered Food
- UK, Europe, Australia
- Recombinant DNA and RNA techniques:
 - Cutting out/isolating gene of interest from DNA
 - Inserting into DNA of another plant using a vector system
 - Grow plant and check for foreign gene/insert i.e GM
 - Checking the gene for proper expression in new envnt.
 - Checking offspring of GM plant for proper inheritance of inserted gene

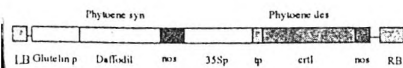
Methods

1. Agrobacterium mediated gene transfer
2. Biolistic

1. Inserted DNA sequences in transgenics



2. pTAV1 vector system in fasten files



Objectives

- Recognized by global scientific community as the next revolution for increased food production – gene revolution
- Increased crop yields
- Decrease post-harvest losses
- Increase tolerance to stress- drought, cold, salinity
- Better use of N,P,K
- Increase resistance to Pests & Diseases – less use of chemicals
- Increase nutritional value of food
- Develop alternative resources for industry- starches, fuels, pharmaceuticals, nutraceuticals
- Production of vaccines
- Increase resistance to herbicides, viruses
- As bioreactors

Humans & Agriculture

- Earliest evidence of farming – 10,000 years ago – present day Iraq (Heiser, 1990)
- 20,000 years before – Humans – nomadic hunters, gatherers & scavengers – survived on wild plants & animals
- Domestication of wild plants & animals – beginning of agriculture – in Andean regions of S.America, Mexico and parts of Asia
- We became Community Dwellers – no need to look for food daily - spawned development of languages, literature, science & technology (Diamond, 1999)
- Some regions developed faster
- Humans intervened in evolution of plant and animal types (Hailan, 1992)

Science & Agriculture

- Early Humans – 250,000 flowering plants
- Reduced to ~1,000 species to ~100 crop species at present – handful supply our food
- Present crops – totally dependent on human care – cannot exist in the wild (Trewavas, 2000) – moved around the world – trans-oceanic navigation : Coffee (Ethiopia), Sugarcane (Papua New Guinea), Oranges (India)
- Development of better crops – array of tools – Hybridization, Mutation breeding, Hybrid Vigour, Embryo rescue, Somaclonal variants, Recombinant DNA Technology –
- (Frary & Tanksley, 2000)
- UN Human Development Report – 2001
- Title: Making New Technology Work for Human Development

World Population

- Future population growth :
 - 152% - Africa, 55% - Latin America, 48% - Asia
- Population of developing world – grow by 2/3rd in 2050 !!
 - 2000 = 6 billion ----->2050 = 9 billion
 - 90% reside in Asia, Africa, Latin America
- Today – 800 m undernourished people in developing countries
 - 3 billion affected by poverty
 - 1.5 b more added by 2020 !!
- 3 Food production systems
 - Oceans – potential exhausted
 - Reared – potential exhausted
 - Arable land – limited
- Food must come from limited arable land for 8 b people in next 20 years !
 - One Solution - Biotechnology

Current research/products

- Flounder tomato: Antifreeze gene
- Chymosin: Biotech version of rennet (from calves) - CHYMOSIN (yeast & bacteria)
- New Bt maize variety – carrying Cry1F tested on cattle – same as non-Bt
- Cornell/USAID: New transgenic indica rice – gene for synthesizing TREHALOSE – tolerant to drought, salinity etc.
- Trehalose found in 'resurrection plants' of the desert regions
- 2 genes from E.coli + special promoter (turned ON during stress; leaves only)
- YieldGard Corn Borer: Insect Res. Corn – approved in the Philippines

Biotech. Crops

Studied for > 25 years, with 25,000 field trials and 110 M acres of crops in 13 countries at present.

- 1st biotech crops in USA in 1995.
- 1996: 6 countries, 1.7 m ha
- 2001: 13 countries, 52.6 m ha --> 19% increase
- Biotech. market : 500 b US \$
- Petrochemicals : 500 b US \$
- Information Technology : 800 b US \$
- USA – Today, 60% of food on sale are transgenic !
- Crops: H₂O₂ tol, Pest res.(Bt), Virus res., Hepatitis B vaccine in potatoes, Smart plants for Mars, Plantibodies, Fishberries, Blue roses, Hawaiian GM coffee, Cardio-friendly tomatoes, Consumer genetics, Fat-free gene in Zebra fish, cholera, rabies vaccines in bananas, cooking oil in cotton, protease etc.

Biotech. Crops cont.....

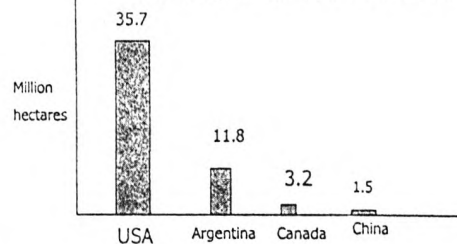
- 13 countries : 7 industrial, 6 developing
- USA, Canada, S. Africa, Australia, Spain, Germany, China, (France)
- Bulgaria, Mexico, Argentina, Uruguay, Romania, Indonesia, (India, Philippines)
- 4 countries grew 99%:
 - USA – 35.7 m ha - 68%
 - Argentina- 11.8 m ha -22%
 - Canada- 3.2 m ha – 6%
 - China- 1.5 m ha – 3%
- Developing countries: 13.5 m ha
- 14% in 1997 --> 26% in 2001

Present Status

- 5.5 million farmers in 13 countries
- 75% Small farmers in developing countries
- 52.6 million hectares worldwide
- Crops: Soybean 63%, Ht Corn 19%, Cotton 13%, Canola 5%, Potato <1%, Squash <1%, Papaya <1%
- Traits:
 - Herbicide tolerance – 77%
 - Insect resistance – 15%
 - Bt/HR – 8%
- Dominant crops: Ht Soybean 63%, Bt Corn 11%, Ht canola 5%, Ht Cotton 5%, Bt/Ht Cotton 5%, Ht Corn 4%, Bt Cotton 4%, Bt/Ht Corn 3%

Major countries

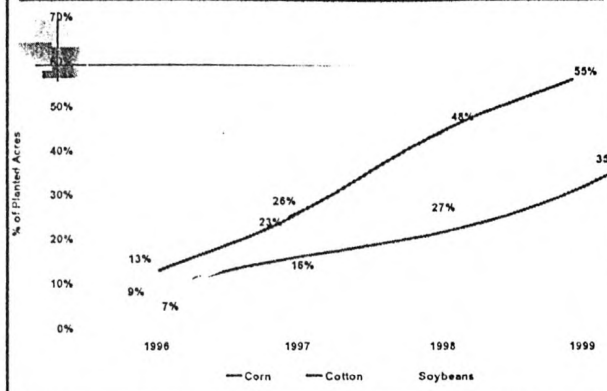
China: 47 Transgenic plant species
Cloned goats – Higher rate of success (10-20 times)
Transplanted genes into – pigs, rabbits, sheep & cows



India

- Transgenics: rice, wheat, potato, mustard, pulses, groundnut, tomato, cauliflower, cotton etc.
- Bt Cotton – 3 hybrids Bt-MECH 12, 165,184: commercial cultivation
- GM Mustard from Proagro: first 100% food product – increased seed & oil by 16-26% - awaiting approval
- Insecticide resistant rice, potato, brinjal
- Potato, Edible vaccines

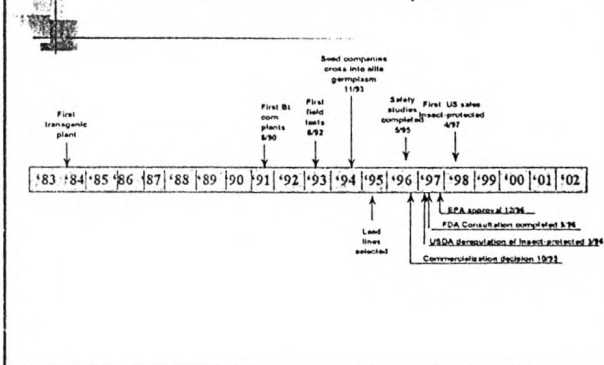
United States: Biotech Adoption Rates



GM CROPS AROUND THE WORLD

Crop	Millions of hectares	
	1998	1999
Soybean	14.5	21.6
Corn	8.3	11.1
Cotton	2.5	3.7
Canola	2.4	3.4
Potato	<0.1	<0.1
Squash	0.0	<0.1
Papaya	0.0	<0.1
Trait		
Herbicide tolerance	19.8	28.1
Insect resistance (Bt)	7.7	8.9
Bt/Herbicide tolerance	0.3	2.9
Virus resist./Other	<0.1	<0.1

Insect-Protected Corn - From Idea to Reality 14 Years of Research and Development



Economic benefits

USA : 8 GM crop varieties in 2001

	Ha (000)	Pesticide use -13.0 m Kg	Economic gain \$/ha
GM Soybean Ht :	20,000	-13.0 m Kg	50
Cotton Ht	3,700	- 2.8	35
Corn IR	6,000	- 1.2	21
Cotton IR	2,000	- 0.9	50
Corn Ht	2,300	-2.6	25
Canola Ht	352	- 0.2	31
Hawaiian papaya Vr	<1	-	2,625
Squash Vr	< 2	-	803

- High Yield, Low cost of production, low use of pesticides, less need for cultivation, less pesticide spraying

Economic benefits.....cont.

- Argentina
 - Soybean Ht : 11.2 m ha with gross gain of \$ 25 / ha
 - Lowers tillage, low toxic h'cides used.
- Philippines (Gonzalez, 2002, Zimmermann & Qaim, 2002):
 - Corn Bt : 41% Higher yield, Decrease cost of production by 24%, Increase profit
 - Blindness : Decrease number of cases of blindness by 1,514 annually, decrease number of deaths by 152.
 - Annual health cost related to VAD = 0.5% GNP = \$ 432 million = savings of \$ 23 million annually
- Spain (Brookes, 2002)
 - Bt Corn : 25,000 ha, yield gains of 10% with economic gain of \$ 5 - \$ 82 / ha, decrease production risks, stable yields, less exposure to h'cides, lower levels of mycotoxins, lower applications of h'cides

China

- 2,000 scientists working on crop biotechnology;
- 50 crop species, using 120 genes, field trials of
- 16 crops, Bt cotton commercialized and adopted by 5 million farmers (2001)
- Rice: Insect, Disease & H₂O tolerance
- Corn: Improved quality, H₂O resistance
- Potato, wheat, soybean, papaya, cashew, chili, sweet pepper
- Vr = 30%; Ir= 20%; Dr= 15%; Qity= 12%; Ht= 7%
- <5% each for salt t, cold t, improved shelf life and colour of petunias
- Invested \$ 112 m / annum in 1999....> 400% by 2005

Issues / Concerns

Human Health

- Inserted gene may cause unknown hazards such as new toxins or allergens – e.g. GM potatoes fed to rats damaged their liver and immune system. How to prove an unknown?
- Products of classical breeding also have allergens – beans – lectins; potatoes – alkaloids; rhubarb – oxalic acid, manioc – HCN
- USA – about 90% of all food allergies caused by cow's milk, eggs, fish & shellfish, tree nuts, wheat & legumes – especially peanuts & soybeans.
- GM products – so far no reports of allergies, except in Starlink Corn (animal feed)!
- GM products – undergo rigorous tests – lab., greenhouse, field - before approval is given.
- Proteins from GMO – sensitive to heat, acid & enzymatic digestion, present in very low levels and not structurally similar to any known allergens.
- Hypo-allergenic wheat !! – Thioredoxin gene

Horizontal Gene Transfer

Transfer of the 'transgene' across species to non-target plants – 'genetic pollution' and cause 'superweeds' - Invasiveness.

- There is no evidence yet.
- Rice pollen travels only a few centimeters ! Also, weeds should be closeby, flower at same time, be compatible, seeds should be viable, offspring should inherit the gene in working order, nature of pollination should comply etc.
- Green revolution- new varieties invaded and completely removed existing traditional varieties
- Occurred during evolution – across species & genera but at very low frequencies because of natural control – to preserve
- Superweeds already exist – by transfer of natural 'exotic' plants to non-native environments – rhododendron, water hyacinth, kudzu grass.
- Genes will be transferred to chloroplast DNA – not in pollen

TRANSFER OF TRANSGENE

- Crop-weed transfer of herbicide resistance genes
- Transfer of glyphosate resistance
 - Wheat to jointed goatgrass
 - Canola to wild mustards

TRANSFER OF OTHER PARTS OF CONSTRUCT

- Transfer of antibiotic marker genes to pathogenic bacteria
- Transfer of promoter sequences such as CMV promoter

Antibiotic Resistant Genes

- Used as markers for selection – concern: can be transferred from plants to disease-causing microorganisms in the gut of man or animal or in the environment. They will acquire resistance to antibiotics !
- Markers used (52) : do not cause toxicity or allergenicity and are not normally prescribed.
- 31/52 – Neomycinphosphotransferase II (npt II), APH (3)-II (27/31)), Hygromycinphosphotransferase (aph IV, hpt) (1) – both had eukaryotic promoters.
- 19/52 – with bacterial promoters – bla, aad, npt II, npt III, cat, tetR – not expressed in higher plants.
- Vancomycin – only drug for certain type of bacterial infection – cannot use
- Future: Use genes for resistance to non-medically important antibiotics, use alternate types of markers, excise out the antibiotic res. gene after selection.
- There is widespread use & misuse of antibiotics in medicine & farming.
- Stringent regulations in force for use of these genes.

Invasiveness

- 3 important environmental problems – Global climate change, Habitat loss, Invasiveness
- Non-native organisms introduced to ecosystem – can be harmful – unintended establishment, persistence, gene flow
- GMOs – novel to the ecosystem
- Hybridization with wild relatives – 12/13 of world's most important crops – rice, wheat, maize, soybean, cotton etc.
- Evolution of weed species by this – 7/13 – wheat, rice, soybean, sorghum, millet, beans, sunflower
- High levels of gene introgression – eliminated genetic diversity & genetic uniqueness of native species – extinction!
- Difficult to predict invasiveness – fecundity, survival, timing, insect predators, competition – limit reproductive ability of GMO and wild relatives

GENETIC TRESPASS

- Cross-pollination of non-transgenic plants by pollen from GM crops
- Contamination of organic and conventional crops
- Gene escape into wild plant populations

Non-target Organisms

- Kill beneficial & non-target organisms as well
- Specially, insect-resistant GM plants – Bt gene
- Eg. Monarch butterfly
- All pesticides – not 100% selective!
- Evolution of resistant strains – can occur even with conventional varieties
- Regulations for GM plants – Refuge fields

Biodiversity & Wildlife

- GM – insignificant factor in accelerating loss of biodiversity & wildlife.
- GM – increase food production in limited land – preserves biodiversity
- Extinction rates – ~ 27,000 species / year due to loss of habitats – due to expansion of human population and demand on food & housing
- Increase use of biodiversity – identifying useful genes and transfer across species and within species – bioprospecting, benefit sharing, Traditional knowledge, IPR come into play!
- Conservation International – Report on Wilderness : Earth's untouched wilderness areas are 46% intact – cf to 52% at dawn of mankind!

GMOs & Environment

- Difficult to assess – natural variation and interaction of organisms with environment
- Intensive agriculture – affects agricultural diversity and natural diversity – whether GM or not !!
- GMOs – increase yield in limited land – help preserve uncultivated habitats
- DNA tools – assess genetic diversity – identify priority species & habitats for conservation

Ethics & Morals

- GMO – 'unacceptable' or 'wrong' – tampering with nature, playing God, unfair benefits to big business & multinationals, exploit the poor/developing world
- Moral: what is right or wrong – highly individualistic
- Ethics: defines values or set of standards by which a group or society decides what is acceptable or not.
- UK survey (1993):
- Most Christians & Jews – GM acceptable in principle
- Muslims, Sikhs & Hindus – object to consuming organisms containing animal genes subject to relevant religious restrictions
- Vegetarians – object to plants carrying animal genes
- Most accepted GM plants & microorganisms if they have clear benefits; few agreed with GM animals; even fewer agreed with GM humans (whatever the benefit)

Other effects-----

- Effect on soil ecosystem
- Herbicide tolerant crops** – kill all weeds – affect food availability to seed specialists
- Bioaccumulation – predators consume prey that contains pesticidal proteins – not enough data!
- Persistence of pesticidal proteins – Bt toxin in soil- Purified, active Bt toxin persisted in certain soil types for at least 234 days in one study – high clay content & low soil pH increases persistence. Roots exuded Bt toxin to soil in lab.
- Viruses with new biological traits can arise in transgenic viral resistant plants through recombination & heteroencapsulation
- Unexpected risks - as frequency & scale of introductions increase – GMOs will interact with diversity of habitats in time & space – potential risks vary!
- Evolution of resistance – Bt toxin – Diamond-back moth (field), 10 species of other moths, 2 species of beetles, 4 species of flies under lab. Conditions.
- Glyphosate tolerance in weeds – in rigid rye grass

The other side-----

- selective breeding – unnatural- new varieties would never have evolved naturally
- No medical treatment is natural!
- Herbicide – not necessarily good – cassava with high levels of cyanide, crop failures due to bad weather or pest attack
- Humanity always interfere with nature – for comfort and security and to avoid natural processes of starvation, disease & death
- Some people – won't eat bacon but take insulin extracted from pigs
- Some – don't eat strawberries containing fish gene (fishberries) but eat fish for main course and strawberries for dessert!
- Conventional breeding – changes phenotype (& genotype) according to our wishes – playing God?

The other side.....

- Decrease use of environmentally harmful chemicals
- Soil conservation** – promote no-till and conservation tillage practices – decrease soil erosion & water loss, increase soil organic matter
- Increase yield – also preserve natural habitats
- Phytoremediation – GM plants & microorganisms – provide in-situ remediation of polluted soils, sediments, surface waters & aquifers.
- GM plants – increase removal of toxic heavy metals from polluted soils & waters / or transform pollutants into less toxic forms.
- GM plants – drought, cold, heat and salinity tolerance
- Over half of economic benefits of new technologies – gone to farmers!
- Increase biomass production – engineering metabolic pathways – nitrogen assimilation, sucrose hydrolysis, starch biosynthesis
- If inserting a new gene causes no change in all of the parameters examined, the improved crop is said to be substantially equivalent to and as safe as the conventional crop

Multinationals – Own Life ?

- entire food chain from seed to plant- controlled by few multinational companies – farmers tied by agreements to buy seeds and agrochemicals from same company
- 70 patents (IP & TP) – is it wrong for business to make money? New crop may take about US \$ 30 M to develop without guarantee of success! – an investment risk!
- owning life? – owning life? What does 'owning life' mean? What are the similarities & differences between owning a dog, flock of sheep, field of rice, or genes or GMOs or new plant varieties?
- Developed countries pay for research that will be of use in countries that cannot afford it – golden rice (Sweden), Vit A tomatoes (UK), Vit. A peppers (France), Virus res. cassava & papaya, Hepatitis b vaccine potato, Cholera, Rabies vaccines banana
- If GM technology is only found in industrialized countries, will it not widen the gap between the rich and the poor and exclude them from world markets?
- US companies mine oil in Saudi Arabia – Saudis getting richer & richer!!!
- Biopiracy!

Labeling

- Let the consumers decide and choose
- USA – no mandatory labeling required
- EC – labeling required if GM ingredients are present at or above 0.9% threshold level in food and 0.5% in adventitious contamination i.e. for non-GM food.
- Some want 0% contamination!
- Methods: ELISA, Lateral flow strip technology, PCR, Real time PCR (lab kits available)
 - PCR – detect & amplify specific segments of DNA and can characterize GM material in food – i.e. GM content, GM variety, % GM DNA
 - Test for species DNA – Soya (lectin gene), Corn (invertase gene), oilseed rape (PEP gene) etc.
 - Test for sequences characteristic of GM crops e.g. S-35, T-Nos, npt II, Bla etc.
 - Test for specific gene e.g. Cry1Ab, Cry1Ac, EPSPS, BAR, CaMV PstIIa, Gox, Gus etc.
 - Require reference material

Labeling ---- contd

- Easy for products like GM puree; difficult for commodity crops like soya because beans from different sources are mixed and processed together – impossible to prevent mixing.
- Highly purified oils, sugar obtained from GM crops contain no detectable protein or DNA – they are chemically identical to non-GM oil or sugar – how to label?
- Sampling- define limits of detection; how to procure GMO seeds from a shipload of grains? Sample to sample variation; accredited laboratories; trained personnel; back-up systems
- How useful is a label that says 'GM' or 'GM-free'? What does it tell you about the product or method of production? If more information is given, will we read it? Will it mean 'BAD'?
- Cost of analysis – e.g. Cornflakes - \$ 150/truck load i.e. 9800 cartons i.e. 1.5 cents /pack + administrative costs + legislative costs + separate silos, rail cars, ships, production lines at factories & mills ... etc.
- Labeling of food made from crops sprayed with pesticides??

Listen to everyone

- Greenpeace, Earth Liberation front (ELF), Animal Liberation front, Friends of the Earth, Union of Concerned Scientists, Campaign to Ban GE Foods, Consumers International, Biotechnology Action Network, The Ark Institute, Natural Law Party etc.
- Frankenfoods, Frankenforests, Biodevastation
- Hongkong- guidelines for labeling
- Thailand – stop field trials of GM crops
- Philippines/Indonesia – discussions
- Europe – labeling mandated
- 2001 - Set fire to U of Washington Hort Lab. & Poplar tree nursery in Oregon

European Commission

- Research: >400 public bodies + 15 years
- No evidence on effect on health
- Negative effect from pesticides
- No GM products since 1998
- EU Parliament: labeling rules: > 0.9% GM in food
- Adventitious presence: 0.5%
- Testing for GM: 1 test costs ~ 200-2000 euros!
- 33rd World Vegetarian Congress : Against animal genes in plant food! About 60% plant genes have similar copies in animals

Less heat.....more light !

- Species extinction- by stone-age people 50,000 yrs ago – Australia; 30,000 yrs ago – N. America
- S. America, Madagascar, N. Zealand, Hawaii
- Substitution- by human inventions - Oil replaced whale oil, Coal replaced wood, Soil(Agriculture) replaced scarce wild game
- Primary power – wood->coal->oil->gas->nuclear
- Hunter-gatherer – needs ~ 5,000 Ac to support 1 human; shallow, organic agric. ~ 10 Ac; Intensive, conventional ~ 1 Ac; Modern ->1,000 people/Ac
- 1,000 years ago – exploited landscape for – food, fuel(wood), transport(horses, bullocks), textile(wool), building material(wood), fertilizer(plant material)
- Today – All from factories – save nature!
- Pesticides :1940's – compound of arsenic – lethal to all org.
 - Replaced by DDT – persist in envt – affect aquatic life & birds
 - Replaced by synthetic pyrethroids – less persistent, killed only target organisms, saved fish & birds but carcinogenic
 - Bt plants – no spray, no collateral effects, not carcinogenic.
- Silicon, fibre-optics etc.

More light

- 1961 – freeze the yield level – then to produce same amount of food as in 1998 – 12.2 b Ac->26.3 b Ac = 38%->82% of global land area – destroy forests, drainage systems, irrigate deserts, destroy species !
- 1961 – 1998 – Doubled population, more than doubled food production, increased cultivable land by only 5% -> Woodland increased by 20% and the survived !
- Modern technology – will feed and fuel the future populations with limited land.
- Market – always for local produce & traditional food !

Quantifying risk

- Risk = hazard x exposure
- Amount of risk = $\frac{\text{hazard} \times \text{xposure}}{\text{safeguards}}$

NEXT GENERATION OF TRANSGENIC CROPS

- Plant-based vaccines
- Enhanced nutritional content
- Functional foods and phytoceuticals
- Plant-derived plastics and polymers
- Transgenic plants for phytoremediation

Cartagena Protocol on Biosafety

- 1995: Working group on biosafety
- 2000: Conference of Parties adopted the Cartagena protocol on biosafety
- Aim: contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of LMO resulting from modern biotechnology that may have adverse effects on the conservation & sustainable use of biological diversity taking into account risks to human health & specially focusing on trans-boundary movement
- Key aspect: provision regarding assessment & management of risks to biological diversity & human health associated with LMO

Provisions & Applications

1. Advance Informed Agreement (AIA)
 2. Risk Assessment – Article 15, Annex III
 3. Risk Management- Article 16
 4. Implementation of risk assessment & management
 5. Biosafety Clearing House
- Developing countries: How to assess? Capacity building? Cost?

Views of Scientific Community

- Threat to human health – Yes 36%, No 47%, Don't know 18%
- Solve our agric. problems – Y 65%, N 23%, DK 12%
- Ban all 17%, Use freely 3%, Ban some (food) 80%
- Research – Y 97%, N 0%, DK 3%
- Label – Y 97%, N 0%, DK 3%
- Govt. invest – Y 67%, N 17%, DK 15%
- Wait & see – Y 8%, N 92%, DK 0%

▪ Ban or Boon ?

There are none so blind as those who will not see !

Let not these 'blind' lead the 'not so blind' !

- Ref
- <http://www.agbioworld.org>
 - <http://www.isaaa.org>
 - <http://www.terin.org>
 - <http://www.genescan.europe.com>
 - <http://www.reason.com>
 - <http://www.gmissues.org>
 - <http://www.geneticfoodalert.org.uk>
 - <http://www.bdt.org.br>
 - <http://www.ifst.org>
 - <http://www.ucsusd.org/agriculture>
 - <http://www.safe-food.org>
 - <http://www.greenpeace.org>
 - <http://www.nbif.org>

Varietal Adaptability trials, Results and their interpretation

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Agriculture research conducted could be classified into the following different categories.

1. Basic or Fundamental Research.
2. Applied Research.
3. Strategic Research
4. Adaptive Research.

Basic Research. This is of an innovative and academic nature, which is not really demand driven to benefit the farmer. The studies conducted and the results accomplished might in the future produce benefits. Studies on inheritance, drawing up genetic maps, plant type concepts and physiological studies on photosynthesis are examples of this. Genetic modification of corn to be immune to the effect of the systemic total herbicide glyphosate is an example.

Applied Research. This is demand driven where research is conducted with a specific purpose to benefit the farmer. Research conducted in evolving varieties of a crop, which give enhanced yields, resistance to specific pests or in determining the spacing or fertilizer recommendations that have to be adopted for a variety of a crop in a specific area fall into this category.

Strategic Research. This falls into a category of research conducted under crisis situations or to solve specific problems that have arisen. Bronzing or a condition caused by iron toxicity in rice, narrow leaf disorder in chilli and tip burn in onion are specific problems that had arisen requiring answers to alleviate the situation. Here concerted research is conducted using all resources available to solve the specific problem.

Adaptive Research. Once a new technology had been developed the technology has to be tested under diverse environmental conditions to test its adaptability, acceptance and practical application. In agriculture a new technology developed has to be tested under diverse environments and farming conditions.

Significance of Adaptive Research.

1. Technology developed in one place being tested under diverse environmental conditions to determine its adaptability and practical application.
2. Unbiased testing of the new technology and independent views are received.
3. Desirable traits or weaknesses yet undetected could be revealed.

4. This is the first instance where broad based evaluation by the end user namely farmer will evaluate the new technology. The new technology if not accepted by the farmer there is no point in recommending it.
5. Specific adaptability of the new technology to certain situations is identified.
6. This has an extension aspect as farmers in the same tract and areas close by will become aware of the desirable traits of the new technology under investigation resulting in lateral spread.

One such new technology is the development of a new variety of a crop. Once a breeder advances a variety as promising following observational yield trials (OYT), preliminary yield trials (PYT) and major yield trials (MYT) in the research station under ideal environmental conditions the evaluation of the variety in adaptive research commences. This comprises the following three stages.

- a. National Coordinated Variety Trials (NCVT).
- b. Variety Adaptability Trials (VAT).
- c. Large Scale Variety Adaptability Trials.

National Coordinated Variety Trials (NCVT). This investigation is carried out at limited locations in the country representing diverse physical or agro-ecological zones. However, the location selected will be ideal for the crop and the investigation is well managed providing all the necessary inputs for the crop. As a result comprehensive data regarding the performance of a variety in the different environments are established. Sensitivity of important traits to environmental changes is determined. Examples of this are the time taken by the variety to mature or a particular strain of the pathogen prevalent in that location. In this investigation the yield potential and other traits of the variety in that particular location is evaluated in comparison with already cultivated varieties.

Variety Adaptability Trials (VAT). The important aspect here is that in addition to environmental diversity the performance of the variety under vast differences in management that exist between farmers is also determined. The principle in this is to determine whether the new variety is performing well under different management conditions. Unlike the NCVT, where only limited number of locations conduct the trial in VAT the number of locations are greater and more representative evaluation is possible.

Procedure.

1. Trial kits containing seed material, design sheet relating to the layout of the trial and data recording sheets are distributed.
2. Method of planting, spacing to be adopted, application of inputs and other cultural practices are the farmer's choice. However directions are given in this regard.
3. The trial should be laid out in a tract where the crop in question is cultivated and the farmer should be a person who traditionally cultivates the crop.
4. All treatments should be treated alike.
5. Each treatment will be replicated once in each location.
6. Farmer should not pay special attention to one variety as it is to his liking.

If one variety that is being tested is subject to pests or diseases necessary control measures should be taken treating all varieties in that location alike to maintain uniformity. However degree of infestation in respect of each variety will be noted.

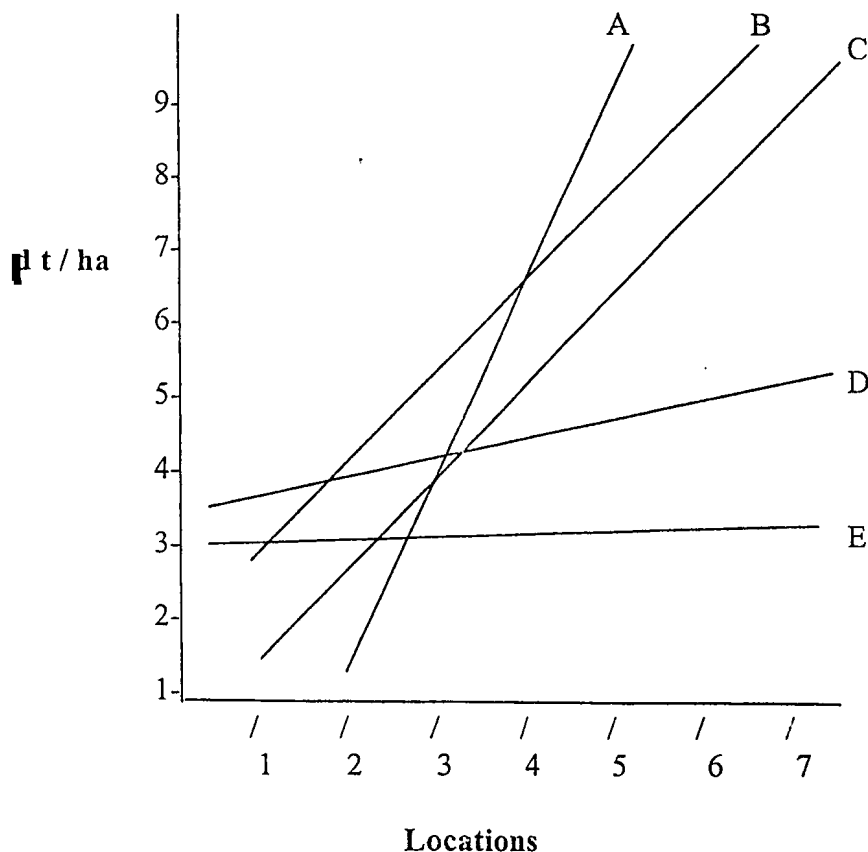
7. Owing to the above researchers should be supervising all the necessary operations.

Researcher should monitor the progress of the trials at regular intervals and also take note of the condition of the trial in respect to the different varieties. This will assist him or her in the final report in explaining the performance of a variety, which is lacking in respect of yield, which we assume to be the final criterion in assessing stability or adaptability.

Adaptability. Adaptability of a variety is a function of mean productivity and production stability across environments.

Stability. Stability of a variety is a function of yield variation due to changing environmental factors across locations or seasons or both.

The figure given below explains these phenomena.



The locations are so ranked considering (1) as the poorest location and (7) being the best location.

- A – Highly sensitive to environment variation giving high yield in the better environments and poor yields in bad environments.
- B – Most stable and adaptable variety providing higher level of yields in almost all locations.
- C – Reference variety reaction where regression coefficient is one.
- D – This variety is not sensitive to the environment to the desired level thus poorly adaptable.
- E -- This variety does not possess the ability to improve yield with better environments.
- F -- Highly stable but poor adaptability owing to low mean productivity.

The question now arises as to the procedure in assessing adaptability and stability of a variety across diverse environments. This is done, by using the phenomenon **Deviation from Maximum Response**. Deviation from maximum response is the deviation in yield of each variety from the variety giving the maximum yield at that location.

Table : 1. Grain Yield (t/ha) of 3 varieties at 3 locations.

Var. / Location	L 1	L 2	L 3	Mean
V 1	3.50	4.50	5.00	4.33
V 2	3.25	3.75	4.50	3.83
V 3	4.00	5.50	6.00	5.17
Mean	3.58	4.58	5.17	

Deviations from Maximum Response.

Table : 2. Deviations from maximum response from table 1.

Var. / Loc.	L 1	L 2	L 3	Mean	Variance
V 1	0.50	1.00	1.00	0.83	0.08
V 2	0.75	1.75	1.50	1.33	0.27
V 3	0.00	0.00	0.00	0.00	0.00

Table 1 gives the grain yield of three varieties at three different locations. Deviation in yield of each variety from the variety giving the highest yield at that location is given in table 2. Columns 4 and 5 in table 2 give the mean of and variance between such deviations of each variety across the various the locations. The variety having the lowest mean and variance is considered the most stable and adaptable variety.

The same principle is applied in a statistically analyzable form by having each treatment replicated once at each location. The method of analysis is given in annex 1.

Breeder Seed Production and Maintenance of varietal Purity in Vegetables

A.Palamakumbura (Research Officer)

1. **Introduction:** Breeder seed production is the first step in the seed production programme of the Department of Agriculture. The plant breeder or the organization, which originally introduced the variety, usually produces it. Breeder seed is produced in relatively small quantities from plants individually selected and seed extracted under very strict conditions. In some cases the plants are propagated by vegetative methods in order to reduce the chances of genetical changes from one generation to another. In breeder seed production programmes such strict measures are necessary so as to ensure the following seed qualities.

- True to varietal purity
- Free from serious seed borne diseases
- Free from obnoxious weeds seeds
- Free from insect damage seeds
- Free from physical impurities
- Having safe seed moisture content
- Having highest vigor
- Having highest viability percentage

Breeder seed is also known as pre- basic or nuclear seed.

2. Vegetable varieties

2.1 Vegetable varieties & the stations involved.

Crop	Variety	Station
Tomato <i>Lycopersicon esculentum</i> (L)	K.W.R	HORDI Gannoruwa
	T-146	HORDI Gannoruwa
	T-245	HORDI Gannoruwa
	Ravi	HORDI Gannoruwa
	Tharidu	HORDI Gannoruwa
	Thilina	HORDI Gannoruwa
	Bianz	RARDC Bandarawela
Brinjal / Eggplant <i>Solanum melongena</i> (L)	SM- 164	Makadura RARDC
	Thinnavelli Purple	RARDC Killinochi
	Padagoda	RARDC Bombowala
Beans	K.W.G	RARDC Bandarawela

<i>Phaseolus vulgaris</i> (L)	T.C	RARDC Bandarawela
Radish	Wade	RARDC Bandarawela
<i>Raphanus sativus</i> (L)	Beeralu	HORDI Gannoruwa
Bitter gourd	M.C.43	RARDC Thinnavelli
<i>Momordica charantia</i> (L)	Thinnavelli	
Snake Gourd	TA-2	RARDC Makadura
<i>Trichosanthes cucumerina</i>	Thinnavelli	RARDC Killinochchi
	MI-Short	FCRDI MI
Luffa	LA-33	RARDC Makadura
<i>Luffa acutangula</i> (L) Roxb		
Cucumber	LY-58	HORDI Gannoruwa
<i>Cucumis sativus</i> (L)		
Okra	MI-5	FCRDI MI
<i>Ablimoses esculentus</i> (L)	MI-7	FCRDI MI
	Haritha	FCRDI MI
Yard long bean	Polon Mae	HORDI Gannoruwa
<i>Vigna unguiculata</i> (L)	Hawari	HORDI Gannoruwa
Pumpking	Ruhunu/ ANK	RARDC A'Pallassa
<i>Cucurbita moschata</i> (Duschata) Poir		
Spinach	Giant spinach	HORDI Gannoruwa
<i>Basella alba</i> (L)		
Winged Bean	SLS-44	HORDI Gannoruwa
<i>(Psopphocarpus tetragonolobus)</i>		
Bushita	BS-1	RARDC Makadura
	BS-3	
Amaranthus	Green	HORDI Gannoruwa
<i>Trianthema portulacastrum</i> (L)		

3. Important procedures necessary in the breeder seed production

The following steps can be recommended, in order to archive varietal purity, and free from seed borne diseases of the breeder seed produced.

3.1 **Crop Rotation:** Same crop should not be grown in breeder seed production fields for about two years. In addition to the usual benefits that we gain from crop rotation, the following conditions are ensured in breeder seed production plots by the crop rotation.

- a. The incidence of soil borne diseases is reduced.
- b. The occurrence of volunteer plants is minimized.

3.2 **Isolation:** Satisfactory isolation of seed crop ensures such factors as.

- a. Cross-pollination prevented between cross compatible crops.
- b. Seed of different varieties of the same crop is not mixed during harvesting.
- c. Transmission of pest and diseases from alternative hosts is minimized.

Isolation is therefore vital to maintain the purity and health of a variety. The isolation can be achieved by planting cross compatible seed crops with satisfactory distances. The isolation distance depends on the type of pollination of the crop. The isolation can be achieved also by growing cross compatible crops at different times of the year. This kind of time isolation is an advantage where land is limited. Minimum isolation distance that should be maintained for breeder seed production for different vegetables is given in the annexure 1.

3.3. **Rouging / Selection:** Rouging means eliminating morphologically different plants of the same crop / variety and also the plants affected with objectionable diseases. Rouging should be carried out before flowering especially in the cross-pollinated crops. To obtain maximum benefits in rouging the following procedures should be followed.

- a. The rouging should be done in early stages of the crop when each plant can be identified separately.
- b. Walk systematically through the crop, so that each plant could be observed thoroughly.

- c. Remove the whole off looking plants.
- d. As far as possible inspect the crop in the early hours of the day which will enable identify correct observation colours of the plants etc. However, when you observe plant during daytime standing behind the sun is important.
- e. Timely inspection and rouging out is essential.
- f. Remove cross- compatible weeds and wild species as off looking plants.
- g. Keep records of numbers and types of plants removed.

3.4 Location: Correct location for breeder seed production is the place where it has been developed. However, when it is not possible location where suitable environmental factors prevailing for the particular crop would be selected.

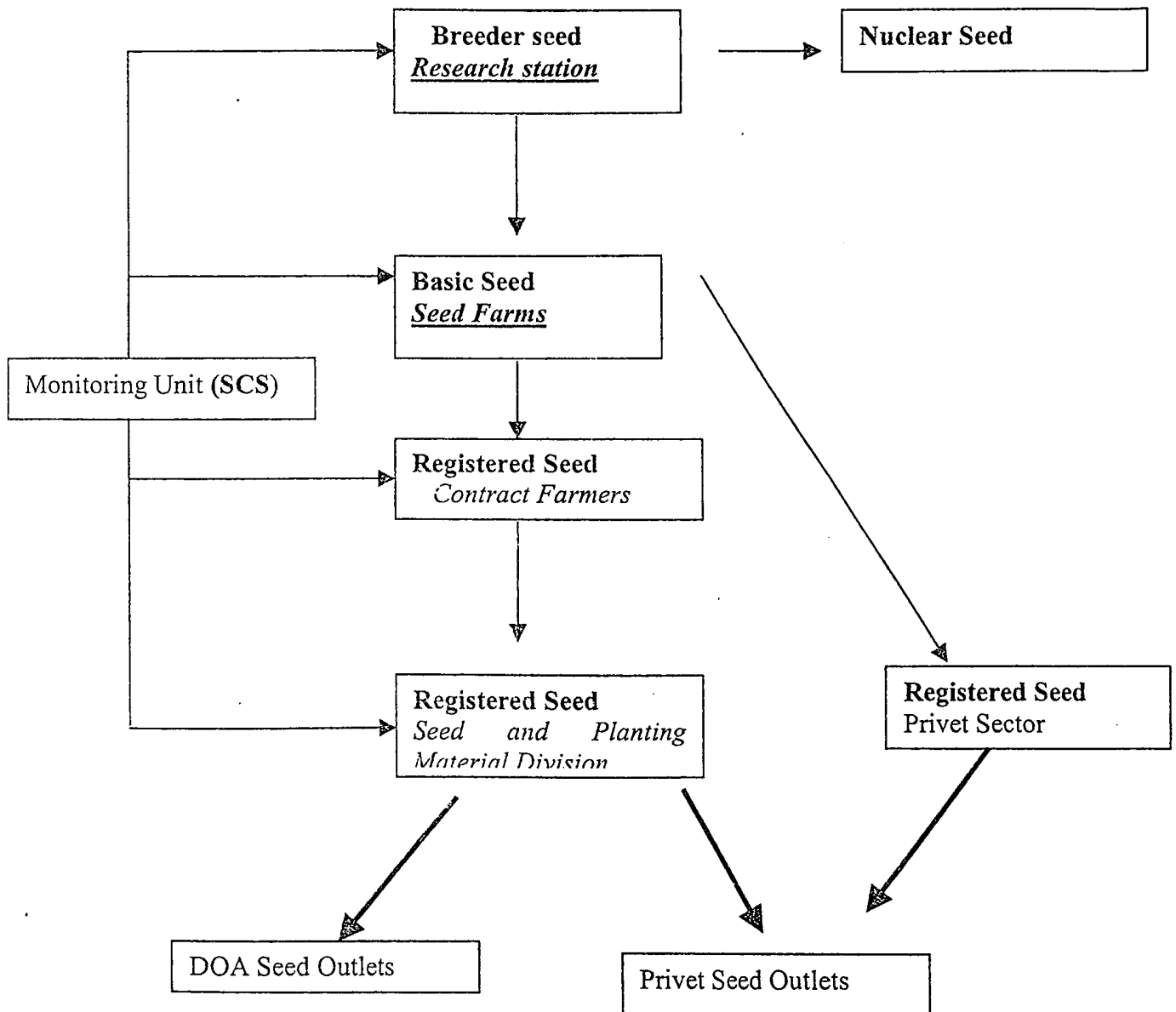
3.5 Time of planting: Selecting correct time of planting for the establishment of breeder seed crop is important to ensure healthy seed crop.

3.6 Plot Size: Breeder seed is generally produced in small quantities. However, the number of plants should be adequate for proper selection and cross-pollination between plant in the breeder seed plot.

3.7 Plot Shape: Majority of pollen contamination occurs around the perimeter of a seed crop. It is therefore important that field plots for seed production should be as near to a square as possible.

3.8 Certification: In order to maintain seed quality, an independent body under the Department of Agriculture is function to certify the breeder seed.

Vegetable Seed Production System of the DOA



Types of Pollination and Recommended Isolation Distances
Breeder Seed production

Crop	Pollination	Isolation
Tomato	S+ C (IB)	50 m
Capsicum	S+ C (IB)	400 m
Brinjal / Eggplant	S+ C (IB)	200 m
Bean/French bean	S	30 m
Radish	C (IB)	1500 m
Gourds	C (IB)	1500 m
Cucumber	C (IB)	1600 m
Gokra	S+ (IB)	400 m

S = Self

C = Out Crossing

IB = Insect Breeding

Important Factors in Breeder seed production

1 Location	Suitable climatic Conditions
2.Crop Rotation	Avoid Mixing Minimize Pest and Diseases
3.Nuclear Seed Production	To continue Breeder Seed Production
4.Isolation	Avoid Out breeding
5. Selection/rouging	Genetic Purity

Off- type Identification

Bean	Plant habit, Vigor, Leaf shape, flower Colour, Pod shape, Pod colour
Okra	Plant height, Plant habit, Pigmentation of leaves, Petioles, and Stems, flower size and colour
Tomato	Growth habit, Leaf characters, General Plant habit, Leaf colour, Immature fruit colour
Capsicum	Growth habit, Vigor, Pod colour, Pod shape Pod Length
Brinjal/Eggplant	Plant habit, Leaf shape, Leaf size, Anthocyanin colour

Procedures Involved in Variety Release

Plant breeders by way of tailoring plant characteristics have played a vital role in the development of agriculture. The varieties so developed have influenced the modern society to a large degree by ensuring self sufficiency, stabilizing production, facilitating multiple cropping, extending the boundaries of cultivation and providing increased nutrition per unit area. While providing varieties superior to the existing varieties has always been the aim of plant breeders the goals of plant breeding and hence the object of new releases have been wide-ranging.

Object of new releases

1. New crops

New crops are brought to existence from time to time either by improvement of wild species or by genetic combination of existing crops (e.g. *Triticale*).

2. Increased yield

New plant types are developed to bridge the gap between maximum biological yield and highest experimental yield.

3. Improved quality

- Organoleptic (*taste, smell, texture, colour*)
- Chemical (*oil, sugar*)
- Mechanical (*length, strength*)
- Biological (*nutrition, digestibility*)

4. Adaptation to production systems

- Mechanization (*uniform seed size, germination and emergence; lodging resistance, suitability for combine harvesting etc*)
- Dense populations (*lodging resistance, modified leaf orientation*)
- Irrigated culture (*semi dwarfism, pest resistance*)
- High fertility (*early vigor, pest resistance, lodging resistance, high tillering ability*)
- Low fertility (*deep root system, high water use efficiency*)
- Multiple cropping (*early maturity, uniform ripening, photoperiod insensitivity etc.*)
- Minimum tillage (*early vigor, good competitive ability against weeds, herbicide resistance etc.*)

5. Stress tolerance

Abiotic stresses (*salinity, flooding, mineral toxicity, drought, heat, cold, herbicides*)
Biotic stresses (*new pests, new strains of established pests, hitherto unimportant pests becoming major pests*)

6. Increased uniformity

Plant uniformity (*facilitate agronomic practices, aesthetic appeal, legal*)

Considering the abundance of new cultivars developed by various breeders in a country, it is imperative that they are systematically named and released in order to facilitate

- Documentation
- Plant variety protection
- Seed certification
- Farmer protection *and*
- Promotion

Release procedures

Variety release procedures vary from country to country. In the United States varieties produced by the breeders of private companies and the public institutes reach the farmers in several pathways. The decisions to release varieties produced by the State Agricultural Experiment Stations are made by boards appointed by the relevant stations. The breeders provide information along with Regional Trial data. The private companies either conduct their own trials or enter their varieties in public trials by paying a fee.

In India varieties are released at two levels. State releases are made by State variety Release Committees in state capitals presided by Directors of Agriculture. Breeders submit their proposals to the committee in a specific pro forma. A release is followed by notification by the Notification Committee based on the recommendation of the VRC. A Central Variety Release Committee with head quarters at ICAR makes Central releases.

In Sri Lanka the authority to release varieties lies on the Variety Release Committee headed by the Director General of Agriculture. The Secretary to the VRC calls for submissions to the VRC periodically. Committee Meetings are held whenever there is a sufficient number of candidate varieties for release. Breeders along with representatives from relevant sectors such as the Extension, Seed Certification, Universities and the seed industry are invited to the meeting.

Justification of the release

Submissions are made on a pro forma (Annex 1) and personally presented and justified by the breeders at the Variety Release Committee Meeting.

Information on both the **quantity** and **quality** of yield of the entry is required. Data from on-station, multilocational and farmer field trials are to be given. Generally, data are generated from two seasons each in coordinated variety trials and farmer field trials. Although a stability analysis is favored no restrictions are imposed on the method used. The recommended practice is to employ several methods of stability analysis. Results from large-scale adaptability tests are called for in some crops. An **economic analysis** to justify the new release may utilize these data. If the candidate variety requires a new **package of agronomic practices** it has to be presented with the relevant research

data. If the new variety is claimed to be tolerant to any **pests and diseases**, it should be confirmed by an independent test report.

Availability of a sufficient quantity of planting material is a prerequisite to release of any new variety.

In Sri Lanka a submission for variety release should accompany the report on **Distinctness Uniformity and Stability (DUS)** provided by the Seed Certification Service. This requirement is in effect in many countries with **Plant Variety Protection** legislation. A report on **Value for Cultivation and Use (VCU)** is also requested in some European countries.

Distinctness Uniformity and Stability Tests

DUS testing is an internationally accepted procedure adopted mainly for the purpose of plant variety protection. It verifies that a new variety is **distinct** from any commonly known variety and it is sufficiently **uniform** and **stable**. Examination of distinctness uniformity and stability is based mainly on growing-out tests carried out in a manner specified by the competent authority. The examination generates a **description of the variety**, using its relevant characteristics by which it can be defined. For this reason, DUS testing can be regarded as a prerequisite for seed certification. DUS testing of new varieties have been practiced in Sri Lanka since 1984.

Definitions:

Distinctness –

A variety must be clearly distinguishable from any other variety whose existence is a matter of **common knowledge** for it to satisfy the requirement of distinctness.

Uniformity –

A variety is deemed uniform if it is sufficiently homogeneous having regard to the particular feature of its propagation.

Stability –

A variety is deemed stable if its relevant characteristics remain unchanged after repeated propagation or in the case of a particular cycle of propagation at the end of each such cycle.

Administration of the DUS examination

In most countries an official authority administers DUS tests with varying degrees of breeder/ applicant participation.

1. **Official testing** - tests conducted by the official authority
2. **Breeder testing** – applicant/breeder conducts the whole test and produce a report based on which the official authority decides on DUS.

The system adopted at present in Sri Lanka is official testing with the Seed Certification Service responsible for testing and reporting.

Usually the applicants are required to submit a **Technical Questionnaire** along with the material for testing. The material submitted should be representative of the candidate variety. Usually entries are submitted for DUS testing simultaneously with submission for adaptability testing.

Characteristics used in DUS Testing

For any variety to be capable of protection it must first be clearly defined. It is agreed that a variety is defined by its **characteristics** and that those characteristics are therefore the basis on which a variety can be examined for DUS. Characteristics used for DUS should fulfill the requirement that its expression:

- results from a given genotype or combination of genotypes;
- is sufficiently consistent and repeatable in a particular environment;
- exhibits sufficient variation between varieties;
- is capable of precise definition and recognition;
- allows uniformity requirements to be fulfilled;
- allows stability requirements to be fulfilled.

Design of DUS tests

Aspects such as layout of the trial, number of plants to be examined, method of observation and the number of growing cycles required depends largely on the nature of the species to be examined.

Layout of the trial –

1 or 2 locations

At least 2 replications per location

Number of growing cycles –

Vegetative propagation - 1 or 2 growing cycles

Other – 2 or 3 maximum 4 growing cycles

Number of plants to be examined –

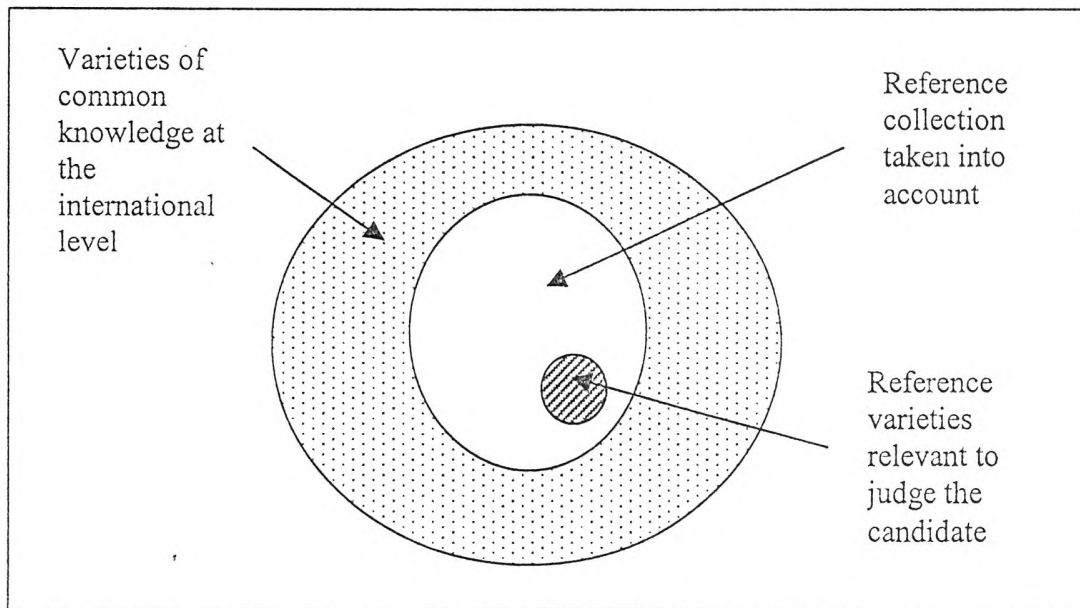
Depends on the crop (less for highly self-pollinated crops such as groundnut, bean and soybean and vegetatively propagated crops such as potato and cassava; more for semi-cross pollinated crops such as capsicum, okra and pigeon pea; most for highly cross-pollinated crops such as maize and cucurbits).

A **Test Guideline** developed for a particular crop allows an agreed and harmonized approach to examination. Different states of expression of a characteristic are given in Test Guidelines.

Examining distinctness

In theory it is necessary to examine distinctness in relation to all varieties of common knowledge of the species. In practice however, it is possible to exclude many varieties, which are belonging to different groups based on specific expression of characteristics. The technical questionnaire completed by the applicant will assist in determining the varieties most similar to the candidate, which are directly compared with the candidate. A variety may be considered to be clearly distinguishable if the differences

in characteristics are consistent and clear. Statistical methods may or may not be required for the assessment of distinctness.



Examining uniformity

It is possible to assess uniformity by the number of obviously dissimilar plants where all the plants of a variety are very similar such as in the case of vegetatively propagated (e.g. onion, potato) and self-pollinated varieties (e.g. soybean, mungbean). Where the range of variation within a variety is larger, as in the case of cross-pollinated varieties (e.g. maize, cabbage), uniformity is assessed by taking into account the overall range of variation in comparison with that of similar varieties. The uniformity and stability of a hybrid may be assessed by examining the hybrid itself or under certain conditions by examining both the progenitor and the hybrid.

Examining stability

. Generally, no special tests are performed to examine stability. Stability may be tested by growing further generations from new seed stock to ensure that it exhibits the same characteristics as shown by the previous material supplied. Stability of hybrids may be assessed by examination of the parent lines in addition to the hybrid.

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Submission of Crop Varieties / Cultivars for Official Release

1. **Crop / Botanical name**
2. **Proposed name of the cultivar**
3. **Justification**
4. **Type of the cultivar / variety**
5. **Method of multiplication**
6. **Origin**
7. **Variety cultivar performance**
 - I. **Yield**
 - a. **Quantity assessment**
 - b. **Quality assessment**
 - II. **Age**
 - III. **Reaction to biotic and abiotic stress in comparison with the control**
(should be based on scientific screening procedures)
 - IV. **Response to fertilizer (if applicable)**
 - V. **Economic analysis of yield performance**
8. **Variety / cultivar description** (follow the standard descriptors prepared by PGRC)
9. **Results of DUS test**
10. **Social response**
11. **Any other remarks**
12. **Other particulars**
 - Time taken for development**
 - Region and station where the variety / cultivar is developed**
 - Availability of planting material / breeder seed**
 - Name / names of the breeder**
 - Names of the collaborators**
 - Recommendation of the Director / DDR / ROIC where the variety is developed**

Vegetable Seed Requirement and Production Systems in Sri Lanka

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1.0 Introduction

1.1 Vegetables in Sri Lanka

Vegetables play an important role in providing a balanced diet for a healthy life. In Sri Lanka too, vegetables are so common in daily diets like in any part of the world. However, the per capita consumption of vegetables in Sri Lanka is, very much lower than the recommended amounts by the nutritionists. As such there is a tremendous potential to increase the vegetable production in order to meet this gap. Potential for employment generation in the vegetable sector is very high due to labour intensive cultivation practices and possibilities of value addition. Since vegetable prices are high these crops have a high income generating potential.

Therefore, the development of this sector has become vital in the overall development of the country. Thus increasing the vegetable production, which will improve the nutritional requirements and provides employment opportunities of the countrys growing population has given a prominent place in the food production plan. This will be achieved by increasing the productivity through the application of advanced crop production technologies. Use of quality seed is one of the important components among the other options available in reaching this goal.

1.2 Importance of quality seed

Good seed is one of the basic and most important input for a successful cultivation. It greatly influences the growers profit. The cost of seed may represent a mear fraction of the expenses of production and yet the quality of seed may be a decisive factor in the profit or loss of growers enterprise.

2. Vegetable seed requirement of Sri Lanka

The annual cultivated extent of vegetables is around 110,000 ha. Almost every farmer is aware of the importance of using good seeds and its contribution to higher yields. Thus invariably farmers make attempt to obtain best seed available within their capabilities. Cultivated extent and seed requirement of local vegetables are given in table 1.

3. Vegetable Seed Production and Production Systems in Sri Lanka

The Department of Agriculture (DOA) has taken the leadership in developing an organized seed production programme as far back as 1950's with the development of high yielding varieties. The DOA was the sole supplier of seed in the country up to late 1980's. However, with the increasing demand on quality seed the government with the dawn of the decade 1990 took the initiative to

involve the private sector in seed production and marketing including vegetable seed. With more private sector involvement in local seed production the government in 1996 declared a National Seed Policy (NSP).

3.1 Classes of Vegetable Seed

There are three seed classed in vegetable crop group.

- * **Breeders Seed**
Breeder's seed is the material, which is directly produced by the originating agency or breeder.
- * **Basic Seed**
This is the progeny of breeder seed handled to maintain to specific genetic purity and identity.
- * **Standard Seed**
Standard seed is the progeny of the basic seed so handled as to maintain satisfactory genetic identity and purity. The certified seed of vegetables are referred to as standard seed.

3.2. Vegetable Seed Production

The total requirement of exotic varieties of vegetable seed like carrot, Beet, Leeks, Cabbage, Lettuce and Knol khol are imported and supplied by private companies, where as seeds of other vegetables are produced locally. Any cultivar growth for a number of years or seasons is likely to deteriorate. Therefor quality assured seed production is very important.

3.2.1 Breeder Seed Production

Maintenance of varietal purity and the production of Breeder Seed of DOA recommended vegetable varieties are done by the Horticulture Research and Development Institute of the DOA.

3.2.2 Basic Seed Production

Seed & Planting Material Development Centre of the DOA is responsible for the production seed of DOA recommended varieties of local vegetable crops (17 crops with 48 varieties). These seeds are produced in five government seed farms.

3.2.3 Certified Seed Production

The certified seed of vegetables are referred to as Standard Seed. Both public and private sector are involved in the production of standard vegetable seed of large number of varieties. The private sector involvement with the industry is quite recent and more participation is yet to come. However, DOA plays a significant role in the production of standard seed through the government farms and as well as through the contract growing programmes. **Annual seeds production of recommended local vegetable varieties is given in table 2.**

Use of high quality seed has a triple impact on the production, namely yield increase, improved quality of final product and low cost of production. Therefore, use of high quality seed will enable to increase the productivity and thereby the total production of the country. In order to achieve this; farmers must have ready access to high quality seed at affordable price.

3.3 Vegetable seed production Systems

There are two main seed production systems in the country

3.3.1 Informal seed production

Majority of farmers produce seed by themselves from their previous crop and share the excess with neighbouring farmers. In vegetable seed it is estimated to be about 50-60%. The quality of such seed varies widely. This production mechanism is known as informal seed production system.

3.3.2 Formal seed production

The other supply mechanism known as the formal seed supply system. The quality of seed produced in the formal system is assured for its genetic and physical purities and germination capabilities. Vegetable seed certified by the Seed Certification Services (SCS) of the Department of Agriculture (DOA) and other quality assured seed produced by the private enterprises using basic seed supplied by the DOA belong to this category.

It is practically difficult to meet the demand for vegetable seeds from the formal system. Though such a situation is beneficial, it is not necessarily required. Farmers can easily continue for several seasons to produce good quality vegetable seed from the original stock purchased from the formal sector. The development of the formal seed supply system is mandated to the Seed & Planting Material Development Centre (SPMDO) of the DOA, while the informal seed sector development is the responsibility of the Extension Services of both Central and Provincial Government. The quality assurance is done by the SCS of the DOA. It should be emphasized, that any strategy to increase the usage of quality seed must involve both formal and informal systems. In the vegetable sector, the final objective is to supply at least 60% of the national requirement with quality assured seed.

3.4 Potato Seed Production

Sri Lanka needs about 9000 mt of seed potato annually. The cultivation is mainly confined to higher elevated areas. In the early years the elite grade of seed potato was imported by the DOA for both seed multiplication in government potato farms (five farms in the district of Nuwara Eliya which is over 1800 meters in elevation) and for limited issues for farmers for seed production. At present most of the seed potato were imported and distributed by the private sector among cultivators in the two main potato-growing districts. There are number of varieties being introduced by the private sector each year. However, there are many complaints on the quality of the imported seed and high prices. In order to overcome this situation Government, in 1999, took the initiative to produce potato seed locally using tissue culture technique.

Table 1. Statistics on local Vegetable Seed Requirement of Sri Lanka

Crop	Approximate annual Extent (ha)	Total seed requirement (M.tons)
Bean	8600	520
Brinjal	9200	03
Bittergourd	4800	30
Capsicum	3900	04
Cucumber	4300	04
Luffa	3400	15
Okra	7200	32
Potato	8000	20000
Snakegourd	3100	22
Tomato	4900	2
Veg. Cowpea	3000	60

Table 2. Annual Seed Production quantities of Recommended Vegetable Varieties

	No of Recommended Varieties	Basic Seed Production (Kg.)	Standard Seed Production (Kg)
Bean	6	4000	15000
Radish	2	100	4600
Capsicum	1	20	900
Tomato	9	60	2500
Egg Plant	3	15	2700
Okra	3	200	17000
Vegetable Cowpea	6	700	9000
Snakegourd	3	200	5000
Bittergourd	2	150	4400
Luffa	2	120	2500
Cucumber	1	25	2300
Spinach	1	25	800
Amaranthus	1	40	400
Wing Bean	1	100	700
Pumpkin	1	50	2300
Melon	1	20	200
Chilli	5	100	10000
Potato	3	G-0 - 12mt, G-1- 90mt, G-2 - 400mt	



POLICY OF THE GOVERNMENT OF
SRI LANKA ON SEED AND
PLANTING MATERIAL INDUSTRY

Ministry of Agriculture, Lands & Forestry

March-1997

POLICY OF THE GOVERNMENT OF SRI LANKA ON SEED & PLANTING MATERIAL INDUSTRY

1. BACKGROUND

The seed industry in Sri Lanka is rapidly maturing into a dynamic and effective force to bring the best and most adapted varieties of crops and horticultural plants to the farmers and home gardeners of Sri Lanka.

The Department of Agriculture (DOA) took the leadership in the late 1950's in developing an organized seed production programme, with the development of high yielding varieties through breeding and selection. The activity of producing and distributing seed of about 70 varieties of more than 20 crops, continued to be the responsibility of the DOA until recently. Additionally, grafts, and seedlings of a wide array of horticultural crops are produced and distributed by the DOA.

2. PURPOSE

In the light of the changing situation, where the private sector is expected to play a role in this sector, it is necessary to provide guidelines to encourage private sector participation in producing the country's requirement of quality seed, in addition to the role of the Department of Agriculture of meeting the basic seed requirement. What is expected eventually is the establishment of viable seed industries. This is being done to facilitate the Sri Lankan farmers gaining easy access to the highest quality seed available, either from domestic sources or through importation thereby enhancing yields, production and farm income. This new policy, therefore, is focussed towards the formation and establishment of seed enterprises, which will produce and market the seed. The government agencies, including the DOA will be playing a more active role in providing the required support, ensure high quality seed production and co-ordination.

3. NEW SEED POLICY

The Seed & Planting Material Policy consists of the following components.

- a. Varietal development and release
- b. Provision of basic seed and planting material
- c. Commercial seed production, processing, marketing and utilization.
- d. Importation of quality seed and planting material.
- e. Co-ordination and development assistance.
- f. Certification and quality promotion
- g. Other support activities.

a. **Varietal Development & Release**

- i. The Ministry of Agriculture, Lands & Forestry (MALF) will invite seed and planting material entrepreneurs to be members in the National Seed & Planting Material Committee which has the mandate for decision making on the general seed programme, varietal release and seed & planting material standards. Through this process better use would be made of the technical capacities of the public sector research agencies.
- ii. MALF will share the manpower, facilities and other resources with the private sector. Detailed procedures mutually acceptable to the government and private sector will be worked out.
- iii. DOA will make available basic genetic material and advance lines developed locally to public and private sector organizations interested in breeding and or testing such material.
- iv. MALF will encourage enactment of Breeder's Rights as an incentive to plant breeders in the next 3 years.
- v. Varietal development organizations will continue to maintain the purity of their respective varieties.
- vi. Testing and release of new local varieties developed by the public and private sectors, requiring official certification will be carried out by DOA in a timely manner.

b. **Provision of Basic Seed & Planting Material**

- i. DOA will provide adequate quantities of basic seed of the recommended varieties of crops to the private seed enterprises at negotiated prices.
- ii. Certified seed production/distribution programme of the DOA will be progressively reduced and eventually phased out. In the medium term, DOA will focus on the provision of basic seed. When independent seed enterprises mature to become capable of producing basic seed, the production of this class of seed by the DOA will be reduced correspondingly.
- iii. Information on promising cultivated varieties of crops will be made available to growers.

contd.....

iv. Limited quantities of plants of varieties that are not yet tested and recommended will be made available to growers to test in suitable regions on an "all care-no responsibility" basis so that interested growers may try them.

c. **Commercial Seed Production, Processing, Marketing & Utilization**

i. The government will not compete with the private sector in commercial seed production.

ii. Seed enterprises will be given assistance for commercial seed production. The concept of "Seed Enterprise" would include Farmer Organizations, Co-operatives, Agro-industrial Firms, Individual Companies, NGO's and others. Assistance to be provided includes;

- Plant Quarantine Services
- Basis Seed when required
- Technical Assistance/Training
- Custom Cleaning and Storage Services to the extent possible.
- Market Information
- Internal Quality Control and Certification
- Quality Promotion

iii. Tax concessions applicable to investments in agriculture will be made available to those engaged in the Seed Industry.

iv. To ensure price stabilization every effort will be made to maintain buffer stocks of selected crops.

v. No duties will be levied on machinery and equipment imported for seed production, processing and quality control.

d. **Importation of Quality Seed & Planting Material**

i. The private sector will continue to import seed and planting material in a manner not to retard the progress of the seed industry.

ii. All seeds and planting material imports should be subject to plant quarantine and quality control.

e. Seed Certification and Quality Promotion

- i. An intensive programme on the use of quality seeds will be undertaken.
- ii. Official Certification will be essential for seed and planting material that are produced and offered for sale as certified or quality assured seed. All seeds marketed must meet the minimum standards prescribed by the Seed Certification Services of the DOA. A unified seed container labelling system will be implemented.
- iii. All seeds imported or locally produced must be labelled for minimum standards laid down in the Seed Law. Until such time the Seed Law passed, the standards established by the seed Certification and Plant Quarantine Centre of DOA will be applicable.

f. Development & Co-ordination

The National Seeds & Planting Material Committee (NSPMC) will be established with the participation of the public and private sectors to include seed producers and seed importers to assist in the development of the seed industry and to co-ordinate activities relating to the industry. This Committee will meet twice a year before each cultivation season, in January/February in respect of Yala and in July/August in respect of Maha. The Committee will be chaired by the Secretary, Ministry of Agriculture, Lands & Forestry.

Functions of the Committee are as follows:

- i. to establish basic guidelines and scientific principles to ensure sustenance and production of highest quality seed at competitive prices.
- ii. to review policy and advice the government on the needed policy directives to achieve the objective of a viable seed industry.
- iii. to undertake periodic review of the progress of the seed industry.
- iv. to identify the needs and facilitate the provision of technical assistance to produce quality seed.

- v. to co-ordinate among public sector agencies in working towards the development of the private sector industry.
- vi. to secure funding and manpower resources required to develop a viable seed industry.
- vii. to review the quality standards of seed periodically with a view to assist in the development of the industry.
- viii. to supervise the development of a seed sector data base.

The Seed and Planting Materials Development Centre of the DOA will function as the Secretariat to this Committee.

INTRODUCTION TO SEED TESTING

One of the greatest hazards in agriculture is sowing seed that does not have the capacity to produce an abundant crop of the required cultivars. Seed testing has been developed to minimize this risk by assessing the quality of seed before it is sown. Seed quality is a concept made up of different attributes.

These attributes are of interest of different segments of the industry.

- To the producer
- The processor
- The ware- house man
- The merchant
- The farmer

The certification authority and the government or agency responsible for seed control. In all cases the ultimate object of making a test is to determine the value of seed for planting.

SEED PURITY

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Objective

- a) To determine the percentage composition by weight of the sample being tested and
- b) To identify the various species of seeds and inert particles constituting the Sample.

Definition of components:

Pure seed:

Pure seed shall refer to the species as stated by the sender or found to predominate in the test, and shall include all botanical varieties and cultivars of the species.

Even if immature, under sized, shrivelled, diseased, or germinated provided they can be definitely identified as of that species shall be regarded as pure seed, unless transformed into fungal sclerotia, smut galls or nematode galls.

Intact seed :

Achenes and similar fruits, schizocarp and mericarp, with or without perianth and regardless whether they contain or pure seed.

Inert matter :

Seed and seed like structure a piece of broken or damaged seed , achenes and caryopsis one half of the original size or less .

Seeds of the Fabaceae with the seed coat entirely removed .

Soil and chaff , stems , leaves , flowers , nematode galls fungal bodies , caryopsis of gamine replaced by insect larvae and all other matter not seed .

Other crop seed :

Other crop seeds include seed and seed like structures of any plant species other than that of pure seed and weed seeds .

Weed seed :

Weeds include , seed and seed like structures of any plant species other than that of pure seeds and other crop seed .

Procedure :

Equipment for purity test :

- a) Dividers
- b) Purity working table
- c) Analytical balance
- d) Weighing table
- e) Pointers and such small hand tools

Equipment for dividing :

- a) Various types of mechanicals dividers are given in the ISTA rules. Soil divider is recommended.
- b) Soil divider gives more accurate results.

Obtaining two following working sample:

- 4. Physical purity testing working sample
- b) Lot control working sample

Obtaining the working sample: for physical purity test

To obtain the working sample , the submitted sample is reduced by a weight estimate to contain at least 2500 seeds subject to a minimum of 0.5 g and maximum of 1000 g by using the dividers .

e.g. Lettuce (*Lactuca sativa*) 0.5 g
beans (*Phaseolus vulgaris*) 1000 g

Before obtaining the working sample, the submitted sample should be thoroughly mixed.

Obtaining the working sample: for lot control test:

The working sample shall be weight estimated to contain ten times of 2500 seeds.

e.g Paddy (Oryza sativa)	Physical Purity ----- (2500 seed)	Lot control ----- (25000 seeds)
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Drawing the sub sample,

Two sub samples are taken from the submitted sample for the purity analysis. The objective is to obtain a sub sample (working sample) that:

- a Takes less time to analyse the composition
- b gives more accurate results .

Separation of the components

Physical purity: determine the composition by weight

- i Pure seed
- ii Other crop seeds
- iii Weed seeds
- iv Inert mater

Weighing of components

The number of decimal places necessary in weighing in order to calculate percentage to one decimal place is indicated below.

<u>Weighing of working sample in grams</u>	<u>number of decimal</u>
<u>places</u>	
Less than 1 g	4
1 g - 9.999 g	3
10 g - 99.99 g	2
100 g - 999.9 g	1
1000 or more g	0

Using the tolerance Table:

- 1. If a duplicate analysis is made of two sub samples, the difference between the two must not exceed the tolerance between duplicate analyses given in the I S T A rules.

2. If the difference is in excess of the tolerance, further pairs have to be analyzed.

Calculation and expression of results:

Test for weight gain or loss during analysis. Add together the weights of all the component fractions from the working sample. This sum must be compared with the original weight as a check against gain or loss. If there is a discrepancy of more than 5% of the initial weight, a retest must be done. The Result of the retest is then reported.

Calculation of component percentages,

For each half working sample, calculate the percentage by weight of each component to at least two decimal places. Percentage must be based on the sum of the weights of the components in each half working sample and not on the original weights of the original sample. Add the appropriate percentage together from each half working sample and calculate the average percentage by weight for each component.

Lot control test: determine the purity by numbers

- i Other distinguishable varieties
- ii Other crop seeds
- iii Weed seeds
- iv Damaged seeds (mechanical damage and insect damage) Other than that, smell and the appearance are tested .

In testing the smell and appearance, the submitted sample is compared with the standard sample, which are prepared for every season.

Reporting results :

The result of a purity analysis shall be given to one decimal place and the percentage of all components must total 100 . Components of less than 0.05% shall be reported as "Trace" . The percentage of pure seed , other seed and inert matter must be reported in the space provided on the analysis certificate . if the result for a component is nil , this must be shown as "0.0" in the appropriate space .

DETERMINATION OF MOISTURE CONTENT

Introduction:

- Seed moisture content is the key factor influencing the storability of seeds.
- This will directly influence the quality of a seed lot.
- Therefore, it's very important to measure initial seed moisture content of freshly harvested seed after storage.

Definition:

The moisture content of a sample is the loss in weight when it is dried in accordance with International seed testing association (ISTA) rules . It is expressed as a percentage of the weight of the original samples.

Apparatus:

The following apparatus are necessary depending on the method used.

- (a) An adjustable grinding mill

The mill used for grinding must meet the following requirements.

- Be constructed of non-absorbent material.
- So constructed that both the seeds to be ground and the resulting ground material are protected from the ambient air during grinding, to the maximum extent possible.
- Grind evenly at a speed that does not cause heating of the ground material.
- Be adjustable to obtain particles according to the ISTA rules.

- (b) Constant temperature oven and accessories

- May be gravity – convection or mechanical convection type .
- Electrically heated with thermostatic control.
- Containers must be made of non-corrosive metal or glass.
- Containers must be approximately 0.5 mm thickness and snug fitting covers to minimize gain or loss of moisture. 1
- It should have sides rounded at the base, a flat bottom, and level edges.
- Both the container and its cover should be identified by the same number.
- The well fitted desiccators.

(c) Analytical balance

- This must be quick weighing and capable of weighing to 0.001 gr

(d) Sieves

- Wire sieves are required with meshes of 0.50 mm 1.00 mm and 4.00 mm.

Sample submitted for moisture determination

The objective of sampling for a moisture test is to determine the moisture content of the seed at the time of sampling. So the submitted sample should be accepted for moisture determination only if it is intact, moisture proof container from which as much air as possible has been excluded. The determination shall be started as soon as possible after receipt.

During the determination exposure of the sample to the atmosphere of the laboratory shall be reduced to the absolute minimum and do not require grinding not more than two minutes may elapse from the time the sample is removed from the container.

Procedure

1. Obtaining working sample

Before the working sample is drawn the submitted sample shall be thoroughly mixed by one of the following methods.

- (a) Stir the sample in its container with a spoon.
- (b) Place the opening of the original container against opening of similar container and pour the seed back and forth between the two containers.

Draw two independently working sample from the ground materials each of the following weight.

Container diameter	Les than 8 cm – 4 to 5 g
	8 cm or lager - 10 g

Oven drying

There are two oven methods.

- (a) Low constant temperature oven method.
- (b) High constant temperature oven method

(a) Low constant temperature oven method

Dried for 17 ± 1 hours at 103 ± 2 °C seeds containing oils with a working sample of exactly 5 g in two replicates.

(b) High constant temperature oven method

The procedure is same as low constant temperature. Oven is maintained at temperature of 130 – 133 °C. The sample is dried for a period of four hours for maize two hours for other cereals, and one hour for other species.

Pre drying

If the species is one for which grinding is necessary and the moisture content is more than 17 % (or 10 % in the case of soy bean and 13 % in the case of paddy) pre drying is obligatory.

Calculating the results

After cooling the dried samples in the desiccators the container plus seed is weighted. The difference of the total weight of the container pulse lid and the seed weighed separately before the drying and after drying and calculate as a percentage.

Tolerance

The result is the arithmetic mean of the duplicate determination of the sample. Provided the difference between for the determinations does not exceed 0.2 %.

Reporting

The moisture content is to be reported to the nearest 0.1 %.

LABORATORY SEED CLEANING

Objective

The objective of the laboratory cleaning analysis is to determine:

- (a) The percentage by weight of good seed and inert matter of the sample being cleaned and by inference the percentage of good seed and inert matter of the seed lot represented by that sample.
- (b) The identity of noxious weed seeds in the sample.

Advantages of laboratory seed cleaning

Paying out of the farmers as soon as possible after harvest of the contract grown seeds before the lot is processed.

Laboratory cleaning machines

The clipper and the indented cylinder are the machines usually used in the laboratory to clean paddy.

There are two machines.

1. Cleaning over the clipper

The weight of the submitted sample is 1 kg. The entire sample is passed over the clipper using a bottom sieve of 1.5 – 2.0 mm depending on the variety being cleaned to separate good seed and inert matter.

2. Cleaning over the indented cylinder

There after only the good seed portion cleaned by the clipper should be passed over the indented cylinder and in this operation all other matter other than seeds are removed. The good seed portion coming out from the cylinder should be analyzed for other distinguishable varieties (ODV), other crop seeds, weed seeds, seed colour, seed smell and viability.

Good seed

Good seed , refers to seed other than other matters which can be removed by laboratory cleaning machines . Besides the variety being cleaned, this includes other distinguishable varieties (ODV) ,other crop seeds ,noxious weed seed ,which cannot be removed by laboratory cleaning machines.

Inert matter

Inert matter shall refer to all other matter, than that of good seed (e.g. weed seeds, earth particles, sand, chaff, dust, pieces of straw, other inert material, ergot, sclerotia etc.)

Noxious weed seed

Weed seeds , which cannot be removed by machine processing .

Reporting results

Results are given as percentages.

SEED GERMINATION

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Objective:

The purpose of germination testing is to gain information with respect to the field planting value of seed and to provide results, which can be used to compare the value of different lots.

The germination test is carried out under the best possible, if not optimal conditions with regard to Temperature, Moisture, Light and Substrate as to give the most complete, rapid and regular germination for the majority of samples of a particular species. The conditions are standardized and therefore, repeatable. Such conditions can be only realized in the laboratory.

Definition:

The emergence and development of the seedling to a stage where of its essential structures indicate whether or not it is able to develop into a satisfactory plant under favorable conditions in soil.

When doing a germination test three things should be considered before starting.

1. Seed structure- Dicotyledons, Monocotyledons.
2. Type of Germination-Hypogeal, Epigeal.
3. The conditions required to get maximum germination – Moisture, Aeration, correct Temperature and in some cases light.

By considering these points the best method for germination to choose.

Procedure:

400 seeds are counted at random from the well-mixed pure seed. Care should be taken not to select seeds as this can cause biased results.

Replicates of 100 seeds are normally used. Split replicates of 50 even 25 may be used. This depends on the size of seeds and type of substratum used. Seeds are placed on the substrate, so that seeds do not touch each other and maximum available space is used

Preparation of the substratum is important. Too much of moisture can kill the seed by not allowing enough aeration and gas exchange necessary for the seed to respire and to germinate. Different substrates are used in the germination test depending on size of the seed and seedling height.

- a. Paper
- b. Sand
- c. Soil

The substrate used should be non-toxic and free from harmful microorganisms, which might interfere with the growth or evaluation of seedlings.

Paper:

The texture of the paper should have an open and porous nature, but it should be such that the roots of the seedlings will grow on and not into the paper. The paper should possess sufficient strength to resist tearing when handling during the test.

Moisture capacity:

The paper should have the capacity to hold sufficient water for the whole of the test period, so as to ensure a continuous supply of moisture to the seed.

Sand:

The sand should be reasonably uniform and free from very small and large particles. The particles of the sand should have the capacity to hold sufficient water to provide continuous movement of water to the seeds and seedlings, but also provide sufficient pore space for aeration for optimal germination and root growth.

Soil:

Soil should be of good quality, non-caking and free from any large particles. It must be free from foreign seeds, Bacteria, Fungi, Nematodes or toxic substances.

Soil or artificial compost is commonly used instead of sand specially for species, which produce seedlings with phytotoxic symptoms when germinated in sand or paper.

Method:

Paper substrates are used for the following method:

Top of paper (TP):

The seeds are germinated on top of one or more layers of paper. Eg. Cabbage, chilli etc.

Between paper (BP)

The seeds are germinated between two layers of paper, loosely covering the seeds with an additional layer of filter paper. By placing the seeds into folded envelopes. E.g. Onion, cels.

Pleated paper (PP)

The seeds are placed in a pleated, accordion like paper strip. Eg. Beet.

Factors Affecting Seed Germination

Temperature:

Temperature is one of the most critical factors in the laboratory germination. Different seeds require different temperature ranges for germination. Below or above that range, germination is prevented. In the temperature ranges, there is usually an optimal temperature where the seed realizes the highest germination in the shortest time. Some seeds require constant temperatures of 20 C or 30 C and some alternating temperatures of 20/30C.

Moisture and aeration:

The substrate must at all times contain sufficient moisture. However, moisture content must not be excessive. The initial quantity of water to be added will depend on the nature and dimensions of the substrate and also on the size and species of the seed to be tested. Special measures for aeration are not usually necessary for TP and PP tests enclosed in boxes or petri dishes. For BP however, care should be taken that envelopes and towel rolls are loose enough to allow for sufficient air around the seeds. For the same reason the material covering the seeds in sand and soil tests should not be compressed.

Light:

Some seeds only germinate in the dark; others are indifferent in their reaction. Light is necessary for forming essential structures of the seedling during the germinating period. Light is usually given for 8 hours in every 24 hours. In case of alternating temperatures, the light is even during the high temperature period. The light intensity should be approximately 750-1250 lux.

Dormant Seed

Many seeds do not germinate under conditions, which are normally regarded as favorable for germination. Such seeds are called dormant, and germination of such seeds can be induced by special treatments.

Causes of seed dormancy:

- a. Mechanically resistant seed coats.
- b. Impermeable seed coats.
- c. Rudimentary embryos.
- d. Physiologically immature embryos.
- e. The presence of chemical inhibitors.

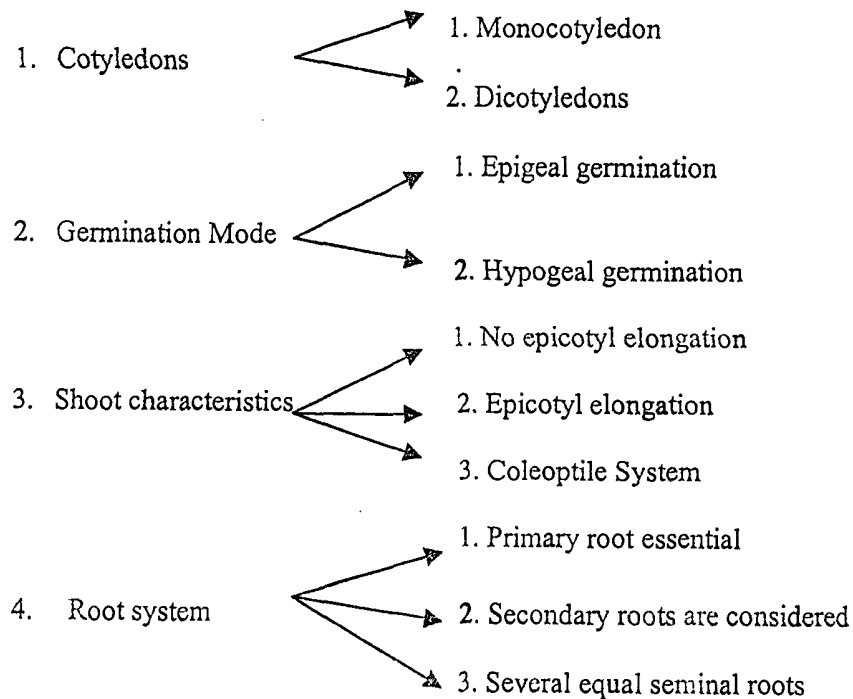
Methods of breaking dormancy:

The method employed in breaking seed dormancy will depend upon the type or types of dormancy that a particular seed exhibits.

- a. Scarification.
- b. Removal of seed coat.
- c. Stratification – pre chill, pre dry.
- d. Use of chemicals GA₃, HNO₃, KNO₃
- e. Leaching.
- f. A combination of the above.

Seedling evaluation:

For easy and correct seedling evaluation-developing seedling in the test period re divided into several groups, according to similar morphological development. In each group four essential structures are considered as follows:



Classification of Normal and Abnormal Seedlings:

Normal Seedlings:

Three categories of seedlings are classified as normal.

1. Intact seedlings.
 - Well developed root system.
 - Well developed shoot.
 - Specific number of cotyledons.
 - Well develop primary leaves.
 - Well develop coleoptile.
11. Seedlings with slight defects.
111. Seedlings with secondary infection.

Abnormal seedlings:

1. Defective.
 - Primary root.
 - Secondary roots.
 - Mesocotyl.
 - Coleoptyl.
11. Decay as a result of primary infection.
111. Entire seedling deformed

BIOCHEMICAL TEST FOR VIABILITY (TETRAZOLIUM TEST)

Introduction

The tetrazolium test is a method of evaluating a lot for potential germination.

The test is recognized by the ISTA it requires considerable experience and practice.

Objectives

- a. To obtain a quick estimate of germination potential
- b. To determine the germination potential of a seed lot which show dormancy.

Principle of the test:

Chemical use:

- a. 2,3,5 Triphenyl Tetrazolium chloride or Bromide salt.
- b. Water - PH of the water is 6.5 - 7.0 (use buffer solution)
- c. The strength of the TTC solution) 0.1%-1.0%

The TTC solution reacts as an indicator and the reduction processes take place within living cells and formation of red stable non-diffusible substance called Triphenyl formazan.

TTC solution + living cells
(Colourless)

Triphenyl formazan
(Red colour)

Equipments:

1. Sharp cutting instruments: Scalpels, razor blades and needles
2. Water bottles
3. Temperature control units: Temp 30° - 40°
4. Seed moistening media: Germination paper etc.
5. Magnifying equipment or lenses.

Procedure:

1. Conditioning:
Most kind of seed requires conditioning before staining either by slow moistening or soaking.
2. Method
 - a. No moistening or additional preparation
(Water permeable some small seeded legumes)
 - b. Slow moistening - soak seeds with moist paper
Large seeded legumes
 - c. Piercing, puncturing or cutting of coat
(Small seeded grasses Chilli etc.)

- d. Cutting longitudinally through the mid section of the embryo
e.g. Maize, Paddy etc.
- e. Removal of seed coat.
(Cucumber, Gourd family)

Evaluation:

By examining the complete embryo to determine whether there is sufficient staining of the essential parts of the embryo.

Advantages of the Tetrazolium Test:

- a. Reliable indication of viability can be obtained in 24-48 hours.
- b. Ability to anticipate weakness before they are evident in a germination test.
- c. Useful if other equipment is unavailable
- d. Doubt at the completion of a germination test because of unbroken dormancy
- e. for an experienced analyst each deviation in embryo staining indicates one or more causes of damage i.e. mechanical damage, heating etc.

Disadvantages of the Tetrazolium Test:

- a. It requires a great deal of skill and experiences to complete this test accurately.
- b. It does not show up dormancy problems unless done in conjunction with a germination test.
- c. Fungicide or insecticide treated seeds may not show phyto-toxic effects as in a germination test.
- d. Although an answer on viability is more quickly attainable, the actual time taken to do a tetrazolium test is much longer than that of the standard germination test.

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