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Volume II

Soil and Crop Management

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NURSERY MANAGEMENT TECHNIQUES IN CASHEW

By

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SEMINAR REPORT

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ABSTRACT

Cashew is one of the most important commercial crops of our country. Eventhough India contributes 43 percentage of the production in the world, it meets only 50 percentage requirement of the country. Indian cashew production scenario is characterised by low productivity because of poor management .By adopting suitable management strategies starting from nursery stage itself only can improve the production. National Research Centre for Cashew recommends softwood grafts as planting material due to its high percentage success. For getting quality graft management of rootstocks and grafts are important.

As a part of Management practices it was found that germination of the seed was enhanced by alkali seed treatment (Sivasubramaniam *et al.*, 1990) and sowing upto a depth of 4 cm (Nawale and Salvi, 1992). The potting media found to be the best was 1:1 proportion of soil and farmyard manure for coarse textured soils and the nutrient supplement of 200 g N + 100 g P_2O_5 +200 g K_2O was found to enhance the performance of root stock (Jagadeeshkumar, 2000). The growth of rootstock was also improved by the use of biofertilizers (Usha, 2000), Supplementation of nutrients through irrigation water (Manjunatha and Melanta, 2001) and biological, chemical and solarization treatments of the potting mixture (Meagle Joseph, *et al.*, 2002). The growth and success of grafts were influenced by the age of rootstock, pre-curing periods and scion length (Pushpalatha *et al.*, 1991). Studies on appropriate temperature and humidity requirement in the mist chamber for successful grafts production was conducted at Cashew Research Station, Madakkathara (Pushpalatha *et al.*, 1993). The application of paclobutrazol was found to induce dwarfism in the cashew grafts (Pushpalatha, 2000).

Cashew being a perennial crop, quality planting materials should be given due importance for healthy and productive orchards. So maximum care should be given at each and every step of planting material production.

NURSERY MANAGEMENT TECHNIQUES IN CASHEW

Introduction

Cashew is one of the most important commercial crop of our country. Eventhough India accounts for 43% of the production in the global scenario, it meets only about 50% requirement of the country. It is because of the low productivity of the cashew plantations. So it is absolutely essential to enhance the cashew production in the country. Cashew growing states in India are Kerala, Karnataka, Tamil Nadu, Goa, Andrapradesh, Maharashtra, Madhyapradesh, Orissa, West Bengal, Tripura and Manipur. Area, Production Productivity of India and Kerala during 1999-2000 are

	India	Kerala
Area	6.86 l ha	0.89 l ha
Production	5.2 lt	0.65 lt
Productivity	758 kg/ha	733 kg/ha

There is a need for an integrated approach in management strategy not only in the main field but starting from the nursery to improve the production.At present soft wood grafts are used for planting since the percentage success of this in the field is more compared to Air layering, Patch budding, Veneer grafting, Side grafting and Epicotyl grafting etc. Propagation through seedlings is not recommended since there is lot of variability seen in progenies. The demand of cashew grafts per annum in Kerala and India is estimated to be 10 & 60 lakhs respectively. This leads to large scale production of grafts in nurseries with assured quality. To get healthy and quality grafts appropriate nursery management techniques are to be adopted.

The cashew nursery includes

1. Selection of nuts
2. Raising of rootstock
3. Selection of scions
4. Production and maintenance of grafts

Selection of nuts

Nuts are selected from the high yielding mother trees whose yield is not less than 5 kg/tree and preferably from trees which are tolerant to pest and diseases. Tree should be dwarf, hardy in nature and with intensive branching.

Characters of good seed nuts

Nuts selected should be of good shape, medium size (7-9 g) and should be of high specific gravity i.e., nuts which sink in water or 10% saline solution are selected. Nuts should be dry, free from fungal or insect attack and current season's nuts are best because it won't loose viability upto 8 months.

Raising of rootstocks

Usually cashew seeds take more than three weeks time for getting around 80 percentage germination after sowing. To enhance this farmers practice is to soak the seeds in cow dung slurry, hot water treatment etc., but this also takes more than 3 weeks. So to enhance the germination and to reduce the time taken for germinations, work was done by Sivasubramanian *et al.* 1990 at National Pulse Research Centre, Pudukottai. The treatments included were soaking seeds in 10% sodium hydroxide half an hour, 1 hour, 2 hours and overnight soaking in cow dung solution, hot water and in water along with untreated check. In this he found that seeds treated with sodium hydroxide 10% for ½ hour gave 90% germination other treatments delayed emergence. This experiment proved the importance of alkali treatment in enhancing the germination (Table 1).

Table 1. Effect of seed treatments on germination of cashew

Treatment	Germination (%) at 17 DAS
T_1 - Soaking in alkali (10% NaOH) for ½ hr	90
T_2 - Soaking in alkali (10% NaOH) for 1 hr	80
T_3 - Soaking in alkali (10% NaOH) for 2 hrs	30
T_4 - Overnight soaking in cowdung solution	66
T_5 - Overnight soaking in hot water	50
T_6 - Overnight soaking in water	54
T_7 - Control (untreated)	64
CD at 5%	15.96

(Sivasubramaniam *et al.*, 1990)

Treated nuts are sown in polythene bags of standard size 25×15 cm and 200 gauge thickness filled with potting mixture. While sowing,depth of sowing also greatly influence the germination percentage. In order to standardise the optimum sowing depth, study was under taken by Nawale and Salvi, (1992) at Maharashtra on variety vengurla-1. In the trial, seeds were sown at different levels of depth viz., surface sowing and upto 10 cm from soil surface in polythene bags filled with a mixture of soil and farmyard manure (2:1) ratio. In case of the surface sowing, treatment seed stalk ends were exposed seeds were soaked in water for 24 hours before being planted. After sowing, and watering was done every day. Observations regarding number of seeds germinated were recorded in each treatment separately.

Results of the study (Table 2) showed up to 100 percent germination of cashew seed nuts under the seeds were sown to the depth of 4 cm with in 28 days and there after germination percent declined. In the treatment surface sowing, eventhough 98 percent germination was obtained in 21 days, the seed nuts were exposed and there fore cotyledons were become more attractive to the pests like crows, rodents and squirrels, which eat the fleshy cotyledons. Hence, sowing of seeds at surface level is not desirable in case of cashew. It was found that the cashew seeds are necessarily required to be placed in soil with stalk ends upwards. If seeds are placed in horizontal position, and with their stalk ends downward position,it results into rotting of seeds.

Table 2. Effect of depth of seed sowing on germination in cashew

Days to germination	Germination %						
	Depth of sowing						
	Surfac sowin	1 cm	2 cm	4 cm	6 cm	8 cm	10 cm
7	Nil	Nil	Nil	Nil	Nil	Nil	Nil
14	96	84	18	2	1	Nil	Nil
21	98	98	87	58	50	48	21
28	98	100	100	100	87	82	59
35	98	100	100	100	87	83	69

(Nawale and Salvi, 1992)

The above two experiment reveals that treatment of seed nuts with 10 per cent sodium hydroxide for ½ an hour and sowing up to 4 cm depth gives higher percentage of germination.

Management of Cashew rootstocks

Healthy rootstock is a pre requisite for the production of healthy grafts weak and unhealthy seedling are one of the major problems for the production of quality grafts in cashew. There fore it is necessary to develop suitable nursery techniques for the production of healthy rootstocks. Here are some of the nursery techniques in management of rootstocks.

I. Effect of potting media and nutrient supplements on growth of cashew rootstocks

This work was carried out by Jagadeeshkumar (2000) at Cashew Research Station, Madakkathara. Here he used three different potting media such as

(i) Soil, sand and FYM (1:1:1 ratio)
(ii) Soil and FYM (1:1 ratio)
(iii) Soil and Sand (1:1)

Nutrient supplements used per 100 kg potting media are

(i) Control
(ii) 100gN
(iii) 200 g N+100 g P_2O_5
(iv) 200 g N, 100 g P_2O_5 and 200g K_2O

Pot culture experiments were conducted to study the effect of different potting media and nutrient supplements on growth and vigour of cashew seedlings intended to be sued as rootstocks. The results from the table 3 shows that among the three potting media compared, performance of seedlings was the best with 1:1 soil: FYM mixture. This is due to the dominant influence of farmyard manure and its ability to provide an optimum moisture and aeration in addition to the supplement of the essential plant nutrients. In 1:1 soil & FYM potting media has 50 percent of farmyard manure while in 1:1:1 soil, sand and FYM potting media contains only 33 percentage of farm yard manure. The result of the experiment also suggest that apart from nutrient content of the media, farmyard manure improves the physical, chemical and Biological properties of the growing media. Addition of sand in potting mixture is to improve the drainage and aeration of potting media. The soil used for the aeration of potting media. The soil used for the experiment contains more than 65 percentage of sand and it is sandy loamsoil. So the result of the present investigation suggest that in a coarse textured soil, where the proportion of sand is around 65 percent, cashew seedlings can be grown in 1:1 soil, FYM potting media.

Among the different nutrient supplement to these potting media, best growth of seedlings was obtained from the treatment 200g N+100g P_2O_5+200g K_2O. This may be due to the balanced and optimum quantity of fertilizers applied to the potting media, which have improved the nutrient supplying capacity of the media with increased uptake and assimilation.

Table 3. Effect of potting media and nutrient supplements in growth characters of cashew seedlings (60 DAS)

Treatments	Height (cm)	Girth (cm)	No. of leaves/plant	Leaf area (cm^2 $seedling^{-1}$)
Soil:Sand:FYM (1:1:1)	23.88^{b}	2.96^{a}	16.83^{ab}	405.6^{b}
Soil:FYM (1:1)	30.11^{a}	3.11^{a}	17.24^{a}	458.2^{a}
Soil:Sand (1:1)	22.27^{b}	2.95^{a}	16.17^{b}	417.2^{b}
Nutrient supplement/ 100 kg potting mixture				
No nutrient supplement	22.35^{c}	2.93^{a}	15.38^{b}	398.5^{c}
200 g N	24.97^{bc}	2.94^{a}	16.60^{a}	421.0^{bc}
200g N + 100 g P_2O_5	25.86^{ab}	3.04^{a}	17.42^{a}	436.9^{ab}
200 g N + 100 g P_2O_5 + 200 g K_2O	28.48^{a}	3.12^{a}	17.52^{a}	451.6^{a}

(Jagadeeshkumar, 2000)

Jagadeeshkumar also studied the effect of lime incorporation in potting media on growth of cashew rootstocks. Incorporation of lime at different levels varying from zero to 500 gram per 100 kg potting media revealed that the response of cashew seedlings to the application of lime was limited. This effect in acid soil media may be due to the buffering action of organic matter, which occupies 33 percentage of potting media. It may also be inferred that the cashew seedlings are probably adapted to acidic conditions of laterite soils.

II. Effect of Nutrient (N, P and K) supplied through irrigation water on growth of rootstocks

Softwood grafting technique is the easiest method of vegetative propagation and is now recommended for commercial multiplication of cashew varieties. Since softwood portion of the rootstock is utilized for grafting, the quality of rootstock influence graft union success. In order to raise the quality rootstock required for soft wood grafting there is a need to encourage the fast growth. In the nursery, it will be easier to encourage the growth of rootstocks by supplying nutrients through irrigation water. Such plants maintained in the nursery will acquire the advantage of establishing well in the field.

This study was conducted at the Gandhi Krishi Vignana Kendra (GKVK), Bangalore by Manjunatha and Melanta (2001). The experiment was conducted in the green house with optimum temperature and humidity. There were three levels of N and K and one level of P tried in nine different combinations. The details of these nine treatments are given in Table 4. Nutrients were applied once in a week through irrigation water at the rate of 100 ml per plant to the rootstocks.

From Table 4 it was found that growth parameters of rootstock was highest in the treatment containing 150: 20: 100 ppm NPK supplied through irrigation water. This may be due to appropriate use of optimum levels of N, P and K.

Table 4. Effect of nutrients (N, P & K) supplied through irrigation water on growth of rootstock

Treatments NPK (ppm)	Rootstock (45 DAS)		
	Height (cm)	Girth (cm)	No. of leaves/plant
100:20:50	20.60	1.42	9.26
100:20:100	20.70	1.50	9.10
100:20:150	19.49	1.50	8.76
150:20:50	22.65	1.61	9.30
150:20:100	23.22	1.66	9.40
150:20:150	22.90	1.58	9.36
200:20:50	21.70	1.59	8.70
200:20:100	22.17	1.64	9.20
200:20:150	20.50	1.63	9.26
CD (0.05)	1.82	NS	0.10

(Manjunatha & Melanta, 2001)

III. Effect of biofertilizers on the growth of cashew rootstocks

Biofertilizers occupy a very prominent role in sustainable agriculture. They are ecofriendly and plays a significant role in improving nutrient availability to the crop plants. Many eminent scientists worked on the effect of biofertilizers on the growth of cashew rootstocks. They all found that biofertilizers have positive influence on the growth and quality of rootstock. One such experiment on biofertilizers conducted in our university was by Usha (2001) at cashew research station Madakkathara.

In this experiment, biofertilizers Arbuscular Mycorhizal Fungi (AMF), *Azotobacter* and *Azospirillum* were applied at the rate of 10 gram to each poly bag at the time of sowing of nuts. The results of this study (Table 5) reveals that, among the three biofertilziers AMF was found to be the best. This is because AMF has high mycorrhizal association and the fungal hyphae function is synonymous to root hairs. This increases the surface area and available nutrient absorption and transportation, which ultimately results in the higher absorption and accumulation of nutrients by the plants. Production of plant hormones leading to better development also favour nutrient uptake.

Azotobacter and *Azospirillum* also improves the plant growth compared to control. Here the higher plant growth is due to the production of biologically active metabolites like IAA, Giberellins, Cytokinins and Vitamin B by the microorganisms in addition to the fixation of nitrogen and the production of antibiotics and quinones which are harmful to the plant pathogens in the rhizosphere.

Table 5. Effect of Biofertilizers on the growth of rootstock (3 MAS)

Treatments	Height (cm)	Girth (cm)	No. of leaves/plant
AMF	55.0	5.4	18.2
Azotobacter	50.4	5.0	16.2
Azospirillum	50.6	5.0	14.2
Control	47.2	4.6	15.2

(Usha, 2001)

IV. Biological, chemical and solarisation effect on seedling vigour in cashew

Biological and chemical treatments of potting mixture as well as solarisation of soil can produce profound effects on seedlings growth. These techniques can also influence germination of seed and vigour of seedlings. No attempts have been made so far to study the effects of soil solarisation and biological and chemical agents, on growth and seedling vigour of cashew. In the context Meagle Joseph *et al.* (2002) conducted this work at cashew research station, Madakkathara to study the effects of biological agents [*Trichoderma harzianum* and Vesicular Arbuscular Mycorrhiza (VAM)], chemical agents (Copper oxychloride and Mancozeb) and soil solarisation techniques, on growth and vigour of cashew rootstocks. The various treatments included were given in the Table 6.

Observation such as germination and growth characters were recorded vigour index of the seedlings was calculated using the procedure suggested by Abdul Baki and Anderson (1973) i.e., vigour index=Germination percentage × Dry weight of seedlings.

From the table it can be found that germination in all the treatments involving fungicides, biological agents and solarisation were high compared to the control. It can be due to the population of harmful micro organisms responsible for lowering germination might have been less in potting mixtures treated with these.

Growth and vigour of cashew rootstocks were high with treatments T_4, T_2 and T_1. But there effects did not differ much. The result clearly suggest that solarisation of potting mixture and inoculation of potting mixture with *Trichoderma harziamum* have got profound effect on growth and vigour of seedlings. It can be concluded that sowing cashew seeds in solarised potting mixture (1:1:1 soil: sand: farmyard manure) or potting mixture involving 1:1:1 solarised soil: Sand: FYM or potting mixture involving 1:1:1 solarised soil: Sand: FYM inoculated with *Trichoderma harzianum*, can help to enhance the growth and vigour of cashew rootstocks. The increase in growth and vigour in solarised potting medium may be due to the increase in available forms of nitrogen, phosphorus and potassium nutrients and the Trichoderma helped in the elimination of pathogen in root zone.

Table 6. Biological, chemical and solarisation effect on seedling vigour in cashew (55 days)

Treatments	Germination % at 20 DAS	Height (cm)	Girth (cm)	No. of leaves	Dry weight (g)	Vigour index
T_1	94.7	28.4	3.2	15.8	7.7	729
T_2	98.7	31.0	3.1	13.4	7.8	769
T_3	92.0	31.1	3.1	18.0	5.3	487
T_4	100.0	33.8	2.4	14.5	7.8	780
T_5	98.7	34.0	3.3	18.8	4.0	395
T_6	98.7	35.3	2.4	18.7	4.7	464
T_7	100.0	30.	31	16.3	4.8	480
T_8	94.7	31.	3.1	15.3	4.3	407
T_9	97.3	30.5	2.8	19.0	5.7	555
T_{10}	89.3	26.5	2.4	20.7	5.3	473

(Meagle Joseph *et al.*, 2002)

T_1 – Solarised potting mixture (1: 1: 1 Soil: Sand: FYM)
T_2 – Potting mixture (1: 1: 1 Solarised soil: Sand: FYM)
T_3 – T_1 + *Trichoderma harzianum* @ 2g/bag at sowing time
T_4 – Potting mixture (1: 1: 1 Solarised soil: Sand: FYM inoculated with *Trichoderma harzianum*)
T_5 – Ordinary potting mixture + *T. harzianum* applied @ 2 g bag at sowing time
T_6 – Potting mixture (1: 1: 1 Soil: Sand: FYM inoculated with *T. harzianum*)
T_7 – Ordinary potting mixture drenched with Copper oxychloride (0.2%) 100 ml/bag before sowing
T_8 – Ordinary potting mixture drenched with Mancozeb (0.2%) 100 ml/bag before sowing
T_9 – Ordinary potting mixture + VAM @ 10 g/bag at sowing time
T_{10} – Control (ordinary potting mixture)

V. Herbicidal weed control in cashew poly bag nursery

Due to frequent irrigation and more Farm Yard Manure in potting mixture, weeds grow luxuriantly in the poly bag and compete with cashew seedling. Conventional method of hand weeding was found to be costly and time consuming with adverse effect on seedling growth. Chemical used control can be an alternative to Conventional method of weed control. In view of this, an experiment was conducted by Burondkar *et al.* (1993) at the Regional Fruit Research Station, Vengurla, during kharif to study the effect of commercially used and available herbicides on control of used for a and growth of cashew seedlings in nursery.

In this work pre emergence herbicide like Atrazine @ 1.25 and 2.5 g/l of water and Fluchloralin @ 2.7 g/l of water were applied next day of sowing whereas postemergence herbicides Glyphosate @ 4.1 g/l and Paraquat @ 1.2 g/l of water were applied on the 9th day after sowing under most of the weeds were visible while cashew seedlings are not visible. The hand weeding were done at 10, 40 and 80 DAS.

The most predominant weeds in the experimental sites were *Euphorbia hirta, Portulaca oleraceae, Eragrostis minor, Cyperus rotundus, Cynodon dactylon, Amaranthus viridis.*

It was evident from Table 7 germination was not affected adversely by an herbicidal treatment. Except higher rate of Atrazine (2.5 g/l), none of the herbicidal treatment had inhibitory effect on plant height, girth and number of leaves. That is because phytotoxicity in case of higher dose of Atrazine was seen as lower leaves of seedling became brownish and generally dried up.

It was found that herbicidal treatments were found significantly more effective than hand weeding. The maximum weed control efficiency was recorded in a treatment with Fluchloralin followed by lower level of Atrazine, paraquat and Glyphosate.

It is thus inferred that weedicides mostly Fluchloralin @ 2.7 g/l as pre emergence and paraquat and Glyphosate @ 1.2 and 4.1 g/l respectively as post emergence could be safely used for effective control of under and for better growth of cashew seedling in cashew poly bag nurseries.

Table 7. Effect of herbicides on weed control in cashew polybag nursery

Herbicides	Application time	Weed population/ 100 bags		Weed control efficiency (%)	
		40 DAS	80 DAS	40 DAS	80 DAS
Atrazine @ 1.25 g/l	Pre- em	10.0	80.00	94.0	63.0
Atrazine @ 2.5 g/l	Pre- em	10.0	92.00	91.0	80.0
Fluchloralin @ 2.7 g/l	Pre- em	2.3	43.00	98.6	80.3
Glyphosate @ 4.1 g/l	Post- em	11.6	68.00	91.0	68.8
Paraquat @ 1.2 g/l	Post- em	12.0	54.60	92.9	75.0
Hand weeding	Thrice at 10, 40, 80 DAS	78.0	22.00	51.0	89.80
Unweeded control	-	169.6	219.00	-	-
CD (0.05)	-	11.7	62.08	-	-

(Burondkar *et al.*, 1993)

Selection of scions

Scions are selected from trees of good canopy spread, dwarf in nature and the scions of current seasons shoot with pencil thickness. These selected scions are precured prior to grafting. Precuring is done by clipping off the lamina leaving the petiole intact on the shoots. Within next few days, these petiole drop off, indicating the shoots are getting cured. Due to the storage of food material, the shoots gets thickened and the terminal bud appears swollen. This swollen conditions indicates that shoots are ready for separation from the tree. Precuring is done to increase the meristematic activity in the axillary and terminal buds.

Inorder to standardise the optimum period of precuring, scion length and the age of rootstock seedlings for softwood grafting, a comprehensive study was taken up at Cashew Research Station, Madakkathara by Pushpalatha *et al*. (1991).

In the first study (Table 8) four ages of rootstocks were compared viz. 21, 28, 35 and 42 days old. There were three precuring treatments viz. 7 days, 14 days and no precuring. In this study the percentage of grafts sprouted and survival recorded two months after grafting and it was found that 100% sprouting and 100% survival was obtained when 28 days old rootstock and 7 days precured scions were used for grafting. It was also observed that as the age of rootstock advanced the success got reduced. Similarly [illegible] not giving the precuring treatment and also increasing it beyond 7 days had a detrimental effect.

In the second set of study the varieties which commonly used as scion material were taken and four different length of scions viz. 10, 12.5, 15 and 20 cm were tried under each of the variety. The percentage of grafts sprouted and survival recorded two months after grafting are given in Table 9. The data revealed that maximum sprouting and survival (95-100%) was recorded when 10 cm and 12.5 cm long scions were used. Increasing the length further resulted reduction in success. It was also observed that longer scions (15 and 20 cm) showed a tendancy for bending because of top heaviness causing poor graft union.

Table 8. Effect of age of Rootstock and precuring period of scion shoot on sprouting & survival of softwood grafts.

Age of rootstock	Precuring period	Sprouting percentage	Survival percentage
21 days	Without	30	25
	7 days	96	90
	14 days	71	65
28 days	Without	81	80
	7 days	100	100
	14 days	96	95
35 days	Without	53	50
	7 days	86	86
	14 days	46	40
42 days	Without	30	18
	7 days	50	36
	14 days	50	16

Table 9. Effect of scion length on sprouting and survival of softwood grafts

Variety	Scion length (cm)	Sprouting (%)	Survival (%)
Anakkayam-1	10.0	100.0	95.0
	12.5	100.0	100.0
	15.0	96.6	95.0
	20.0	88.3	80.0
Madakkathara-1	10.0	100.0	95.0
	12.5	100.0	100.0
	15.0	98.3	95.0
	20.0	93.3	70.0
Dharasree	10.0	100.0	100.0
	12.5	96.0	95.0
	15.0	96.0	94.0
	20.0	90.0	75.0
Madakkathara-2	10.0	100.0	100.0
	12.5	100.0	100.0
	15.0	88.3	80.0
	20.0	81.6	60.0

(Pushpalatha *et al.*, 1991)

Softwood grafting

After selecting the rootstock, precured scions softwood grafting is done by wedge technique. Here two pairs of bottom leaves are retained on the stock and stock was decapitated 5 cm above the second pair of leaf and a vertical incision, along the length of the stump to 3.75 cm from the top of the stock was made. The scion was prepared like a wedge giving 3.75 cm long slanting cut on the opposite sides of basal end of scion with a very sharp knife. The scion was inserted into the stock and graft joint was firmly tied with polythene strip of 100 guage. To create a humid atmosphere around the scion bud, polythene caps of 4" x 3" size of 100 guage thickness were provided above the scion top for 15-20 days till the bud sprouted. The caps were dipped in water on alternate days to keep them wet.

Management of cashew grafts

I. Influence of a mist chamber on graft take in cashew

After grafting great care should be given to get good quality grafts vegetative propagation no doubt is the accepted method for the multiplication of planting materials in cashew. Of the propagation techniques available in cashew, softwood grafting is the most important. The success percentage of vegetative propagation depends on the season during which it is done. The seasonal difference in graft take is mainly due to the influence of temperature and humidity. Inorder to find out the effect of humidity and temperature on graft take work done by Pushpalatha *et al.* (1993) on the influence of a mist chamber on graft take in cashew at Cashew Research Station, Madakkathara.

There were two treatments for the study namely (1) grafts kept in a mist chamber and (2) grafts kept in partial shade without a mist chamber. Humidity was created inside the mist chamber by spraying water with a rocker sprayer. The humidity and temperature of the chamber was regularly monitored. So that the R.H. in the chamber was maintained around 90% and the temperature between 23-27°C. The temperature in the partial shade during the study period ranged from 24-36°C and humidity from 75-80%.

The results revealed that (Table 10) keeping grafts in a mist chamber had definite positive influence to increase the graft take. This had reduced not only the time taken for sprouting but also enhanced the success percentage of grafts. The grafts kept in the mist chamber sprouted within 12 days where as those kept under partial shade took 12-25 days for sprouting. It was also noted that the sprouting percentage as well as the survival of grafts were high (95.3) in respect of grafts kept in mist chamber compared to those kept in partial shade. When the grafts were kept in partial shade without mist chamber 80.5% of the grafts sprouted but only 75.6% survived. Between the mist chamber and partial shade conditions the sprouting percentage was higher by 14.7% in the mist chamber. The corresponding figure in the survival percentage was 19.7. The advantage of a mist chamber in grafts taken in terms of sprouting and survival was clear. This can be mainly attributed to the difference in the temperature and humidity of the two environments. This high humidity, low temperature and minimum fluctuations in these parameters in the mist chamber might have contributed to this high graft take and survival of grafts.

Table 10. Influence of Mist chamber on sprouting and survival of softwood grafts

Months	No. of days taken for sprouting		Sprouting (%)		Survival (%)	
	MC	PS	MC	PS	MC	PS
March	7-9	13-16	98	85	98	82
April	6-10	15-20	98	80	98	75
May	7-12	16-24	90	77	90	70
Average			95.3	80.6	95.3	75.6

(Pushpalatha, 1993)

MC - Mist chamber
PS - Partial shades

II. Effect of Nutrients (N, P and K) supplied through irrigation water on growth of grafts in cashew

Work conducted by Manjunatha and Melanta (2001) at GKVK, Bangalore. The experiment conducted in the greenhouse with optimum temperature and humidity. There were three levels of nitrogen and potassium and one level of phosphorus tried in nine different combination as given in Table 11.

Nutrients were applied once in a week through irrigation water at the rate of 100 ml per grafts. After weighing the nutrients, each nutrient was dissolved in a small quantity of water. Volume was made up to a required level by using known quantity of water to supply nutrient to plants under each treatment separately.

From the table it was found that graft union success rate and growth characters of the grafts were highest in the treatment containing 150:20:100 ppm NPK supplied through irrigation water.

Table 11. Effect of nutrients (N, P & K) supplied through irrigation water on growth of grafts

Treatments NPK (ppm)	Grafts (30 DAS)		
	Graft union success (%)	Height (cm)	No. of leaves/ plant
100:20:50	71.60	19.62	3.93
100:20:100	80.00	21.20	3.46
100:20:150	69.80	19.70	4.06
150:20:50	59.90	20.80	4.33
150:20:100	81.54	22.50	5.26
150:20:150	58.30	19.20	3.80
200:20:50	75.40	20.90	3.73
200:20:100	79.60	21.70	4.60
200:20:150	73.01	20.50	3.66
CD (0.05)	12.96	1.18	0.86

(Manjunatha & Melanta, 2001)

III. Response of cashew grafts to soil application of cultar (paclobutrazol) in nursery

Paclobutrazol is used as a broad spectrum growth retardant in recent years. This has been reported to selectively control tree vigour in many fruit species without markedly affecting the fruit size. No attempts were reported in cashew to control tree stature through manipulating seedling growth by chemical application. By the induction of dwarfism in cashew grafts would help to enable high density planting and to reduce the cashew management in the field.

In this aspect work conducted by Pushpalatha (2000) on the induction of dwarfism in cashew grafts at the nursery stage. Here work done by applying cultar twice to the cashew grafts, first at one month age and then at three month age. This chemical diluted to one litre with water and was applied around the plants 3 cm away from the base. The grafts were not irrigated for 3 days and irrigated slightly for next 3 days and then irrigated as usual.

The data from Table 12 revealed that application of cultar at one and two ml per plant reduced the height of grafts to a substantial level. This was true at all stages of observation. When observed two years after treatment, grafts were much reduced in their size. Girth of grafts was improved significantly in response to soil application of cultar. Leaf production was reduced drastically in response to application of chemical during early stages of grwoth. But when observed at 24 months age number of leaves were statistically on par in treated and control plants. When cultar was applied at 4 and 6 ml per plant, they showed symptoms of wilting. Defoliation occurred gradually and the plants died within one week. Plants applied with cultar at 8 and 10 ml per plant dried completely within three days after application. Only those plants which received the lower two doses were survived.

The dwarfism exhibited in due to the antigiberellin activity of the chemical which might have helped to reduce the internodal length. This chemical may be checking the apical dominance of plants by inhibiting the basipetal movement of auxin. Also due to the alteration in the synthesis of endogenous plant hormones by the application of paclobutrazol. This dwarf stature of these grafts were found maintained even after transplanting to field. This highlights the effectiveness of paclobutrazol the control huge size of cashew which cause serious problem for orchard management.

Table 12. Growth parameter of cashew graft treated with cultar (Paclobutrazol)

Growth characters	Dose of cultar/ plant	Period of observation		
		6 MAG	12 MAG	24 MAG
Height (cm)	1 ml	18.50^{b}	24.83^{b}	33.76^{b}
	2 ml	18.61^{b}	24.26^{b}	33.89^{b}
	Control	20.53^{a}	30.09^{a}	52.49^{a}
Girth (cm)	1 ml	2.28^{b}	3.15^{b}	6.03^{b}
	2 ml	2.35^{a}	3.59^{a}	6.93^{a}
	Control	2.19^{c}	2.84^{c}	4.69^{c}
No. of leaves ($Plant^{-1}$)	1 ml	7.00^{b}	12.00^{b}	35.60^{a}
	2 ml	8.00^{ab}	11.10^{b}	34.20^{a}
	Control	9.80^{a}	17.68^{a}	34.00^{a}

(Pushpalatha, 2000)

Values having any common superscript are not significantly different from one another

These are the some of the important management strategies considered in the nursery. While taking up the planting of grafts caution should be exercised in selecting the grafts of good quality of more than five months old to avoid mortality in the field. Hardening of the grafts in the nursery is a must before the grafts are supplied for field planting. The time of planting should coincide with the onset of monsoon especially in low rainfall areas to ensure proper field establishment. These measurers will reduce the mortality of grafts in the field.

CONCLUSION

Basically seedling vigour is a genetically controlled trait , it can be manipulated by some agronomic practices discussed so far. Higher the seedling vigour, more would be the yield. Therefore as a starting point in the nursery if we pay more attention, it will pay more yield. So dedicated care must be taken at each and every steps involving selection of nuts, raising of rootstocks, selection and precuring of scions grafting. The grafting success mainly depends on quality of rootstocks, scions, skill of grafter, environmental conditions as well as pest and disease control. So by adopting suitable management practices in the nursery as discussed so far would be able to produce healthy and productive cashew orchards.

DISCUSSION

1. Pest and diseases in cashew nursery and this control

Pests

Tea mosquito bug (*Helopeltis antonii*) is the major insect pest attacking in the cashew nursery. The plants infected by Tea mosquito bug is more prone to dieback disease caused by *Colletotrichum gloeosporioides*. This can be controlled by applying 0.1% carbaryl or 0.05% quinalphos. Spraying cuman 0.1% (COC) in combination with Dimecron 0.03% reduce the tea mosquito bug and colletotrichum infection.

The white ants attack during the germinating stages of seed. The severe attack during this stage will induce undesirable branching in the young seedlings. In severe cases the vegetative growth of the plant will be spoiled. To contest the attack of the white ant, it is recommended to treat soil with BHC 50% at the time of filling the bags.

Diseases

Damping off caused by *Phytophthora palmivora*

In nurseries with poor drainage and during rainy season infection seen in collar region. On collar region water soaked lesion, it enlarges and stem girdles. In severe infection, lesion on leaves also.

Seedling blight - *Cylindrocladium scoparium*

Cause root rot symptoms, resulting in wilting and withering of leaves.

Root rot - *Phythium ultimum*

Root rotting symptoms, seedling fall off.

Control

These diseases can be controlled by providing good drainage and drenching with Bordeaux mixture of copperoxychloride or Dithane-M-45.

2. Whether cultar is used for inducing flowering in cashew, like in mango?

In mango cultar is applied to overcome the alternative bearing. In cashew no such attempts has been made so far to induce flowering. Here cultar is attempted to induce dwarfism.

3. In cashew epicotyl grafting gives about 80% success but this method is not used for propagation - Why?

Though epcotyl grafting gives about 80% success, due to collar rot just below the graft union percentage survival got reduced to 30-40%. Here 10-15 days old rootstocks are used for grafting.

4. Why two or three pairs of leaves are retained on the rootstock while grafting?

This is to get higher graft success by better nourishment provided by leaves on rootstocks. The newly emerged leaves on scion stick are not able to potentially nourish the whole graft.

5. What is the spacing of high density planting?

Spacing is 4 m x 4 m. By this can accommodate around 625 plants per ha. While with normal spacing of 7.5 m x 7.5 m can accommodate only 177 plants per ha.

6. For the application of biofertilizers in our soil, need to correct the pH?

Our soil is acidic in large. So liming is needed to correct the pH for the better activity of biofertilizers. Nowadays biofertilizer strains suited to acidic range are available. In such cases no need to correct the pH.

7. Causes of mortality in cashew grafts?

(i) Watering becomes sometimes excess and drainage in bag in problem.
(ii) Sometimes the taproot of cashew tries to pierce the bag and go to the soil below the polythene bag. If the plant is shifted, roots gets detached from soil and root suffers heavy shock.
(iii) Suficient development of roots are not there in polybag seedlings as the tap root is only developed inside.
(iv) At the time of removing the polythene cover, the ball of earth falls and damage the minute root system.
(v) After grafting the success is also less as the primary tap root is unable to provide good sap movement from the potting mixture as the root system in the polybag is very poor.

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IRRIGATION SYSTEMS IN VEGETABLES

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ABSTRACT

Majority of vegetables are shallow rooted with roots rarely exceeding below 60 cm. These herbaceous and succulent crops which are valued for their appearance and fresh weight are highly sensitive to water stress (Hegde, 1979). As the tropical vegetables are mainly grown during summer months, the efficiency of irrigation has great relevance on their productivity. The frequency and method of irrigation primarily depends on the climate, soil, topography and the crop. Furrow and basin methods of irrigation are commonly followed for vegetables. Furrow irrigation is practiced in row planted crops like tomato, chilli, brinjal, okra etc. and basin irrigation in widely spaced vegetable crops. Surge irrigation, a modified furrow irrigation method, increases the water front advance by 1.67 per cent and reduces the quantity of irrigation water (Vishalakshi, 1995). Drip irrigation resulted in better growth, high yield and substantial saving of fertilizer in watermelon (Srinivas *et al*., 1989). A comparative study of surface, drip and sprinkler methods showed that the irrigation efficiency was high for drip (Patel, 1999). Bubbler irrigation has added advantage of working with low pressure without any clogging.

IRRIGATION SYSTEMS IN VEGETABLES

INTRODUCTION

India is the second largest producer of vegetables next only to China. The estimated area under vegetables during VII plan period was 5.5 million hectares with an annual production of 53.8 million tonnes which contribute roughly 12 per cent of world production of vegetables. The overall productivity is 9.98 t/ha with annual growth rate of 3.96 per cent. During VIII plan period, production target have been projected at 120 million tonnes from an area of 8 million hectares. As compared to the developed countries India's productivity of vegetables is very low. Besides other constraints of production, paucity of irrigation water at critical stages of growth is an important aspect for lowering productivity. Regular and adequate water supply to vegetable crops does not only increase the yield, but it increases quality and market acceptance of produce also. Whenever irrigation water becomes important commodity, it becomes more imperative and vulnerable in respect of vegetables because almost all vegetables are fleshy and therefore, very sensitive to water stress at critical stages of growth (Lawande, 1998).

In considering irrigation systems for commercial vegetable production, four general aspects must be looked into

i) Need for irrigation

ii) Time of irrigation

iii) Method of irrigation

iv) Quantity of application at each irrigation

(Hegde, 1989)

I. NEED FOR IRRIGATION

Vegetables are succulent and herbaceous plants where in the edible part is mostly of leaves, fruits and storage organ and have potential productivity manifold than cereals, being valued on the basis of fresh weight, need high soil moisture content throughout the growing period.

Vegetables are shallow rooted with its roots rarely extending below 60 cm, it allows only a depletion of 25-30% of available soil moisture while other crops allow a depletion of 40-50% (Michael, 1979). So it need frequent interval of irrigation with short duration.

Roots of tomato, chilli and brinjal reach to the depth of 120-150 cm, however active root zone is from 30-45 cm. Maintenance of optimum moisture at 30-45 cm is essential and fluctuation in this will lead to cracking of fruits in tomato and drop of fruits in chilli (Yalwakar, 1980).

The effect of water stress on cucumber variety Premier revealed that reduction in the rate of vine growth and the number of nodes when plants are subjected to water stress for a period of one week. Thomas (1984) found that bittergourd respond well to frequent irrigation and biometric characters like leaf area index and dry matter production was favourably influenced by frequent irrigation. Frequent irrigation at low depletion of available soil moisture was congenial for growth and development of cucurbits.

Prakash (1990) reported that water stress decrease the number of flowers in brinjal. Dhanabalan (1994) reported that number of flowers has been increased at higher moisture regime (0.75 IW/CPE ratio) than that of lower moisture regime (0.6 and 0.4 IW/CPE ratio).

Harold *et al.* (1998) reported that higher water application rate resulted in higher soil water content, higher root density and improved plant water status than with lower application rate in brinjal.

II. TIME OF IRRIGATION

This mainly emphasis on "When to irrigate the crops". Several approaches have been made to answer the question and the approaches are

a) Soil moisture approach

b) Climatological approach

c) Plant indices

a) Soil moisture approach

Soil moisture content is estimated to know the deficit in available soil moisture in the root zone. It is proposed to irrigate based on pre-determined soil moisture content to bring the soil to the field capacity. Soil moisture content approximately estimated by farmers by 'feel and appearance' and irrigation is scheduled accordingly. Irrigation water can be applied at a pre-determined soil water tension at a specified depth as it considered that plant response to irrigation is better correlated with soil water suction than soil water content. These approaches are reliable but can't be recommended to farmers because the means to measure soil water content are not readily available (Yellamanda Reddy, 1992).

Dastane *et al.* (1967) pointed out that the proper approach to schedule irrigation is based on soil moisture deficit in root zone.

Michael (1979) reported that irrigation to vegetables must be scheduled by observing soil moisture level and not by observation of crop. The soil moisture at 15 cm depth should not be allowed to fall below 70% of available soil moisture.

Brinjal

Gupta (1984) reported that 80 per cent available soil moisture in 0-80 cm soil depth as optimum in a research carried out in sandy loam soil in Banglore.

Tomato and chilli

In tomato 60% available soil moisture 0-120 cm soil depth on sandy loam soil was optimum in spring season. In chilli on clay loam soil, irrigation at 60% depletion of available soil moisture was found better (Hegde, 1979).

Cucurbits

Irrigation before flowering at a soil moisture content of 50% of field capacity and after flowering 60-65% field capacity increase the yield of cucumber .In Ashgourd, cucumber, oriental pickling melon, 75% depletion of available soil moisture irrigated at 5-7 days interval is found to have better fruit growth (Radha, 1989).

b) Climatological approach

Evaporimeter is an instrument which integrates the effect of all the different climatic elements furnishing them their natural weightage (Dastane, 1967). Evaporation values measured from a standard USWB class. A open evaporimeter is extensively used for scheduling of irrigation using a suitable IW/CPE ratio (Sharma, 1969).

Bittergourd, cucumber

Studies carried out at ARS, Chalakudy revealed that 3 cm irrigation at IW/CPE ratio 0.4 was optimum for both the crops in summer rice fallows (ICAR, 1981).

Ashgourd and Watermelon

Similar studies in ashgourd recorded the highest yield at IW/CPE ratio of 1.0 which is on par with IW/CPE ratio 0.7. Both these significantly superior to IW/CPE ratio 0.4 (ICAR, 1982). Watermelon var. Sugarbaby had highest fruit yield when irrigation scheduled at 20 mm CPE (Khade, 1995).

Brinjal

Dhanabalan (1994) reported that number of flower has been increased at higher moisture regime (0.75 IW/CPE ratio) than that of lower moisture regime (0.6 and 0.4 IW/CPE ratio).

Oriental pickling melon

Alemeyhu (2000) reported increase in yield at IW/CPE ratio of 1.5 and with paddy straw mulch.

Tomato

Gupta (1987) at Jodhpur obtained highest yield of tomato when 30 mm of water was given at each irrigation at 30 mm CPE.

c) Plant indices

Water requirement of any crop is depended upon its season and stage of crop growth, apart from other several other factors. Plant water status has a marked effect on growth and reproductive characters. Moisture stress at flowering, vegetative and fruit formation stages leads to reduction in vegetative growth, flower drop, reduction in fruit set and yield. Hence the three stages viz., vegetative, flowering and fruit formation are highly responsive to moisture (Vadivel, 1990).

CRITICAL STAGES OF VEGETABLES

Crop	Stages
Cucumber	Flowering to fruit enlarging
Tomato	Flowering, fruit setting and enlarging
Watermelon	Flowering to fruiting
Muskmelon	Vegetative to flowering
Egg plant	Flowering, vegetative, fruit enlarging
Amaranth	Throughout crop period

In cucumber the period between flowering to fruit ripening was critical for fruit development. During this period it was necessary to supply the crop with 40 mm water. However excessive application of water found to be deleterious (Vargha, 1973).

Study in oriental melon regarding effect of irrigation on fruit weight and total yield indicated that plants irrigated from transplanted to 20 days after flowering (88.8 mm) produced high yield (11.4 tones ha^{-1}) of good quality fruit (Lee-Kyenobogo, 1995).

Drip irrigation studies on muskmelon and watermelon found that neither crop was affected by irrigation applied during vegetative flowering or fruit set. However, irrigation given during the fruit development stage resulted in average yield increase of 24.5 and 13.5 tones ha^{-1}, but did not affect fruit quality.

III. QUANTITY OF IRRIGATION WATER

After timing of irrigation, the next step is to determine how much water to apply. Irrigation water applied should bring the soil to the field capacity.

Tomato

Research carried out on red sandy loam soil at Bhavanisagar in Tamilnadu revealed that water requirement and consumptive use values were found to be 775 and 950 mm, when 50 mm rainfall was received (Kailippa, 1974).

Brinjal

Time of irrigation is very important for high yield of brinjal. It is recommended to irrigate brinjal after every 3rd or 4th day during summer season and after 12-15 during winter season with the water requirement of 100-110 cm (Yalwakar, 1980).

Cucumber

The highest yield of cucumber was obtained when the crop was supplied with a total water requirement of 650 mm (Veeraputhiran, 1996). Cucurbitaceous vegetables require about 500-600 mm of water. It is also found that constant supply of moisture is necessary during the growth of cucumbers, especially during flowering and fruiting (Reddy, 1992).

Muskmelon

Total water consumption in muskmelon plants found that total water consumption by a fruit bearing plant with a leaf area of about 11000 cm^2 was 85-90 liters. As the plant grow the ratio of total water consumption per plant to pan evaporation increased to a maximum of the netting stage and then declined with ageing (Konishi, 1974).

It can be thus be seen that consumptive use depends on the physiological stages of crop, evaporative demand of the atmosphere and duration of crop (Thomas, 1984).

IV. METHOD OF IRRIGATION

The irrigation method which we select should ensure uniform distribution and high efficiency of water application. It mainly depend on

Natural condition

Type of crops

Type of technology

Required labour input

Cost and benefits (Reddy, 1992)

The methods used for growing vegetables are

Irrigation methods

Surface	Drip	Overhead
1. Furrow 2. Alternate furrow 3. Basin 4. Surge		1. Bubbler method

1) Furrow method

It is most ancient method of irrigation and this method still holds good for more than 95 per cent of irrigated area in the world.

Furrows are small channels having a continuous uniform scope in direction and ridges serve as planting bed. When a small stream of water applied in the furrow, crops in ridges absorb water by capillary action (Michael, 1979). Mainly practiced in uniform gentle slope in order to have a continuous flow and where water availability is more.

It is practiced for row crops such as tomato, brinjal, chilli (Hegde, 1979). For vegetables furrows of short size with 5-6 m length and 7.5 m depth is ideally suited. Vegetables such as carrot, lettuce often have two or more furrow where as melons have one row and furrow.

Soil type influences the shape of furrow in sandy soil 'V' shape reduce soil area through which it percolate and clay soil much later movement in order to increase infiltration (Wolfe, 1990).

Advantages

- Water in furrows contacts only one half to one fifth reduce puddling, existing and evaporation.
- Singh (1990) at Hissar studied performance of tomato under drip and furrow irrigation in heavy soil and planting at ridge top is found better than drip.
- Patel (1969) obtained higher yield of radish planted on ridges and irrigated on furrows as compared to basin irrigation when water was saline.
- Provide uniform drainage during heavy monsoon rains.

Disadvantages

- Sivanapan (1979) working on Brinjal and chilli, found that water used in drip system was only 29.47 cm as compared to 69.18 cm under furrow irrigation, so there was poor water conservation.
- Arborol (1972) reported that okra is normally irrigated by furrow however significant increase in yield and water use efficiency was observed in drip irrigation
- Land leveling is must which cause additional cost.

2) Alternate furrow irrigation

Alternate furrow irrigation is modified from furrow method in its frequency. It is mainly practiced where water is limited and salt accumulation is problem. Application of water to one side of each crop row. Here small amount of water given frequently rather than large amount at longer intervals (Yellamanda Reddy, 1992).

Furrow 2, 3, 5 - irrigated on 5th day

Furrow 2, 4, 6 - irrigated on 10th day

If irrigation interval is for period of 10 days instead of irrigating every furrow at 10 days, furrow 1, 3, 5 are irrigated after 5 days and 2, 4, 6 are irrigated after 10 days. Thus the crop receives some water every 5 days interval, than large amount every 10 days.

Advantages

1. Hegde (1979) at Banglore indicated that alternate furrow irrigation in widely spaced furrows with double planting in bell pepper could save irrigation water to the extent of about 40 per cent without any adverse effect on productivity as compared to every furrow irrigation. This could profitably be adopted in medium to heavy textured soils with good lateral movement of water.
2. The entire soil surface may still be thoroughly wetted after irrigation due to lateral movement.
3. Reduce evaporation loss.
4. Vasanthakumar (1984) observed that in tomato furrow irrigation in uniform row as well as alternate furrow irrigation produced higher yield compared to furrow-

furrow. However, at lower level of irrigation alternate furrow irrigation was superior to furrow irrigation.

Disadvantage

Crop yield was reduced to the extent of 2-16% (Reddy, 1992).

3) Basin irrigation

Water from channels or from wells is let into the basins when irrigation water was under scarce.

Pot watering

Summer vegetable cultivation in Kerala is confined to summer rice fallows when sufficient water is available for vegetable cultivation. In vegetable growing tract the water table is 2-3 m below the soil level. In this area irrigation is usually done by pot watering from the small pits/shallow wells dug in between the plots. During cropping season family of vegetable farmer is involved in irrigation. Water is lifted manually with the aluminium pots or kudams and irrigated manually.

In vegetable growing villages of Trivandrum, aluminium vessels hung on either side of a bamboo beam is common device used for pot watering in vegetable garden planted at a definite distance.

Basin irrigation

Ring or circular basin of the size 1 m is taken and plants are planted inside the basin. Water application from the source reaches the field channels which is connected by basin and thus only the basin area is wetter. The size increases as the plant size increase.

Advantages

- Reduce crust formation and logging.
- Balakumaran (1982) reported that basin irrigation have higher water use efficiency in cucumber. But care should be taken to see that water from basin do not overflow and inundate the plants because if they stand in water for any length of time foliage become chlorotic.

- It is mainly practiced for crops cucumber, bittergourd, snakegourd, muskmelon (Hegde, 1979).
- Leaching loss will be less.
- Can be practised in slop land.

Disadvantages

Labour requirement is more.

Mangal (1987) reported that pitcher irrigation in raising muskmelon was found to better than basin due to minimum water requirement as low as 1.28 cm. Patel (1969) obtained higher yield of radish planted on ridges and irrigated in furrows as compared to basin irrigation when the irrigation water was saline. Work carried at Tirupathi in snakegourd found that pitcher irrigation of snakegourd increased water use efficiency as compared to basin irrigation.

4) Surge irrigation

Recent development in surface irrigation technology have largely overcome the irrigation efficiency advantages of pressurised irrigation systems and reduction in labour requirement with the use of automatic devices. The increase in efficiencies of surface irrigation methods are possible by doing alternations in management practices. One of the popular modification is the intermittent application of water instead of continuous application of water. This is also called surge irrigation.

Surge flow irrigation is basically a method of intermittent application of water. In this technique total time of irrigation is divided in to a number of surges (viz. two, three, four etc.) water supply is kept 'on' for particular period and immediately turned 'off' for same period of time/ The concept of surge flow surface irrigation was introduced in 1979 by Stringham and Keller. Surge irrigation consists of intermittent application water to furrows in a series of pulses or surges, rather than a continuous furrow stream. Usually the water is alternated between two sets of furrows until the irrigation is complete. The switch is accomplished with a surge valve and an automatic controller, typically located between two sets of furrows. Gate pipe is used to distribute the irrigation water to each of the two sets from opposite side of surge valve (Walker and Skogerboe, 1987).

Surge terminology

On time: It is the time for which water is applied to one set of furrows before it is alternated to another set.

Off time: It is usually the same duration as the on time and is the time for which water is not applied.

Cycle time: It is the time to complete a full on/off cycle and is equal to on time prices off time.

Cycle ratio: Ratio between the on time and cycle time. A cycle ratio of 0.5 is prevalent.

Advance phase: The phase in which the dry furrow is wetted.

Advantages

Phillips (1982) found that surge flow treatment significantly accelerated furrow advance per unit of water applied. It is theorized that furrow drainage between surges accelerates formation of thin surface seal thereby reducing water intake rate.

Vishalakshi (1995) reported that there was 1.65% increase in water front advance when compared to furrow irrigation.

Forest (1985) found surge infiltration function appeared to undergo step reduction from the time dependent rate to the basic rate after one completes wetting and dewatering cycle. This reduction in infiltration rate tend to reduce the amount of time and water necessary to complete advance in surge.

Kemper (1988) studied the mechanism by which surge irrigations reduce furrow infiltration and found the consolidation of furrow perimeter, filling of cracks, forced settlement of suspended sediments on furrow perimeter when water supply is interrupted and greater sediment detachment and movement caused by more rapid advance of surge steam front.

Disadvantages

It requires high level of management and may be a problem when using unskilled labour (Lawandae, 1998).

Additional cost of surge valve and gated pipes, if automation required.

Surge irrigation primarily designed for vegetables under extensive cultivation. However, in India short furrows with dikes are observed. Therefore the rules now set for surge irrigation can't be directly applied to Indian situation. Lot of research work is required to determine the number of surges on time and stream flow size to obtain maximum efficiency.

Drip irrigation

Drip irrigation a recent and novel innovation in irrigation technology is a concept involving slow and steady application of water directly to the crop root zone or on the soil surface in the vienity of crop plants to replenish the soil moisture to a desired level through a net work of plastic materials. The introduction of drip system for widely spaced vegetable crops would result in increased productivity and quality of the produce justifying the initial investment for the system It is well established all over the world as most efficient irrigation method especially where there is water scarcity and salt problem exist.

It is a technique by which water and fertilizer can be placed directly near the root zone of the plants at any frequency and quantity with the help of specially designed emitters. The emitter selected based on soil and crop.

Some classical examples where drip irrigation is proved to be advantages are furnished below:

Yield increase

Tomato

Kataria and Michael (1996) working on response of tomato to drip and furrow method of irrigation under Delhi condition reported that drip irrigation gave higher yield of 47.4 per cent over furrow method of irrigation. Drip method of irrigation in tomato recorded higher yield of 48 tones per hectare compared to 32 tones per hectare with flood irrigation (Jadhav *et al.*, 1996). Hanna *et al.* (1996) reported that in tomato early morning drip irrigation increased marketable and total yields and average fruit weight compared with afternoon irrigation.

Brinjal

Sivanappan (1978) found that drip irrigation was found to be quite beneficial for reducing water use and weed growth as compared to conventional surface irrigation. The water used in drip system was only 24.47 cm as compared to 69.18 cm under furrow irrigation.

Okra

Irrigation study carried out in Tamilnadu in trickle irrigation and surface irrigation on performance of yield growth and water economy on okra cultivar Pusa Sawani. It was found that saving of water over surface irrigation.

Cabbage

Singh (1990) reported that drip irrigation resulted in better growth and higher yield of cabbage with bigger head size of higher quality.

Cucumber

Yingjajaval (1993) found that in cucumber the yield increase by drip irrigation was due to fruit number rather than the fruit size.

Saline water use

Potato

In potato saline water irrigation through drip produced reasonably good yield of tubers as compared to normal water (Kamarkar, 1986).

Performance of potato under drip irrigation using saline and normal water

Treatment	Water used (mm)	Yield ($t\ ha^{-1}$)	WUE (kg/ha mm)
Normal water A=0.70 Epan	366	33.4	91
75% of A	274	27.6	101
50% of A	183	20.5	112
Saline water 0.70 pan	366	26.4	72

Chilli

In chilli crop irrigated with drip system using brackish water with an electrical conductivity of 6 dsm^{-1} found to increase the yield (Chattopadhyay, 1990).

Cabbage

Bhorgonde (1981) reported that water of high salinity can be used with drip than other irrigation methods without drastic reduction in yields of cabbage crop.

Use of mulches

Cucumber

Veeraputhrian (1996) reported that incorporation of paddy waste, coir pith and sawdust increased net profit by Rs.27,697.99 (68%) for paddy waste Rs.13,958.99 (34%) for coir pith and Rs.4,254.79 (10%) for sawdust over control.

Okra

Sunilkumar (1998) in an irrigation study in Bhindi at Agricultural Research Station, Mannuthy maximum BC ratio of 1.58 was derived when the crop was mulched and irrigated at soil moisture tension 90.08 MPG.

Oriental Pickling melon

Aleymeymu (2000) in an irrigation study in oriental pickling melon at Agricultural Research Station, Mannuthy found increase in yield under drip irrigation at 125 EP with paddy mulch.

Fertigation

Potato

Chalwa (2000) found the maximum fresh tuber yield was 36.29 t/ha with an average of 30.13 tonnes/ha in a trickle fertigated crops as compared to 21.5 t/ha for the furrow irrigated crop.

Garlic

Callestons (2001) garlic under furrow irrigation took up 64 kg P_2O_5/ha while under fertigation took up 89 kg P_2O_5/ha yields were 19.1 and 29 t/ha. Higher yield potential of crop under fertigation increased 'P' demand by the plant by almost 50 per cent.

Chilli

Deolankar (1999) revealed that fertigation of 75% of recommended dose of NPK through solid soluble fertilizer was good as 100% R.D. of conventional fertilizers for rabi chilli in paired rows. Thus water saving of 58% was achieved due to drip irrigation.

Tomato

In tomato uptake of N, P, K and micro nutrients viz. Fe, Mn, Zn and Cu by tomato plants were higher in vermicompost (50%) and liquid fertilizer drip irrigated treatments. Yield and quality found to increase at different level of liquid fertilizer (Kolte, 1999).

Disadvantages

* Chauhan (2001) reported that in general the spacing of vegetable crops both plant to plant and row-row in much smaller. This requires more number of laterals and emitters. Thus the cost of installation is quite for vegetable crops than tree crops.
* Restricted root growth
* Salts may concentrate and become hazard drip irrigation with saline water 10 dsm^{-1} in tomato found to decrease in yield by 35.8 per cent due to salt concentration.
* Logged by particles of mineral or organic matter.

Yield and water use of vegetables in drip and furrow irrigation system

Crops	Yield ($kg\ ha^{-1}$)		Water used	
	Furrow	Drip	Furrow	Drip
Bhendi	10,000	11,316	535	86
Brinjal	12,400	11,900	692	245
Chilli	4,233	6,086	1098	478
Tomato	5,187	8,872	498	108
Radish	10,450	11,860	464	108

Bubbler irrigation

The research work carried out at ARS, Chalakudy for the development of an affordable, dependable, simple and farmer friendly technology resulted in a low cost micro sprinkler called Bubbler head.

Water is delivered through a network of main pipes, submains and laterals and fall as a circular spray through these bubbler head, ensuring wetting of the basin area of the crop. In bubbler head holes of equal diameter were provided at opposite sides, the moment of couple constituted by a stream coming out of the nozzle cause bubbler head to rotate while in operation.

Yield of bittergourd kg/ha influenced by bubbler and drip (ARS, Chalakudy)

Treatment	Yield kg/ha	Water use (mm)	Increasing yield kg/ha
T_1 Bubbler at 100% EO	4458	302	+28.33
T_2 Bubbler at 75% EO	3794	227	+16.42
T_3 Bubbler at 50% EO	3463	151	+ 9.10
T_4 Drip at 100% EO	3036	362	+ 7.35
T_5 Drip at 75% EO	2963	227	- 8.32
T_6 Drip at 50% EO	2394	151	-19.60

Advantages

* Less operating pressure than sprinkler

  KAU (1998) work carried out in okra revealed that bubbler works with the pressure less than that of sprinkler and profound increase in water use efficiency.
* Area coverage between drip and sprinkler.
* More distribution uniformity
* Minimum loss
* Initial investment, running cost comparatively less.

  Crops suited are bittergourd, snakegourd, cucumber is ideally suited for close growing crops (KAU, 1998).

Disadvantage

Research is going on so far no distinct disadvantage had been found.

Irrigation efficiency of various systems (Patel,1999)

Irrigation efficiencies	Various methods		
	Surface irrigation	Sprinkler irrigation	Drip/Biwall irrigation
Conveyance efficiency	60-70 (well irrigation)	100	100
Application efficiency	60-70	70-80	90
Surface water/moisture evaporation	30-40	30-40	25
Overall efficiency	30-35	40-60	75-80

CONCLUSION

Lack of water influences yield of vegetable crops in complex and dynamic ways. The effects depend on the severity, duration and timing of the stress relative to the developmental stages of the plants, while interactions with other environmental and cultural variables modify responses still further. For these reasons, it is virtually impossible to give general recommendations on how and when to irrigate individual vegetable crops. Our knowledge of how water influences the development, yield and quality in vegetable crops is with a few exceptions, still very limited. This calls for generation of more information from well designed field studies on how different vegetable crops respond to irrigation under a wide range of environmental and operational variables. Reliable quantitative data so obtained could then be used to optimise the allocation of limited quantities of water between crops in order to maximize production, profit, water use efficiency and even energy productivity. There is a need to study improved methods of irrigation such as drip to standardise various factors such as emitter frequency, evaporation replenishment, etc. Studies are also needed to find out the effect of irrigation practices on post-harvest and processing qualities of vegetables. Of equal importance is the need to determine ways of reducing the need for irrigation by, for example, selecting cultivars of vegetables which are less sensitive to short periods of dry weather and making better use of water stored in the soil through suitable changes in soil management practices. In India, traditional, labour-intensive systems of applying water will continue to predominate in the coming years. Therefore, there is a need for initiating studies on methods of increasing the efficiency of present irrigation practices with greater emphasis on methods involving low monetary investment.

DISCUSSION

1) A farmer is cultivating okra by following normal furrow irrigation at the fague end of the crop there arise water shortage then what type of irrigation you recommend to the farmer?

Alternate furrow irrigation is being practised under water shortage condition since every plant is able to get some amount of water with frequent interval which enable them to survive.

2) What is the reason for getting high yield in drip irrigation?

It is due to proper soil and air water balance and increase in root activity lead to high yield in drip irrigation.

3) What happened to watermelon if irrigation is being carried out after maturity?

In watermelon irrigation after maturity will lead to fruit cracking and decrease in TSS content.

4) What is chemigation?

It is a broad term which include application of fertilizer, growth regulators, herbicides along with irrigation water.

5) What is type of irrigation followed in vegetable grown under green house condition?

Nutrient fix on technique is the type of irrigation system being followed in green house condition.

6) How it is possible to save water in surge irrigation when compared to conventional irrigation?

Uniform infiltration rate and reduce infiltration opportunity time lead to save water in surge irrigation when compared to conventional method.

7) What is advance phase?

Wetting of dried furrow is termed as advance phase.

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NUTRIENT UPTAKE MODELLING

BY

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SEMINAR REPORT

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ABSTRACT

Present soil fertility evaluation procedures in India are inadequate in the sense that it cannot explain the uptake mechanism. In mechanistic models of nutrient uptake, various soil and plant factors which influence the uptake mechanism are fixed as the parameters (Claassen and Barber, 1976). The models are developed based on equations describing the processes involved in the nutrient uptake mechanism (Nye and Tinker, 1977) with certain modifications (Barber and Cushman, 1981) for calculating predicted uptake. Validation experiments showed a high correlation between the observed and predicted uptakes (Claassen and Barber, 1976; Schenk and Barber, 1980). Once such successful validation is done the model can be widely used for prediction of consequences due to change in any of the parameters (Silberbush and Barber, 1983). Improvement of the basic model has been suggested recently in the works of Reginato and Tarzia (2000).

In India also experiments conducted at IARI in 1993 by Sureshkumar, showed that Zn uptake predicted by the model for rice varieties at 80 days after transplanting were in perfect agreement wit the observed uptake.

Thus the introduction of nutrient uptake modelling provide the background as the most effective soil fertility evaluation and recommendation tool.

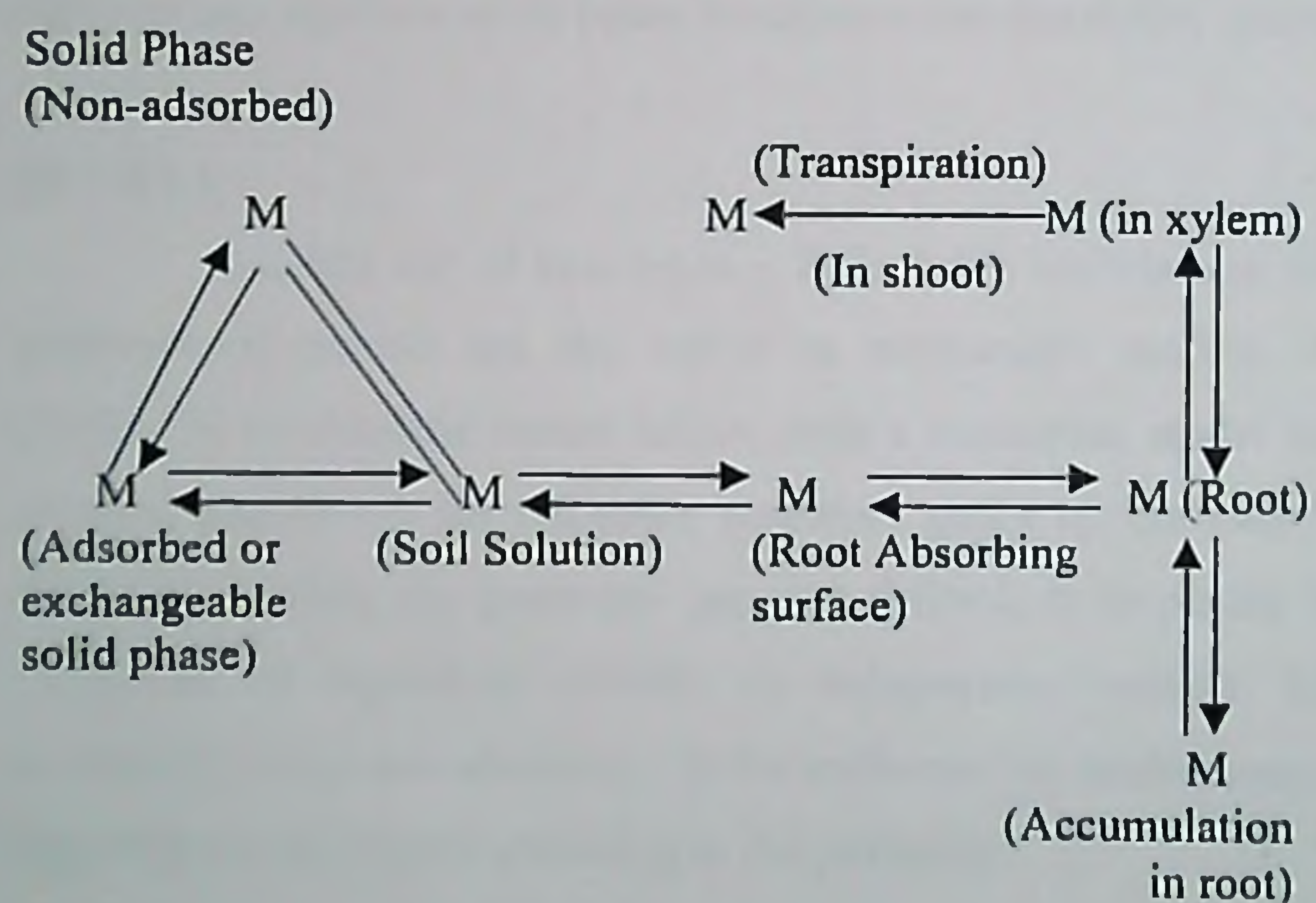
NUTRIENT UPTAKE MODELLING

INTRODUCTION

Soils provide the starting point for successful agriculture. People are dependent on soils for their existence and in turn good soils are dependent on people and the use they make of the land. Good soils mean the productive soils and all productive soils are fertile.

The very basic aspect of any soil plant relationship refers to the plant growth with respect to the plant nutrients available in soil. The soil plant system can be represented as

Soil plant system



M - represents a nutrient ion

It is an open steady state system in which the nutrient ions in the solid phase are in equilibrium with the nutrient ions in the solution phase and from the solution phase plant roots absorb the nutrients.

Generally now for soil fertility evaluation we make use of the two most common methods - soil test and plant analysis. By this soil testing we are able to assess the nutrients in soil. Plant analysis gives the actual fraction of these soil nutrients that is taken up by the plants. Sometimes there may be large quantities of nutrients in soil but the plant may not be able to take up those nutrients efficiently. In such cases plant analysis do not reflect the nutrient content in soil. The reasons for this, is not explained by any of the usual fertility evaluation procedures. It is in this context comes the importance of nutrient uptake models.

In the nutrient uptake models, various soil and plant factors which are having great influences in the uptake of nutrients from soil is given importance. The models clearly explain, how the uptake mechanism is affected even by very low changes in these factors. Hence a better explanation for nutrient uptake can be got which in turn lead to a much better fertilizer recommendation system.

MODELS

Models are of two types - Regression models and Mathematical models. Mathematical models are also called as mechanistic models. According to Barber (1984), "A mechanistic model differs from a regression model where coefficients are obtained statistically for unknown processes going on between black boxes" i.e., in regression models the processes are not defined, it is purely based on significant correlation of dependent variable on independent variable. Mathematical models describe the processes accurately. In the mathematical models processes are defined and equations are developed according to the processes.

In a mechanistic nutrient uptake model equations describing nutrient influx are combined with equations describing plant growth in order to describe nutrient uptake. In these models parameters are fixed. After measuring or calculating the fixed parameters these are applied in the model to get the predicted uptake. Comparing it with the actual uptake is called validation or experimental evaluation. If the predicted uptake and the actual uptake are closely related, the model is said to be successfully validated.

Once a model has been developed and successfully validated with the parameters under study (both soil and plant) the model can be widely used for prediction of consequences due to change in any of the parameters, i.e., the consequence of changing various soil and plant parameters with respect to the nutrient uptake by the plant. Thus it can be used to asses the fertility status, nutrient requirement, amount and method of fertilizer application in a given soil under specific environmental conditions. Fate of nutrients applied in soil and their uptake by plants can be predicted and thus such nutrient uptake models will be the most effective tools for assessment of soil fertility.

Metabolic processes govern the accumulation of nutrients by plants. The delivery of nutrients to the metabolic sites is equally important for plant growth. The two main processes of the movement of the nutrient ion to the root surface, mass flow and diffusion and uptake of nutrients by roots play a major role in developing an uptake model.

Stanley A. Barber is the most eminent scientist working in this field and from 1960's itself he had contributed very much to the development of mechanistic models.

In 1962, Barber developed a model where he allotted the contribution simply either to mass flow, diffusion or root interception for nutrient concentration at the root surface. Barber *et al.* (1962) calculated whether the nutrients in maize could be acquired solely by mass flow by multiplying the soil solution concentration by the amount of water transpired by maize. It was the most primitive work in this regard.

Early modeling of nutrient fluxes around the root was done by Passioura (`1963), Nye (1966), Olsen and Kemper (1968) and Nye and Marriott (1969).

Nye and Tinker (1977) suggested that the solute moves both by mass flow and diffusion. If the solute is absorbed faster than water, then the concentration of nutrient ion in the soil solution at the root surface decreases creating a gradient enabling the ions to diffuse towards the root surface. If water is absorbed faster, ions accumulate at the root surface and tend to diffuse away from the root. Thus diffusion, and also mass flow are the processes by which solute moves in response to the disturbance created by the presence of the root surface.

CONTINUITY EQUATIONS

If movement of solute is by diffusion alone, it is described by Fick's first law.

FICK'S FIRST LAW

(for steady state diffusion)

$$F = -D \left(\frac{dc}{dx}\right)$$

F - Flux,
D - Diffusion coefficient
$\frac{dc}{dx}$ - Concentration gradient

The negative sign indicates that movement is from higher to lower concentration.

This equation applies to steady state diffusion. If it is transient state diffusion as in the case of diffusion of nutrients in soil, Fick's second law describes the movement as,

Transient State Diffusion

$$\frac{\delta c}{\delta t} = \frac{\delta}{\delta x} D\left(\frac{\delta c}{\delta x}\right)$$

c - Ion concentration in soil solution
t - Time of uptake

For combined mass flow and diffusion, the continuity equation is

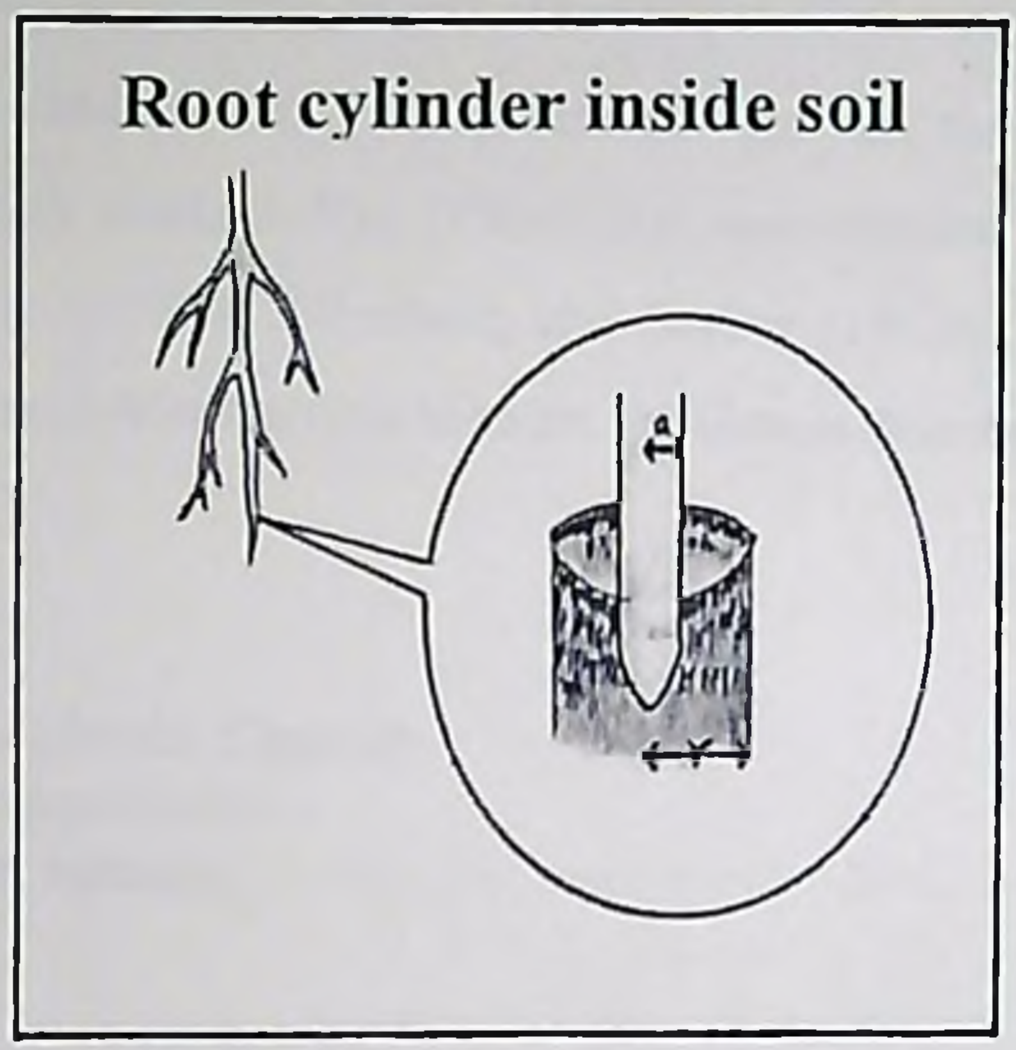
$$\frac{\delta c}{\delta t} = \frac{\delta}{\delta x}\left(De \frac{\delta c}{\delta x}\right) + \frac{\delta(vC_l)}{\delta x}$$

v - the water flux in the direction x
C_l - concentration of ion in soil solution
De - effective diffusion coefficient

The next equation is for the movement of the nutrient ion in a direction normal to a cylinder.

$$\frac{\delta c}{\delta t} = \frac{1}{r}\left[\frac{\delta}{\delta r}\left\{ r D \frac{\delta c}{\delta r} + r \nu C_1 \right\}\right]$$

This equation is developed with the assumption that roots are having cylindrical symmetry and these root cylinders are placed inside a homogeneous soil cylinder.



Here 'a' is the root radius, and distance 'r' is termed half distance between root axes. It is the maximum distance upto which root influence exists. Hence the equation is for movement perpendicular to the cylindrical surface.

This equation forms the basis for development of any uptake model. This equation can be solved to satisfy various boundary conditions that there is a specified concentration of solute at the boundary between the root surface and the adjacent soil.

Ion uptake kinetics

Nye (1966) defined root absorbing power 'α' as

$F = \alpha C_1,$ α - Root absorbing power

According to Nye and Tinker (1977) the root absorbing power 'α' is the best compromise between the need to represent root properties with accuracy and the need for a boundary condition which allows relatively simple analytical solution of diffusion equation.

The influx I i.e., the uptake rate per unit length of root and uptake rate per unit fresh weight of root 'S', were related to 'α' as,

$I = 2 \pi \alpha a C_1$, a - Root radius

$$S = \frac{2 \alpha C_1}{a}$$, C_l - Ion concentration at the root surface

Nye and Tinker (1969) termed 'αa' in the equation as 'root demand coefficient'. Many workers, Nye (1966), Nye and Marriott (1969), Claassen and Barber (1974), Cushman (1982), Silberbush and Barber (1983b), have found that ion uptake follows a Michaelis-Menten type kinetics. Michaelis-Menten relationship is,

$$V = \frac{V_{max} C_l}{K_m + C_l}$$

K_m - Michaelis - Menten Constant
C_l - Substrate concentration
V_{max} - Maximum velocity

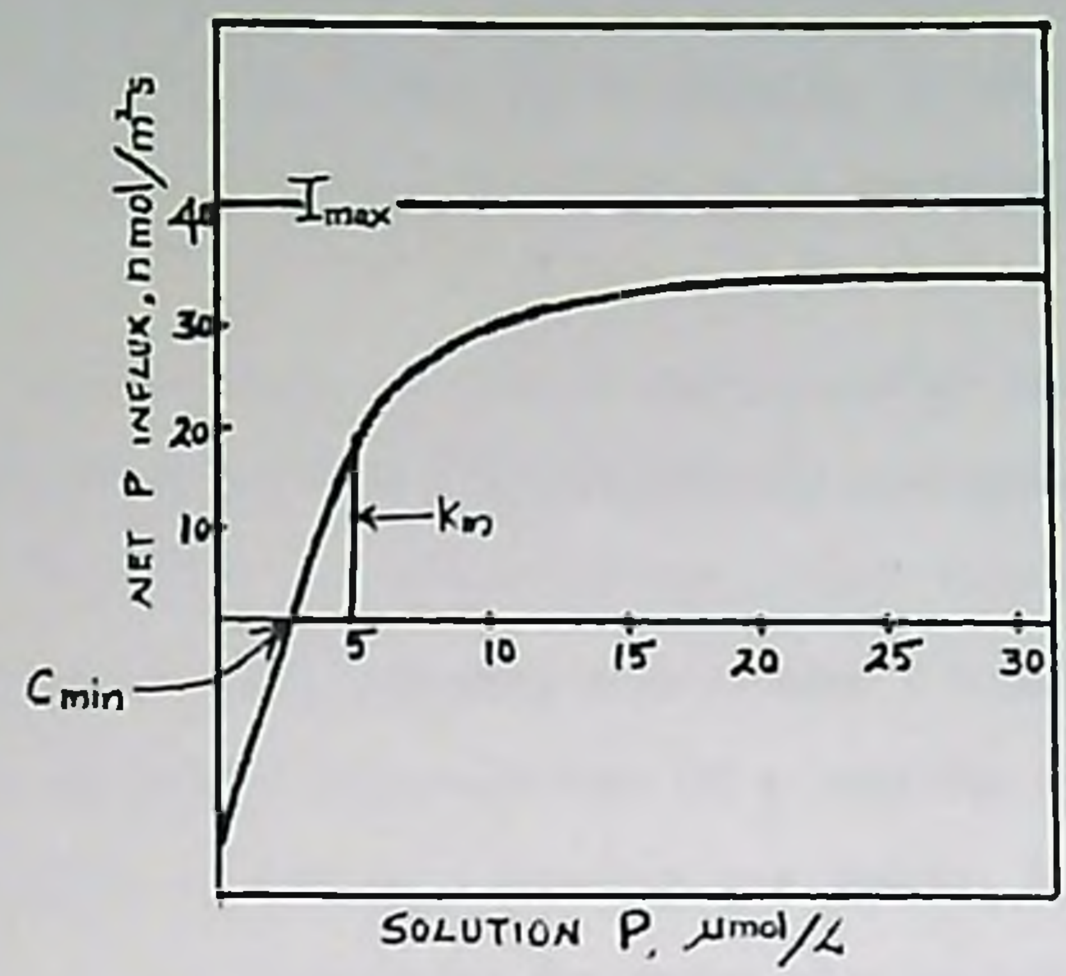
Claassen and Barber in 1976 described the ion uptake kinetics in terms of Michaelis-Menten relationship between concentration and influx. The equation given by them is

$$I_n = \frac{I_{max} C_l}{K_m + C_l} - E$$

I_n - Influx
I_{max} - Maximum influx
K_m - Concentration at which influx equals 1/2 of Imax

E is the efflux rate from the root. E was defined on the basis of the fact that uptake was zero at a concentration above zero and the line obtained by plotting concentration vs. influx was extended to ordinate where they got negative uptake at zero concentration which they termed efflux.

Nielsen and Barber (1978) introduced a term 'C_{min}' the concentration solution, at which influx reaches zero or the concentration below which there is no net influx. This is shown in the graph.



The corresponding equation is

$$I_n = \frac{I_{max}\left(C_l - C_{min}\right)}{Km + C_l - C_{min}}$$

C_{min} - Concentration at which influx is zero

BOUNDARY CONDITIONS

The equations are developed to satisfy various boundary conditions. The boundary conditions when the soil volume is infinite are,

$$t = 0,\ a < r < \infty,\ C_l = C_{li}$$

$$t > o,\ r = a,\ F = \alpha C_l$$

$$t > 0,\ r = a,\ De\ \frac{\delta C_l}{\delta r} + v\,C_l = \frac{I_{max}\,C_l}{K_m + C_l} - E$$

At the initial time the nutrient ion is away from the root surface, but it should be within the root influence, for movement to occur. Hence the maximum distance possible is 'r'. As time went on, the ion moves towards root surface and when it reaches the root surface the flux is given as $F=\alpha C_l$. This flux may be contributed by mass flow and diffusion. In the 3rd condition, the partitioning of flux into contributions by diffusion and mass flow is given and this equals the equation suggested by Claassen and Barber (1976).

The solution of this equation is made possible initially by a **FORTRAN** programme. This programme helped to calculate the concentration at the root surface and the rate of net influx per cm^2 of root surface as time went on and thus total uptake of a particular nutrient element from time zero to time 't' was calculated. Total uptake can be obtained by summing influx over time for a root that was not growing. Further to calculate the nutrient uptake by a growing root system, initial root length 'L_0' is measured and rate of root growth for the entire time period is also calculated. For calculating the rate of root growth, root length at different time intervals is to be measured and best fit equation for rate of growth either linear, quadratic or sigmoid expression should be used.

Cushman (1979) developed a model which was slightly modified from Claassen and Barber (1976) model. Cushman considered the 'inter root competition', also. In Claassen and Barber model the movement of ion perpendicular to the root cylinder is considered. But in the actual field situation there are so many root cylinders and each root is having its own influence which may lead to inter root competition. Cushman considered this, and developed a modified equation as,

$$T = 2 \pi a L_0 \int_0^{t_{max}} (S)\, ds + 2 \pi a \int_0^{t_{max}} \frac{df}{dt} \int_0^{t_{max}-t} F(S)\, ds\, dt$$

L_0 - Initial root length
a - Root radius
t_{max} - Maximum time of uptake

In this equation the first term represents the ion uptake of a root of length 'L_0' for the entire time period and in the second term by all the roots for the entire time period, the uptake is calculated. It was suggested by Cushman (1979) that equation given by Claassen and Barber (1976) was incorrect and should be replaced by this equation. Later Hoffland *et al*. (1991) suggested the inclusion of inter-root competition and time dependent root density by assigning to each root a finite cyclindrical soil volume that delivered nutrients.

The development of Barber and Cushman model (1981) using the modified continuity equation has the following assumptions,

ASSUMPTIONS

1. 'The soil is homogeneous and isotropic'. This assumption guarantees the independence of location with reference to soil characteristics involved in determining nutrient flux. Where soil volumes differ uptake can be calculated separately for each volume.
2. 'Moisture conditions are maintained essentially constant near field capacity. No appreciable moisture gradient perpendicular to the root is assumed in the calculation of nutrient flux. The moisture gradient at this moisture level is usually relatively flat'. This assumption simplifies nutrient transport mechanism.
3. 'Nutrient uptake occurs only from nutrients in solution at the root surface'. This assumption is necessary in order for assumption 5 to be used.
4. 'Nutrients are moved to the root by a combination of a mass flow and diffusion'. This assumption describes what has been shown experimentally.
5. 'The relation between net influx and concentration can be described by Michaelis-Menten Kinetics'. This assumption selects a relationship between influx and concentration in solution - other relations could be used, but this is the commonly used one.
6. 'The roots are assumed to be smooth cylinders placed in a homogeneous soil cylinder. Nutrient movement is perpendicular to this cylinder'. This assumption is necessary to have radial symmetry. Root hairs may be taken into account by calculating flux to the root hair surface as well as the root cylinder.

MODEL PARAMETERS

The mathematical model has the following '11' parameters

1. I_{max} → Maximum influx at high concentration (nmol/m²s)
2. Km → Nutrient concentration in solution - C_{min}. Where I_n is one half of I_{max} (μmol/L)
3. C_{min} → Concentration in solution below which 'I_n' ceases (μmol/l)
4. Lo → Initial root length, cm
5. K → Rate of root growth, cm/s
6. a → Mean root radius, cm
7. v → Mean water influx
8. r → Half distance between root axis
9. De → Effective diffusion coefficient for the nutrient in the soil, cm²/s
10. b → Buffer power of nutrient on the solid phase for nutrient in solution dimensionless
11. C_{li} → Initial concentration of the nutrient in the soil solution, μmol/L

MEASUREMENT OF THE MODEL PARAMETERS

The first three parameters are measured in solution culture. These kinetic parameters can be measured by the method proposed by Bowen (1986). The plants grown in sand culture were irrigated with Hoagland solution. At the time of determination of kinetic parameters plants were uprooted and the roots were incised, and these roots were placed in appropriate nutrient solution. At the end of the uptake period the roots were washed, weighed, dried and again weighed. 'I_{max}' and 'K_m' were determined from double reciprocal plots of influx and concentration in solution viz.

$$\frac{1}{C} \text{ Vs } \frac{1}{In}$$

The equation used is $I_n = \frac{I_{max} C}{K_m + C}$

Linear form of equation is

$$\frac{1}{I_n} = \frac{K_m}{I_{max}} \cdot \frac{1}{C} + \frac{1}{I_{max}}$$

From this equation,

$$I_{max} = \frac{1}{\text{Intercept}}$$

$K_m = I_{max}$ x slope

'C_{min}' is the concentration at which net influx is zero, and it is obtained from the graph of concentration Vs. influx.

Parameters 4, 5 and 6 give the amount of root surface, its geometry and its rate of change with time. They are determined by measuring root length and radii of roots growing in the soil (Tennant, 1975) investigated after several periods of growth. A value for 'k' can be calculated from root lengths at various values of 't'. Depending on the growth period investigated rate of root length increase can be described by either a linear, exponential or sigmoid expression. In the case of exponential growth, 'k' was obtained using the equation given by Mullins *et al*. (1986).

$$k = \ln \frac{L}{L_0} / t$$

Lo = Initial root length
L = root length at time 't'

Mean root radius (a) was determined from root volume and root length as

$$a = \sqrt{\frac{\text{Volume}}{\pi L}}$$

Mean water influx 'ν' can be calculated from change in root surface area with time and total water use. Total water use is obtained by measuring water additions to weighed pots. Evaporative losses are estimated by subtracting water loss over the same periods from pots without growing plants.

The half distance between root axes is calculated from root density Lν in the soil.

The relation is $r = \frac{1}{\sqrt{\pi L_v}}$

This is by assuming the roots are in a regular parallel array of length Lv per cm^3, the cross sectional area per root on a plane normal to them is L_v and hence radius of soil cylinder around the root is $\frac{1}{\sqrt{\pi L_v}}$

The last 3 parameters which determine the nutrient supply are measured on soil in the laboratory using the same temperature, moisture, bulk density and aeration conditions that will occur in the verification experiment. Values of C_{li} are obtained by measuring the concentration in displaced soil solution. Values of 'b' are obtained from desorption curves of ΔC_s versus ΔC_l and De is measured according to the equation

$$De = D_l \, \theta \, f_l \frac{dc_l}{dc_s}$$

D_l - Value of D in water
θ - Volumetric moisture content
f_l - Tortuosity (Impedence factor)
$\frac{dc_l}{dc_s}$ - Reciprocal of buffer power

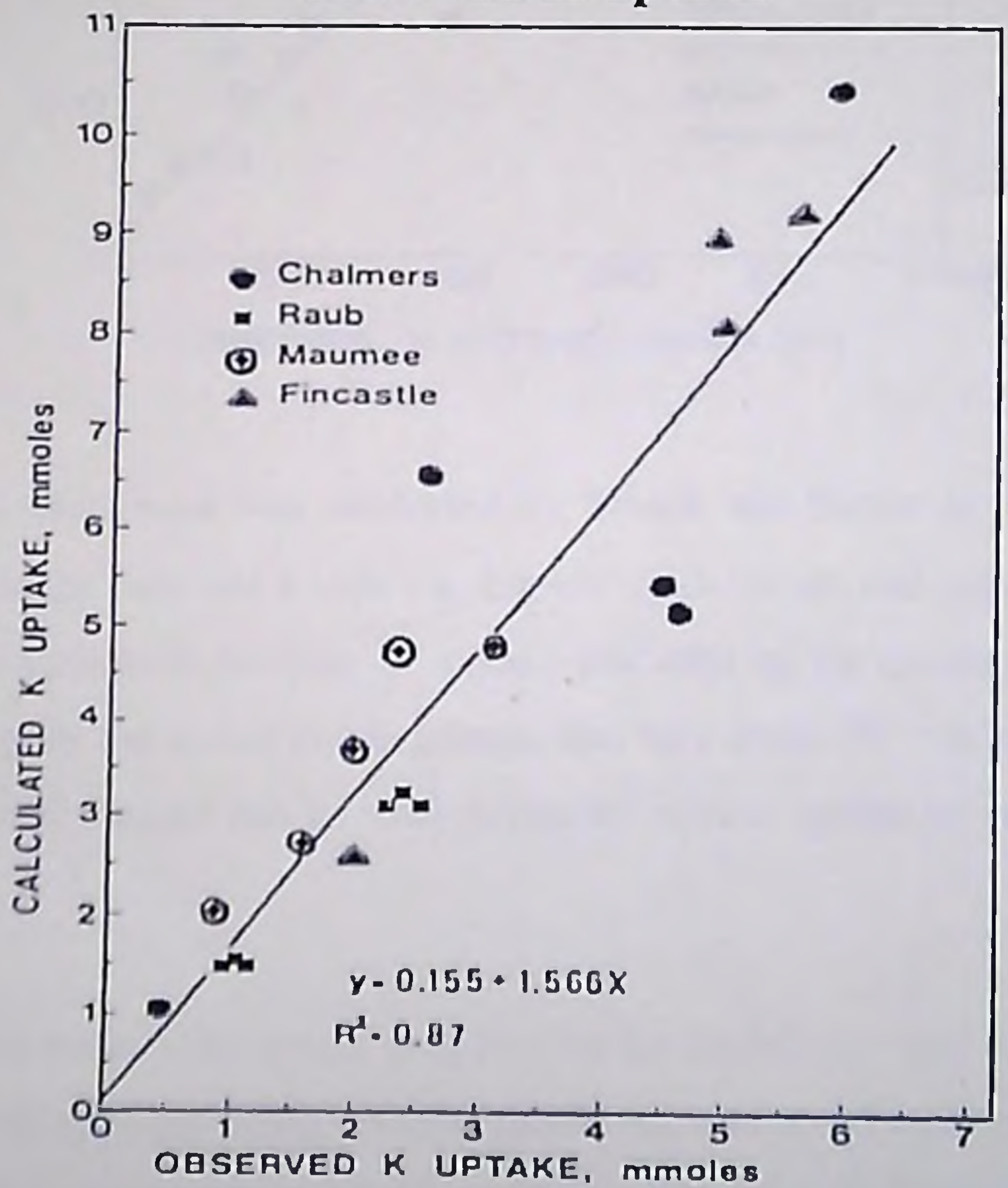
Rattan and Deb (1981) observed an increase in diffusion coefficient, and uptake of Zinc by corn roots due to increase in volumetric moisture content.

EXPERIMENTAL EVALUATION OF THE MODEL (VALIDATION)

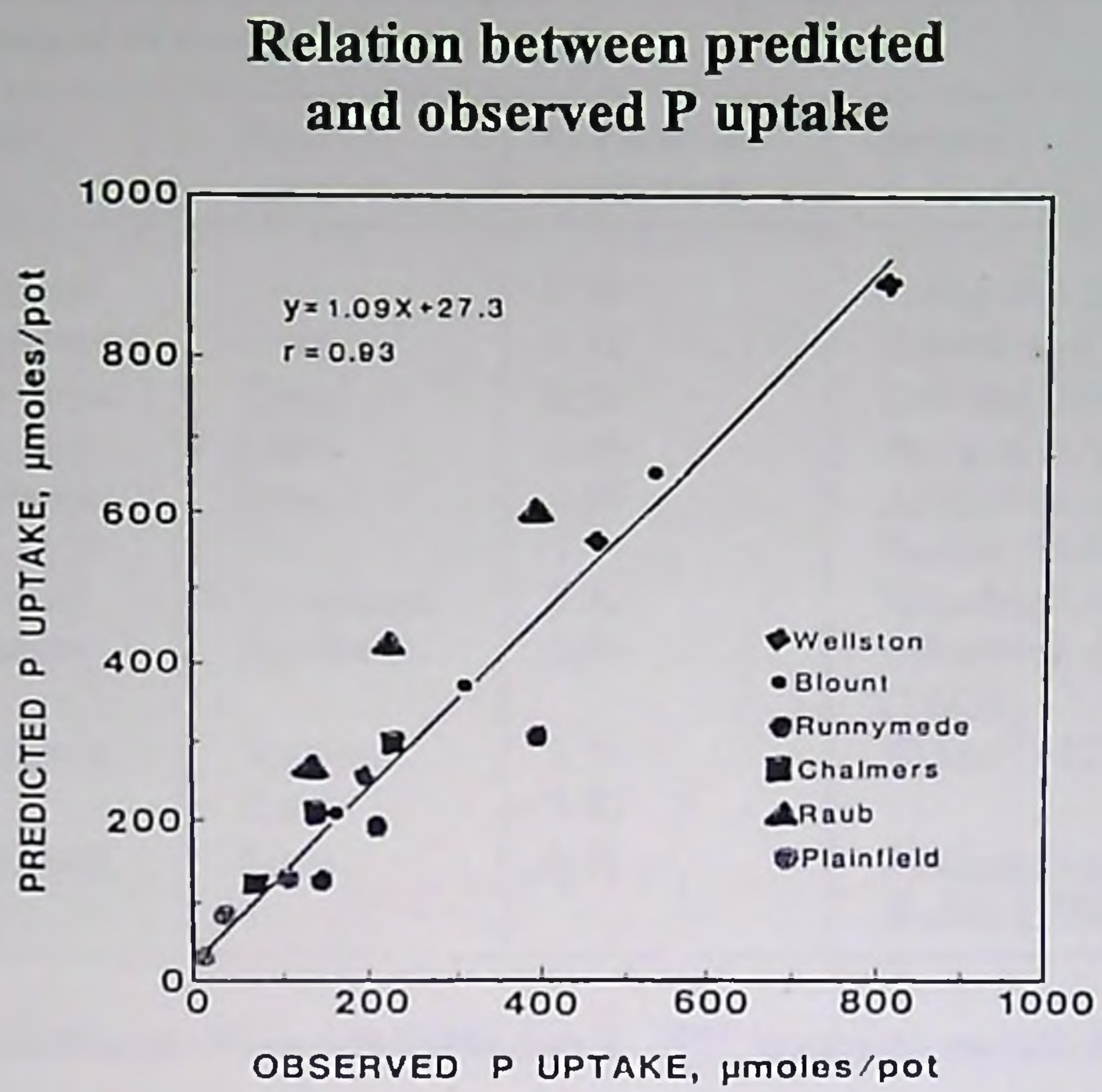
The 'Claassen and Barber' and Cushman models have been validated with a series of pot experiments, using a range of plant species and soils.

Claassen and Barber (1976) grew corn for 17 days in 4 types of soils with 5 levels of added 'K' each at a single level. K uptake measured from plant analysis was compared with K uptake predicted from the model. The results gave a correlation of $R^2 = 0.87$. This is diagrammatically represented in the figure.

Relation between predicted and observed K uptake



An example of the relation between 'P' uptake predicted by the Claassen-Barber model and the actual amount taken by the plant is shown in the figure.



This experiment was conducted by Schenk and Barber in 1980 in 3 maize hybrids grown in the field and 6 soils varying widely in texture and organic matter level were used. The agreement between 'P' uptake predicted by the mechanistic model and the 'P' taken up by the maize plants grown, was very close (R^2 = 0.93). Experiments have shown that the model can be used to predict nutrient uptake by crops growing in the field.

Since the nutrient uptake predicted by the model may vary with the nutrient, plant species, soil type and environmental conditions, additional validation experiments were conducted using a wide range of conditions. The relation between predicted and observed uptake for these experiments given in terms of correlation coefficients is shown in the table

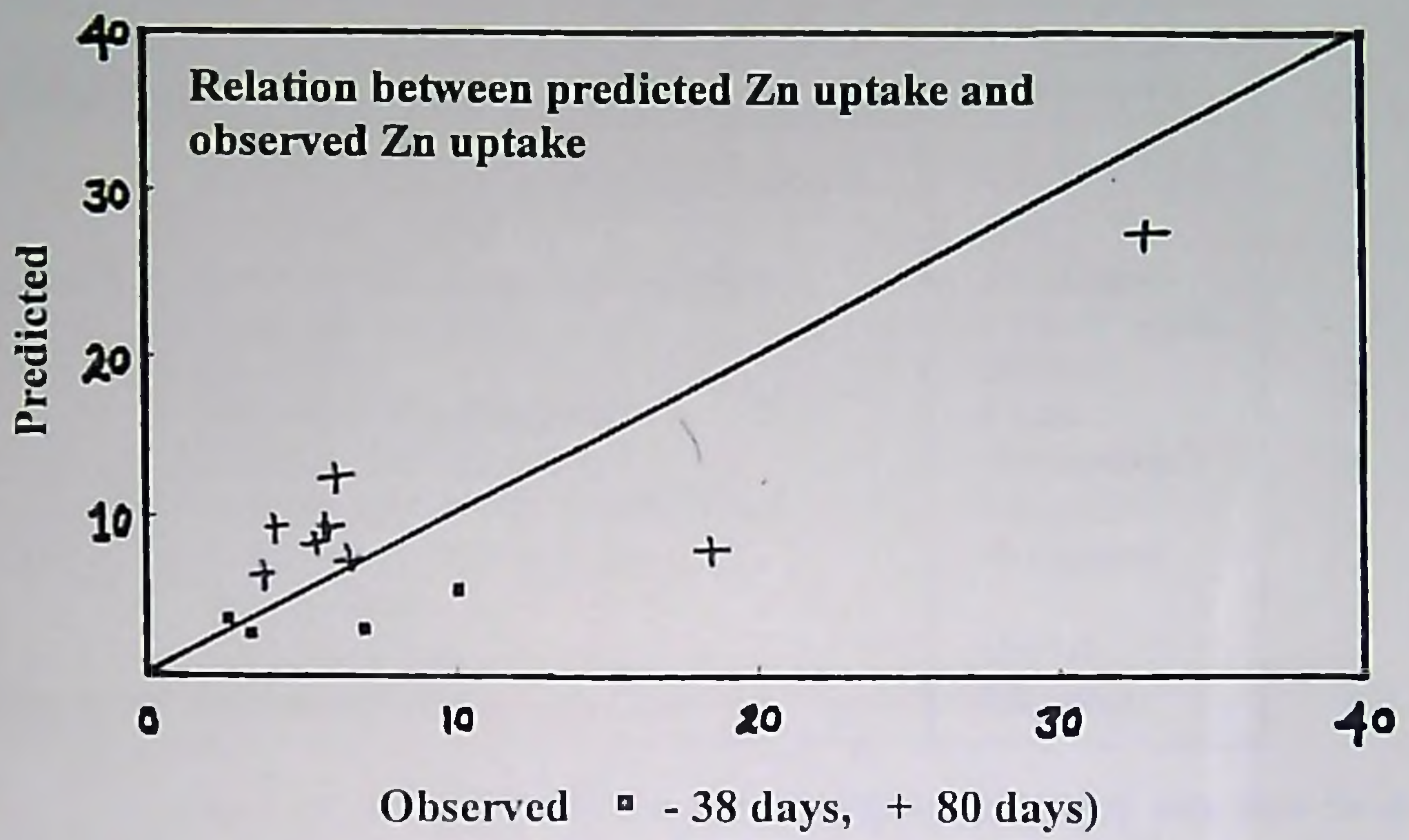
Correlation coefficients for the relation between predicted and observed nutrient uptake obtained in a series of experiments

Nutrient	Plant species	Correlation coefficient	Source
Potassium	Corn	0.98	Ching and Barber (1979)
Phosphorus	Corn	0.98	Schenk and Barber (1979)
Phosphorus	Corn	0.89	Itoh and Barber (1983)
Potassium	Corn	0.96	Shaw et al. (1983).
Phosphorus	Corn	0.85	Anghinoni and Barber (1980)
Potassium	Soyabeans	0.90	Silberbush et al. (1983)
Potassium	Soyabeans	0.96	Silberbush and Barber (1983b)
Phosphorus	Sorghum	0.96	Bidin (1982)
	Carrot	0.93	
Cadmium& Zinc	Corn	0.91	Mullins, Sommers and Barber (1986)

Geelhoed, Mous and Findenegg in 1997 compared models incorporating the influence of root hairs on nutrient uptake from soil using 2 different methods. In this, the roots and root hairs are assumed to behave as a zero sink. Hence all nutrients that is transported to the absorbing surface is taken up.

Reginato and Tarzia in 2000, suggested that the boundary of soil surface is not fixed. As the root growth increases, the soil cylinder volume for which the influence of root exists also increases. Therefore they introduced the 'Moving Boundary' approach. The correlation between the 'S' uptake predicted by this model and observed 'S' uptake showed R^2 value of 0.95.

In India this type of work was done at IARI during 1993 by Dr.P.Sureshkumar. The experiment compared the relation between Zn uptake predicted by the model and observed Zn uptake for rice plants at various growth stages. The experiment was conducted using different rice varieties with 4 levels of added 'Zn'. The observed uptake compared with that predicted for 38 Days After Transplanting and 80 DAT. AT 80 DAT the Zn uptake predicted by the model were in perfect agreement with the observed uptake. For 30 DAT also some values showed high correlation. This is graphically represented in the figure.



SENSITIVITY ANALYSIS

As the model describes the uptake process accurately it is useful to get an estimate of the relative effect on nutrient uptake of each parameter in the model by changing the value of each parameter separately while holding other parameters constant. This is called a sensitivity analysis.

The effect of changing the level of one parameter may be influenced significantly by the levels chosen for other parameters. If the nutrient supply to the root is so great that influx approaches 'I_{max}', changing the level of a parameter to increase nutrient supply to the root will have little effect on uptake, since the root is already absorbing at its maximum rate. For the discussion on sensitivity analysis effects of changing parameters are described under the assumption that plant is getting insufficient quantities of the nutrient in question but is not greatly deficient.

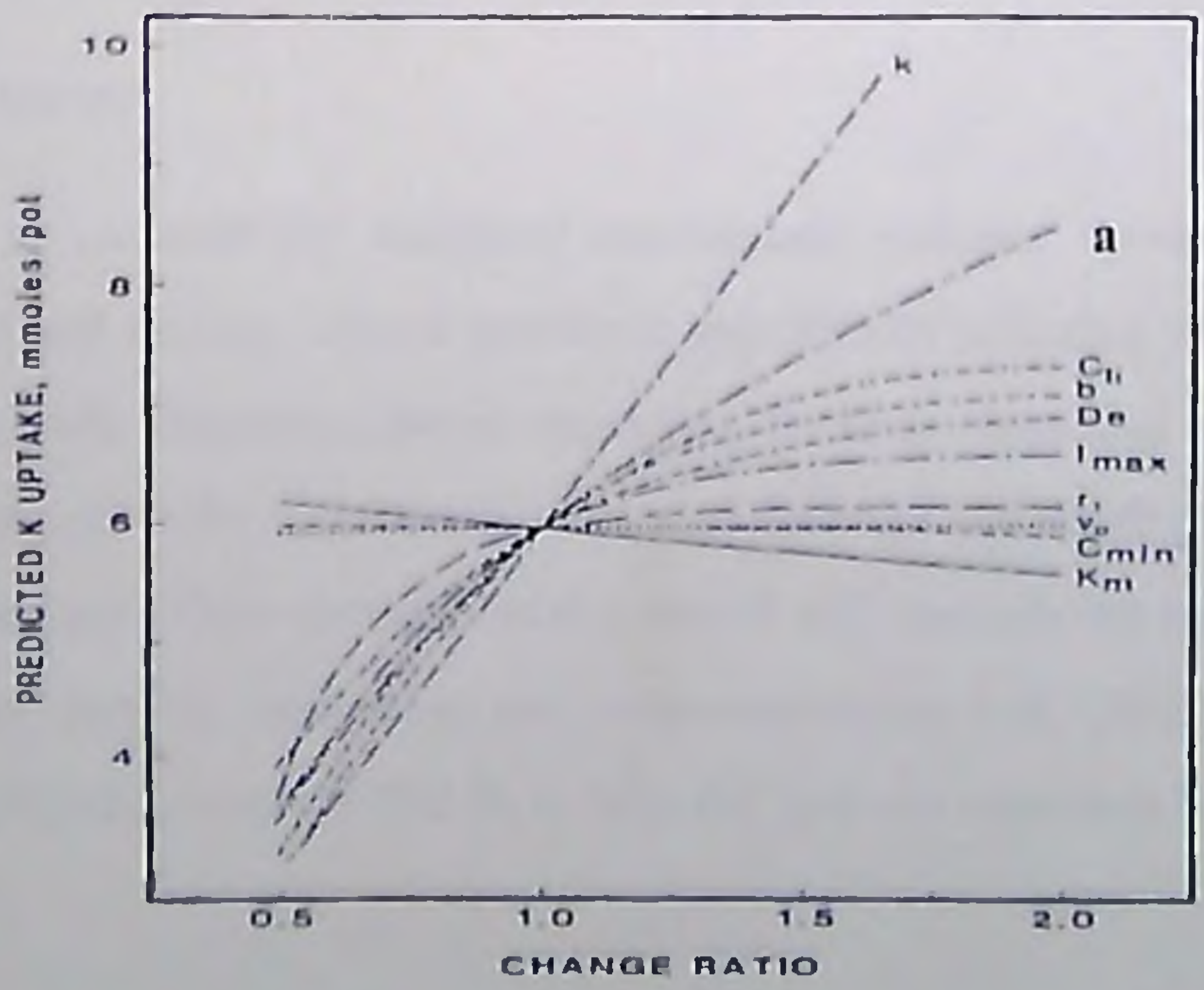
Silberbush and Barber (1983a) conducted such a sensitivity analysis using data from an experiment that investigated 'K' uptake by soybeans grown in pots of silt loam soils in a growth chamber. The initial values used for each parameter are given in the table.

Soil and Plant parameters for the model and values for potassium uptake

Symbol	Parameter	Initial value
De	Effective diffusion coefficient in bulk soil	3.47×10^{-8} cm^2/s
b	Soil buffer power	24.0
C_{li}	Initial concentration of soil solution	250 µmol/L
v	Water influx to root	5.0×10^{-7} cm^2/s
a	Root radius	0.015 cm
r	Half distance between roots	0.2 cm
I_{max}	Maximal influx rate	70.5 $nmol/m^2s$
C_{min}	Minimal concentration, where In = 0	1.4 µmol/L
K_m	Concentration -Cmin where In = 1/2 Imax	10.3 µmol/L
L_0	Initial root length	250 cm
k	Root growth rate	0.03 cm/s

Root growth was assumed to follow a linear relationship with time for the growth period from 10-20 days after planting. Sensitivity analysis was conducted by systematically changing individual values from 0.5-2 times the initial value while all other parameters remained at the initial values. For this analysis, the model was used to predict K uptake for a period of 10 days.

Results of the sensitivity analysis are shown in the figure



Predicted 'K' uptake was most sensitive to root growth rate, root length. Since 'r' was held constant this predicts a pattern of uptake where soil volume would be increasing at the same rate as root length.

The second most sensitive parameter was 'a', the root radius. Increasing 'a' increases the root surface area for uptake and as long as 'r' is sufficiently large so that little competition occurs, predicted uptake increases.

The soil supply parameters C_{li}, b and De were the next most sensitive parameters which suggests that with a constant root surface area, soil supply of 'K' was restricting 'K' uptake more than kinetics of 'K' absorption by the root.

Changing I_{max}, K_m and C_{min} had smaller effect on predicted 'K' uptake and changing v had little effect indicating that most of the 'K' was reaching the root by diffusion.

ADVANTAGES

Compared to other soil fertility evaluation procedures the nutrient uptake models have got additional advantages. These models describe.

- Root growth rate and morphology
- Kinetics of nutrient absorption related to concentration at the root
- Kinetics of soil supply of nutrients by mass flow and diffusion
- Reasons for low recoveries of some nutrients and high recoveries of others
- Reasons for higher nutrient requirement of some crops

CONCLUSION

A successfully validated mechanistic nutrient uptake model will help to identify the soil fertility related problems specifically affecting the yield and will make possible specific recommendation regarding fertilizer dose and method of application, level of moisture to be maintained, the radial distance and depth at which the fertilizer is to be applied etc. Thus nutrient uptake model will provide the background as the most effective soil fertility evaluation and recommendation tool. Using these models we can design fertilization systems that fit in with the systems approach to crop production.

DISCUSSION

1. What is meant by buffer power of soil?

It is the ability of the soil to resist changes in the intensity factor, i.e. the concentration of nutrient ions in the soil solution. Quantity factors gives the potential reserve nutrient ions on the adsorbed phase. When you plot ΔQ against ΔI the slope of the curve $\Delta Q/\Delta I$ gives buffer power.

2. How the mean water flux is measured from total water use?

$$\text{Mean water flux} = \frac{\text{Total water used by plant during time 't'}}{\text{Increase in surface area during time F' x 't' seconds}}$$

3. How the influence of various parameters, is assessed?

It is by using sensitivity analysis.

4. What is the practical utility?

Once this model has been developed, successfully validated and fixed for a particular area, it can clearly predict the uptake mechanism, and influence of various soil and plant factors, to detect very minute differences. Therefore efficient fertilizer recommendation systems can be designed for each locality.

5. Will it possible to fix model for fruit trees?

For any crops it can be practiced.

6. What is tortuosity, what are the factors influencing it?

Tortuosity is the resistance offered by the path for the movement of ions in soil. It is influenced by bulk density, texture of the soil etc. sandy soils are less tortuous. As bulk density increases from 1.1 to 1.3, tortuosity decreases and diffusion increases.

7. What are the main limitations of the procedure of modelling?

Once the model is fixed for an area it is highly useful. But for this, for a particular locality suitable model should be fixed. Measurement of the parameters is very important for suiting a model to the specified location. For each area appropriate changes should be made in the model. Initially, fixation of parameters need high expertise and care and it is laborious.

8. In which crop usually this type of modeling works conducted?

Most commonly used crop is Maize for conducting, modelling experiments.

9. $R^2 = 0.93$ what does it mean?

It means there is 93% accuracy for the model and chance of deviation is only 7%.

10. What is the difference between mass flow and diffusion?

Massflow is the movement of nutrient ion along with the convective flow of water. Diffusion is the movement of nutrient ion along the concentration gradient i.e. from higher to lower concentration.

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A REVIEW ON SOIL TEST CROP RESPONSE (STCR) STUDIES IN INDIA

SEMINAR REPORT

Submitted in the partial fulfillment of the course Ag.Chem.651 - Seminar

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ABSTRACT

Soil Test Crop Response (STCR) approach is the study of the relationship between soil test values and crop yields. This will enable us to prescribe the nutrient requirements to obtain a desired yield. The STCR studies were started during 1967-68 at IARI, New Delhi, with eight Coordinating Centres. In 1975, the headquarters was shifted from IARI to AICRP on STCR correlation at Hyderabad. In Kerala STCR study was started on 1-11-1996 at KAU, Vellanikkara.

A well established soil test calibration help to apply fertilizers in precise amounts, obtain high use efficiency of applied nutrients and maximum possible yield in an ecosystem. STCR studies have different approaches viz., 1) Targeted yield concept, 2) Multiple regression model, 3) Soil test based fertilizer prescription for cropping sequences, 4) Soil test based integrated plant nutrient supply system. On farm trials and Front line demonstration on STCR will be done at the farmers field based on the above approaches.

The STCR project has generated over the years numerous adjustment equations for important crops at different centres for different agroclimatic region. These equations permit derivation of calibrations for fertilizer application at different levels of soil test N, P and K.

Based on STCR approach, we can follow the balanced use of fertilizer under resource constraints and the maintenance of soil fertility. This approach also results in higher response ratio in terms of kg grain per kg applied nutrients over general recommended doses.

A Review on Soil Test Crop Response (STCR) Studies in India

Introduction

The importance of fertilizers in increasing the production of food grains and other crops is well recognised by the farmers. In India, the contribution of fertilizers to total grain production has been remarkable as it increased from 1% in 1950 to 58% in 1995. For raising the production of food grains from a current level 208 million tonnes with 156 million tones of fertilizer in 2000-2001 to an estimated level of 338 to 423 million tones in 2025. The expected fertilizer nutrient requirement would be around 30-35 million tonnes excluding the other sources of nutrients.

Fertilizers are costly input in agriculture. In future, production costs of N, P_2O_5 and K_2O fertilizers will become more costly and the demand for them will depend upon the ability of the farmers to pay for them. Economic rationality, therefore, dictates a more comprehensive approach to fertilizer utilisation incorporating soil tests, field experimentation and economic evaluation of results.

Soil test calibration is intended to establish a relationship between the levels of soil nutrient as determined in the laboratory and the crop response to fertilizer observed in the field. Such relationship helps to develop calibration charts and permits balanced fertilization of crops. Complexity in soil test crop response studies arises due to great diversity of soils, climate, crops and management practices (Rao,1999)

Soil Test Crop Response (STCR) approach is the study of the relationship between soil test values and crop yields. This will enable us to prescribe the nutrient requirements to obtain a desired yield. The STCR studies were started during 1967-68 at IARI, New Delhi, with eight coordinating centers. In 1975, the headquarters was shifted from IARI to AICRP on STCR correlation at Hyderabad. Now, recently the AICRP on STCR project is headed under Indian Institute of Soil Science (IISS), Bhopal (M.P.). Now it has 17 coordinating centers under this control. In KAU this study (STCR) was started on 1-11-1996 at College of Horticulture, Vellanikkara.

A well established soil test calibration help to apply fertilizers in precise amounts obtain high use efficiency of applied nutrients and maximum possible yield in ecosystem. In this part research achievements of the project have different approaches viz., 1) Targeted yield concept, (2) Multiple regression model,

(3) Soil test based fertilizer prescription for cropping sequences, (4) Soil test based integrated nutrient supply system, (5) Technology recommended for adoption and (6) Results of the front line demonstration on soil test crop response are presented.

Objectives

The main objectives of the project are,

- To develop relationships between soil test values and crop response to fertilizers, in order to provide a calibration for fertilizer recommendation based on soil testing.
- To obtain a basis for making fertilizer recommendations for targeted yields.
- To evaluate various soil test methods for their suitability under field conditions.
- To evaluate the join use of chemical fertilizers and organic manure for enhanced nutrient use efficiency.
- To derive a basis for making fertilizer recommendations for a whole cropping sequence based on initial soil test values.

Research accomplishment of this studies (STCR)

I. Targeted yield concept

It may be defined as, target the yield based on fertilizer availability, in order to find out the nutrient requirements of the crop.

Dimensions of the concept

In extending this concept over large areas, the basic data appropriate for the soil type and crop variety generated from local research experiments need to be used, selecting an appropriate target suited for the climate as well as the genetic potential of the plant and the managerial ability (Velayutham *et al*, 1987).

1) The concept of targeted yield resolves, the much debated approaches viz., "Fertilizing the soil" versus "Fertilizing the crop" and provides the real balance between the applied

nutrients among themselves and with the available nutrients already present in the soil. Thus, the new dimension to the value and utility of soil testing has been brought up by this concept.

2) When fertilizer availability is limited or the resources of the farmer are also limited, planning for low yield targets (at the same time higher than the yield levels normally obtained by farmers) provides a means for efficient and economic use of the available fertilizer. By such an approach, more areas could be covered with the available fertilizers ensuring increased total production also.

3) Long term maintenance of soil fertility

If soil fertility is to be maintained, heavier doses of fertilizer have to be used over and above that removed by the crop so that enough residuals are left in the soil even after the normal losses of nutrients. However, this will not make the economic return from the investment on fertilizer. To get the maximum return from the investment, the turn over from it must be very quick as when fertilizer is applied for low yield targets. In such situations, the native soil nutrients will make a great contribution to increased yield, which over seasons, however, would mean unduly exhausting the unutilized excess nutrients from the soil resulting in faster rate of depletion of soil fertility.

Fertilizer recommendation based on targeted yield concept

The concept of fertilizer prescription for targeted yields, first advocated by Troug (1960). In India Ramamoorthy *et al.*(1967) established the theoretical basis and experimental proof for the fact that the Liebig's "Law of minimum" operates equally well for N, P and K.

Liebig law of minimum states that the growth of plants is limited by the plant nutrient element present in the smallest amount, all others being in adequate quantities.

The linear model is represented by

$Y = a + bx$

where y - yield

a and b are constants

x - fertilizer nutrient

Even today, Liebig's concept is the first principle in fertilizer use and management (Velayutham, 1987).

Among the various methods of fertilizer recommendation, only the targeted yield approach is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve it good agronomic practice are followed in raising the crop.

The essential basic data required for formulating fertiliser recommendation for targeted yield are

(i) Nutrient requirement in kg/q of produce (grain or other economic produce)

(ii) The percent contribution from the soil available nutrients

(iii) The percent contribution from, the applied fertilizer nutrients.

The above mentioned three parameters are calculated as follows.

I. Nutrient requirement of N, P and K for grain production

$$\text{Kg of Nutrient/q of grain (NR)} = \frac{\text{Total uptake of Nutrient (Kg)}}{\text{Grain yield (q)}}$$

II. Contribution of nutrient from soil

$$\text{\% Contribution from soil (CS)} = \frac{\text{Total uptake in control plots}}{\text{Soil test values of nutrient in control plots}} \times 100$$

III. Percentage contribution of nutrient from fertilizer

Contribution from Fertilizer (CF) = {Total uptake of nutrients in treated plots} — {Soil test values of nutrients in fertilizer treated plots} X (CS) Fertilizer

$$\therefore \text{\% contribution from fertilizer} = \frac{CF}{\text{Fertilizer dose (kg/ha)}} \times 100$$

Calculation of fertilizer dose

The above basic data are transformed in to workable adjustment equation, that as follows.

$$\text{Fert. dose} = \left[\frac{NR}{CF} \times 100 \times T\right] - \left[\frac{CS}{CF} \times STV\right]$$

Where, T = Targeted yield

(Ramamoorthy *et al*, 1967)

This model is useful for computing optimal fertilizer doses for varying soil test values for obtaining different yield targets. The optimal doses are then tested under farmers' field conditions for their reproducibility before they are generalized for large scale adoption.

Velayutham *et al*, (1987) refined the estimation of soil and fertilizer efficiencies for calibrating fertilizer adjustment equations.

The fertilizer recommendations based on this concept are quantitative, precise and meaningful because the combined use of soil and plant analysis is involved in it. The real balance for the maximum yield is not that merely between the applied nutrients but that after taking into account their relative availability from soil and from the fertilizer.

The sum of the available from the soil and fertilizer together for the different nutrients should be in the same ratio in which they are actually needed by the plant and plant variety. This is possible only by fertilizer application for the targeted yield model and not by any other method of applying fertilizers.

Table : 1

Targeted yield equations generated by the co-operating centres for different crops

Centre	Year	Crop	Equation
1. IARI, New Delhi	1993	Maize	FN = 5.972 T - 0.312 SN F P_2O_5 = 4.398 T - 3.329 SP F K_2O = 3.225 T - 0.281 SK
	1995-96	Wheat	FN = 4.845 T - 0.486 SN F P_2O_5 = 2.918 T - 4.368 SP F K_2O = 2.169 T - 0.256 SK
	1995-96	Bajra	FN = 5.87 T - 0.42 SN F P_2O_5 = 4.00 T - 3.69 SP F K_2O = 3.41 T - 0.32 SK
2. Hyderabad	1994-95	Rice	FN = 3.481 T - 0.370 SN F P_2O_5 = 2.535 T - 2.130 SP F K_2O = 1.885 T - 0.195 SK
3. Coimbatore	1994-95	Rice	FN = 3.845 T - 0.377 SN F P_2O_5 = 1.736 T - 2.625 SP F K_2O = 4.191 T - 0.402 SK
	1997-98	Sunflower	FN = 10.29 T - 0.45 SN F P_2O_5 = 7.36 T - 2.185 SP F K_2O = 12.69 T - 0.45 SK
4. Pusa	1995	Sesame	FN = 13.86 T - 0.34 SN F P_2O_5 = 11.91 T - 1.22 SP F K_2O = 10.54 T - 0.59 SK

Centre	Year	Crop	Equation
5. Jabalpur	1996-97	Mustard	FN $= 8.364\ T - 0.094\ SN$ F $P_2O_5 = 5.697\ T - 1.409\ SP$ F $K_2O = 5.697\ T - 0.032\ SK$
6. Hisar	1993	Bajra	FN $= 9.42\ T - 1.00\ SN$ F $P_2O_5 = 3.46\ T - 3.22\ SP$ F $K_2O = 2.87\ T - 1.24\ SK$
	1995-96	Durum wheat	FN $= 5.20\ T - 1.00\ SN$ F $P_2O_5 = 1.95\ T - 3.22\ SP$ F $K_2O = 2.09\ T - 0.129\ SK$
7. Pant Nagar	1994	Wheat	FN $= 3.15\ T - 45.04\ SN$ F $P_2O_5 = 2.05\ T - 0.5\ SP$ F $K_2O = 1.77\ T - 0.06\ SK$
8. KAU, Vellanikkara	1997	Banana	FN $= 83.49\ T - 7.69\ SN$ F $P_2O_5 = 19.34\ T - 34.93\ SP$ F $K_2O = 121.18\ T - 5.38\ SK$
	1998-99	Cassava	
	1999-2000	Ginger	FN $= 7.8\ T - 0.37\ SN$ F $P_2O_5 = 2.8\ T - 0.64\ SP$ F $K_2O = 10.6\ T - 0.83\ SK$

Advantages

- Giving fertilizer recommendations efficiently
- Fertilizer allocation under conditions of fertilizer credit shortages
- Fertilizer recommendations for targeted yields and maintenance of soil fertility in a cropping system
- Prediction of post-harvest soil test values in multiple cropping systems
- Area wise fertilizer recommendation based on yield targeting and nutrient index of soil
- INM for yield targeting using organic manures and chemical fertilizers.

Targeted yield concept strikes a balance between 'fertilizing the crop' and 'fertilizing the soil'. The procedure provides a scientific basic for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is a linear relationship between grain yield and nutrient uptake by the crop, as for obtaining a particular yield, a definite amount of nutrients are taken up by the plant (Jana et al, 1996).

Once this requirement is known for a given yield level, the fertilizer needed can be estimated taking into consideration the contribution from soil available nutrients conditions.

The yield targeting equations are valid under the following situations.

1. These should be used for similar soils occurring in a particular agro-eco region.
2. Targets chosen should not be unduly high or low and should be within the range of experimental yields obtained.
3. Adjustment equations must be used within the experimental range of soil test values and cannot be extrapolated.
4. Good and recommended agronomic practices need to be followed while raising crops.
5. Other micro and secondary nutrients should not be yield limiting.

This approach forms the basis for the National programme of soil test crop response correlation studies under the coordinated scheme of the ICAR. The work on this approach for almost all the field crops have been conducted in all the canters and fertilizers adjustment equations developed (Rao, 1999).

These soil test calibration equations have been vigorously tested and evaluated for their predictability through series of well conducted field verification trials in farmer's holdings. The fertilizers adjustment equations, after evaluation in the follow-up trials, are used to rationalize the fertilizer recommendations for all the major crops grown in the states in which the STCR scheme is being operated.

In Maharashtra state, this targeted yield approach is exclusively used by the state Department of Agriculture for giving fertilizer recommendation of field crops. Some work on these lines was initiated at IRRI. Almost for all the major soil series of each state, the targeting of yield has been done. Though mapping out our soils in that details has not been attempted, sufficient results are generated through the research work conducted in the All India Coordinated Research Project on STCR for rationalized use of fertilizer for various crops. Thus, this approach may not continue to be a distant research goal. By establishing proper linkage between the information generation point and the use point (i.e.) the Agricultural University and state soil testing service, the transfer of this particular agro-technology on soil test based balanced fertilizer use for various yield targets to the users viz., farming community is not far off (Rao, 1999).

II. Multiple Regression

The functional relationship between more than two variables is known as multiple regressions. So here, yield parameter 'Y' is regressed with different nutrients status of the soil.

Multiple regression approach is used to calculate the dose of nutrients required to obtain the maximum yield of crops under given set of experimental conditions.

It can further be used to calculate the economic dose of fertilizer nutrients by incorporating a constant factor.

$$(R)\ C.F. = \frac{\text{Per unit cost of input (fertilizer)}}{\text{Per unit cost of produce}}$$

In this approach yield is regressed with soil nutrients, fertilizer nutrients, their quadratic terms and the interaction between soil and fertilizer nutrients.

Conditions for application

Soil test crop response calibration for economic yield of a crop is possible only when the response to added nutrients follows the low of diminishing returns.

There are eight different response types signified by the signs for the linear and quadratic terms of the added fertilizer and the interaction term between the fertilizer and soil test value (Ramamoorthy *et al*, 1967).

The following eight response types are recognized, but except the last, first seven types are non-ideal for derivation of soil test based fertilizer recommendation.

(i) - - + (ii) - - - (iii) + + + (iv) + + -

(v) - + + (vi) - + - (vii) + - + (viii) + - -

The quadratic function has been fitted with combination of

(i) Linear terms of soil and fertilizer nutrients

(ii) Quadratic terms of soil and fertilizer nutrients

(iii) Interaction between soil and fertilizer nutrients

Though numerous experiments it has been realized that for high order of predictability the co-efficient of determination should be equal or ($R^2 > 0.67$) more than 67% and also the partial regression co-efficient obtained from the relationship should be statistically significant between yield and soil tests.

The next step is to establish a significant relationship between the soil tests the added fertilizer levels and the crop yield. This relationship is established by fitting a regression of the quadratic form as given below.

$$Y = A \pm b_1SN \pm b_2SN^2 \pm b_3SP \pm b_4SP^2 \pm b_5SK \pm b_6SK^2 \pm b_7FN \pm b_8FN^2 \pm b_9FP \pm b_{10}FP^2 \pm b_{11}FK \pm b_{12}FK^2 \pm b_{13}FNSN \pm b_{14}FPSP \pm b_{15}FKSK$$

Table : 2

Work done in India

Centre	Year	Crop	R^2 value
1. Pusa	1994	Sugarcane	0.93**
2. Hisar	1994-95	Wheat	0.98**
3. Rahuri	1996-97	Sugarcane	0.77**
4. Hyderabad	1995	Rice	0.96**
	1995	Maize	0.68**
	1996	Sunflower	0.80**
5. Ludhiana	1996-97	Wheat	0.69**

Y = Crop yield (kg/ha)

A = Intercept (kg/ha)

b_1 to b_{15} = regression co-efficient

SN, SP, SK - soil available, N, P and K (kg/ha)

FN, FP, FK - Fertilizer N, P and K (kg/ha)

Other Nutrients

From the multiple regression models, where all the three essential conditions are satisfied for a particular nutrient, its dose for maximum yield is calculated at a given soil test value of that nutrient. However, this dose for maximum yield should be used only with adequate levels of other associated nutrients.

Alternative approach

For multinutrient experiments, a complete factorial experiment with a number of levels of each nutrient is considered the best design for both evaluating the models and then estimating the optimum nutrient levels. In many soil crop situations, experiments with only NP, N or P are required because the other nutrients may already be present in adequate levels.

III. Targeted yield equations for cropping sequences

Nutrient availability in the soil after the harvest of a crop is much influenced by the initial soil nutrient status, the amount of fertilizer nutrients added and the nature of the crop raised. Of late, the monoculture is replaced by cropping sequence. For soil test based fertilizer recommendations the soils are to be tested after each crop, which is not practicable. Hence, it has become necessary to predict the soil test values after the harvest of the crop. It is done by developing post-harvest soil test value prediction equations making use of the initial soil test values, applied fertilizer doses and the yield obtained or uptake of nutrients following the methodology outlined by Ramamoorthy *et al.* The post harvest soil test values were taken as dependent variable and a function of the pre-sowing soil test values and the related parameters like yield/uptake and fertilizer nutrient doses.

The functional relationship is as follows

YP/H = f [F, IS, yield/nutrient uptake]

YP/H = Post harvest soil test value

F = applied fertilizer nutrient

IS = Initial soil test value

Mathematical form of this function

YP/H $= a + b_1F + b_2\ IS + b_3$ yield/uptake

a = absolute constant

b_1, b_2, b_3 - respective regression co-efficient

Prediction equations for post-harvest soil test values were developed from initial soil test values. Fertilizer doses applied and yield of crops/uptake of nutrients in order to obtain a basis for prescribing the fertilizer amounts for the crops succeeding the first crop in the cropping sequence at New Delhi and Coimbatore canters.

Coimbatore canter has developed post harvest soil test prediction equations for several cropping sequences. The post-harvest soil test value prediction equations for predicting the soil test values after the harvest of crops in the cropping sequence were developed making use of the data generated in the first and second test crops of rice (Santhi, 1995).

Fertilizer Recommendations for cropping sequence

Since the changes is soil nutrient status after the harvest of crops will vary from soil to soil, crop to crop and even from season to season. It is quite imperative to assess the residual soil fertility in cropping sequence and this would form the basis for yield targeting and optimization of fertilizer requirement of succeeding crops in a cropping sequence.

Keeping all the parameters at an optimum level, the changes in soil nutrient status are predicted as a function of initial soil test values, applied N, P and K fertilizers and the actual yield/uptake of nutrients of the crop in a particular season. These equations are termed as post-harvest soil test prediction equations.

They are useful because under intensive agriculture, the soils of the farmer's fields cannot be tested between each season for practical reasons. Thus, the predicted soil test values are used for giving rationalized fertilizer prescriptions based on the fertilizer adjustment equations developed for individual crops in the cropping sequence.

Appreciably large R^2 values significant at one per cent level are obtained for these equations. This suggests that such regression equations can be used with confidence for the prediction of available nutrients viz., N, P and K after the first crop in any cropping sequence for making soil test based, balanced fertilizer recommendation for the succeeding crops in the sequence.

IV. Integrated nutrient supply system

Four co-operating centres viz., Pusa (Bihar), Coimbatore (Tamilnadu), Jabalpur (Madhya Pradesh) and Rahuri (Maharashtra) have generated technologies for integrated supply of plant nutrients involving fertilizers, organic manures and Biofertilisers. In this technology, the fertilizer nutrient doses are adjusted not only to that contributed from soil but also from various organic sources like FYM, green manure, compost and biofertilizers like Azospirillum and Phosphobacteria (Jayalakshmi, 2001).

Methodology of IPNS using STCR calibration

As in the regular STCR studies, the field experiment consisted of two parts,

a) Creating artificially a large variation infertility status by applying four graded dose of N, P and K fertilizers to four strips and by growing a gradient crop to stabilize the treatments. The 'P' and 'K' levels were fixed based on P and K fixing capacities of soils.

b) Test crops were grown following fractional factorial design with treatments consisting of varying levels of N, P, K and two to three levels of organic manures and absolute controls.

The test crops were grown up to maturity and harvested. The yields of economic produce were recorded. The available NPK before initiation of the experiment and the concentrations of NPK in the plant samples collected at harvested were chemically analyzed. Using the concentrations and yield data, the total uptake of NPK by the test crops were calculated (Selvakumari *et al*, 1998).

Basic parameters

Making use of the data generated in the test crop experiments, the nutrient requirement (NR) in kg/q of economic produce, percent availability of soil available nutrients (CS) as measured by soil tests, percent availability of the fertilizer nutrients (cf) and percent availability of organic nutrients (co) were computed.

The method of calculation of basic data are furnished below.

1. Nutrient requirement [q/ka] (NR) = $\dfrac{\text{Total uptake of nutrients (grain + straw) (kg/ha)}}{\text{Yield of economic produce q/ha}}$

2. Contribution of soil nutrients (CS) = $\dfrac{\text{Total uptake of nutrients (grain + straw) in control plots (kg/ha)}}{\text{STV of available nutrients in control plots (kg/ha)}}$

3. Contribution of nutrient from Fertilizer (CF) = $\dfrac{\text{(Total uptake of nutrients in fertilized plots) - (STV of nutrients in fertilized plots) X (Mean CS of nutrients)}}{\text{Fertilizer Nutrients applied in kg/ha}}$

Table : 3

Some of the targeted yield equations - IPNS at different centres

Sl.No.	Centre	Crop & Variety	Season	IPNS component
1	Jabalpur (MP)	Sunflower, Modern	Rabi	FYM
2	PUSA (Bihar)	Rice - Gautam	Kharif	Compost
3	PUSA	Wheat	Rabi	Compost
4	PUSA	Maize - Deoki	Rabi	Compost
5	Bhavanisagar (TN)	Rice, ADT 36	Kharif	GM + PB
6	Bhavanisagar (TN)	Rice, ASD-18	Rabi	GM + PB
7	Ariyanur (TN)	Tapioca - Burma	-	FYM
8	Vellayani (Kerala)	Cassava - M_4	-	FYM

$$\text{4. Contribution of nutrient from from organics (CO)} = \frac{\text{(Total uptake of nutrients in organic plots)} - \text{(STV of nutrients in organic plots in kg/ha)} \times \text{mean CS of nutrients}}{\text{Amount of nutrients added as organics in (kg/ha)}}$$

Based on this basic data we can develop targeted yield equations as followed in STCR approach.

Equations, however, are empirically derived and should be used with caution considering the following points.

1) Equations should be used for similar soils varying only in their soil fertility status.

2)Within the range of soil fertility from which the equations have been derived

3) Yield target chosen should be within the range of yields obtained in the experiment

4) Recommended agronomic practices are followed to realize the yield targets

V Technology Recommended for adoption

The STCR project is expected to provide a scientific back up for the state soil testing laboratories either to revise or modify the existing methods for determination of N, P and K nutrient status and / or suggest new approaches or method of reviewing or time tuning the fertilizer recommendation on the basis of the STCR project research results (Murugesaboopathy *et al*, 1993)

V) Technology recommended for adoption

STCR project has generated voluminous data and their statistical analysis to work out relationships between crop yields and soil test values, regression co-efficient and adjustment equation for targeted yields.

Results of the follow up experiments

Soil testing is the best means to know the nutrient status of soils and assess the fertilizer requirements for a crop or cropping system. Soil test crop response correlation project employs targeted yield concept to work out fertilizer nutrients requirements to obtain a desired yield. Fertilizer adjustment equations were generated incorporating nutrient requirement of crop and fraction of soil and fertilizer nutrients utilized.

These targeted equations were tested in follow up trials and frontline demonstrations on farmers field. In this section several examples where balanced fertilizer use based on targeted yield approach helped to produce higher crop yields and obtain higher benefit : cost ratios have been presented. These follow up trials also revealed that soil test based recommendations help to efficiently use available resources, maintain soil fertility and practice integrated plant nutrient supply to crops (Swadija, 1997)

VI) Front line Demonstration on soil test Based crop Response

The magnitude of crop response to any particular nutrient depends not only up on the status of the particular nutrient but also upon the deficiency or sufficiently status of other essential plant nutrients in soils. So the real crop response to N, P and K cannot be realized if any one of the essential plant nutrients is in short supply. Further more, the magnitude of response of crops to applied nutrients is largely controlled by the extent or emergence of constraint of one or more nutrients during the crop growth, as a result of their continuous depletion by heavy crop harvest; or their imbalance / sub optimal or no use

The response (kg grain/ kg applied nutrient) to fertiliser nutrient has been decreasing with time and it is more so in recent years after the decontrol of fertilizers. STCR correlation project has generated targeted yield equations and calibration charts for targeting higher yield and recommending fertilizers on the basis of soil tests.

To create an awareness among the farmers about the technology developed in STCR project for balanced use of fertilizers, front line demonstrations on soil test based crop response have been launched during rabi 1996 with a grant of Rs. one crore from the Department of Agriculture and Co-operation, Government of India under this project in 10 states, 11 co-operating centres of STCR in collaboration with 34 soil testing laboratories have conducted 155 front line demonstrations on farmer's field on important cropping systems and on dominant soils in the respective region during rabi 1996-97. The demonstrations have been continued in the kharif 1997 and rabi 1997-98 by laying our 110 and 115 demonstrations respectively.

In these demonstrations, the soils have actually been analyzed and fertilizers to be applied in different treatments have been calculated on soil test basis. The results obtained by eight STCR centres Hisar-Haryana, Pusa-Bihar, Hydrabad - A.P., Coimbatore - T.N. and Jabalpur and Raipur - M.P., New Delhi, Rahuri - Maharastra and furnished here under (Rao, 1999).

CONCLUSION

In view of the emerging trends in current agriculture, the need for optimum utilization of both renewable and non-renewable resources and the concern for the quality of the soil health and environment, the research on soil testing needs reorientation for meeting the future challenges.

- Based on STCR approach, we can follow the balanced use of fertilizer under resource constraints and the maintenance of soil fertility.
- This approach also results in higher response ratio in terms of kg grain per kg-applied nutrients over general recommended doses.
- It will increase the farmer's economic status by reducing the cost of fertilizers.

DISCUSSION

Q. Whether the same equation is used every year or it varies?

A. Based on the soil test values we can modify this equation because the soil fertility status will vary year by year.

Q. How will you calculate CF value?

A. CF = Total uptake of nutrients in treated plots - (Soil test values of nutrient in fertilizer treated plots) x CS

$$\% \text{ contribution from fertilizer} = \frac{CF}{\text{Fert. dose (kg/ha)}} \times 100$$

where,

CF - Nutrient contribution from fertilizer

CS - Nutrient contribution from soil

Q. Whether STCR work is done for perennial crops?

A. Yes, STCR work was done in some tree crops and orchard crops.

Q. The soil fertility status varies with in a location whether STCR changes (or) not?

A. The STCR work is doing for location specific and this results are tested in farmers field. After getting better response, then only we can recommend the fertilizer doses.

Q. In KAU, what are the crops being tested under this STCR approach?

A. The research work was done in different crops at Vellanikkara, those are 1) Banana, 2) Ginger, 3) Turmeric, and at Vellayani STCR, work is done in cassava.

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NUTRIENT MANAGEMENT IN UPLAND RICE

SEMINAR REPORT

For the partial fulfilment of
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ABSTRACT

Rice is the most important crop of India, being grown all over the country under diversified ecosystems. In past few decades, there has been a quantum jump both in production and productivity of rice, which occurred mainly under irrigated ecosystem. To meet the future demand of rice, minimum of two to three million tonnes must be added to current level of rice production. Considering future food demand, dwindling natural resources, inherited advantages and customs related to rice, it is imperative to improve upland rice ecosystem.

Although upland rice covers 21.9% of rice area of the country it contributes only 10% to total rice production (Mishra,1999). Poor soil fertility, land degradation and lack of availability of plant nutrients to crop are important bottlenecks in increasing and stabilizing the productivity of upland rice. As the extent of annual depletion due to removal by crop and soil erosion is high, its replenishment through fertilizer and manure is a must for sustainability.

The nutrient regime of upland soil is very different from other types of rice soils. Oxidized soils are characterized by deficiency of P and Fe in neutral and alkaline soils, and Mn and Al toxicity in acid soils fertilized with Ammonium sulphate. The pH of soil is mostly acidic under upland situation resulting in lower availability of P, Si and cations.

Upland rice soils are deficient or marginally sufficient in N content, which is the main bottleneck in increasing and stabilizing the yield. Only 20-35% of the applied N fertilizer is used by the crop due to various kinds of losses. For most of the upland rice in different parts of the country, 40-60 Kg N ha^{-1} has been found to be the optimum dose. The studies conducted at College of Agriculture, Vellayani, have arrived at a recommendation of 60 Kg N ha^{-1} in open situation (Thomas,2000) and 80 Kg N ha^{-1} under the shaded situation in coconut garden (Anu,2001). NUE can be improved by split application, placement, using modified forms of urea and foliar application.

The P deficiency may be a limiting factor in upland, especially in acid soils. Rock phosphate @ 20-30 Kg P_2O_5 ha^{-1} as basal dose has shown better result. P use efficiency can be improved by liming, organic matter application and P solubilizing bacteria. With the adoption of improved varieties and increased cropping intensity, there has been considerable depletion in the K status of the upland soils. Application of 45 Kg/ha under shaded condition have recorded higher grain and straw yield (Anu,2001). A sizeable portion of silica is taken up by the rice crop and hence this has to be replenished through application of silica containing materials.Liming is required to ameliorate the adverse effect of soil acidity on plant growth. In soils having pH less than 5.5, the problem of toxicity of Mn and Al associated with Ca and Mg may occur.

Integrated nutrient management is the key factor to improve the productivity in upland rice. Hence, balanced fertilization including use of organics is essential for ecofriendly and sustainable agriculture and also to prevent antagonistic effects of plant nutrients.

NUTRIENT MANAGEMENT IN UPLAND RICE

INTRODUCTION:

Rice is the most important crop of India, being grown all over the country under diversified ecosystems. In past few decades, there has been a quantum jump in both production and productivity of rice, which occurred mainly under irrigated ecosystem. To meet the future demand of rice, minimum of two to three million tonnes must be added to current level of rice production. Considering future food demand, dwindling natural resources, inherited advantages and customs related to rice, it is imperative to improve upland rice ecosystem.

On a global basis, upland rice is 30Per cent. In India, out of the 42.7 million hectares of land under rice, 21.9 per cent of the area is occupies upland rice (Mishra, 1999) and more than 80 per cent of the upland rice area is concentrated in the states of Assam, Bihar, Madhya Pradesh, Orissa, West Bengal and Uttar Pradesh.

Both the area and production of rice in Kerala are showing declining trends. The total rice area declined sharply from 8.74 lakh hectares in 1972-73 to 3.5 lakh hectares in 1998-99 (FIB, 2001). The crop registered a fall in production at the rate of 1.18 per cent per year, with the area under cultivation reduced to the tune of 2.44 per cent per year and the decline is attributable to the conversion of rice fields into buildings and for the cultivation of other remunerating crops.

The productivity of upland rice is very low because of most of problems. Availabilities soil moisture, proper varieties, plant nutrient, serious weed infestation poor investment capacity of the farmers, infestation of pest and diseases etc., are some of the very serious constraints of increasing rice productivity in the upland rice.

Integrated crop management (ICM) including the integrated plant nutrient supply system (IPNS) and integrated pest management (IPM) can play a key role in improving the productivity of upland rice, work done by International Rice Research Institute (IRRI), Los Banos, Philippines and many national institutes have demonstrated that upland rice yield could be as high as irrigated.

Scope of upland rice in Kerala:

We have to raise our rice production at least four times to meet our internal demand and become self sufficient in rice production.

For this, we have no cultivate rice in every possible inch of land, including our homesteads, coconut gardens and even converted paddy fields among which coconut gardens offer tremendous scope in our state.

Area under coconut in Kerala	- 8.99 t/ha
Area that can be put under rice cultivation	- 1 to 1.25 t/ha

Varieties, which perform well under shaded conditions, are:

1. Matta triveni and
2. AA-A-2

(Kumar, 2000)

Upland rice soils:

Soil on which rice is grown are as diverse as are the climatic conditions to which rice is exposed. Soil texture varies from sandy to clayey, pH varies from 3 to 10, organic matter contents from 1 to 50 per cent, salt content from nearly 0 to 1 per cent and nutrient availability from acute deficiency to surplus condition, moisture regimes from dryland to various depth of flooding. Flooding creates a unique condition conducive for rice growth and development which is generally absence in case of upland rice. On the basis of available data it is observed that upland rice soils has the following characteristics.

1. pH is low (4.5 to 5.8)
2. Both moisture stress and soil problems induced by moisture stress are common
3. Fe, M and Mn toxicity are frequently observed

The problems of upland rice:

All factors that limit the grain yield of low land rice also limit the yield of upland rice, but some are more critical in the production of upland rice (De Datta and Beachell, 1972). They are:

- **Rainfall distribution**: The amount and variability of rainfall are two important constraints on production of upland rice

- **Change in nutrients in soil**: The forms and availability of nutrients are directly related to moisture supply in soil. These changes in nutrients under low moisture supply have profound effects on nutrition and growth of upland rice. Among the growth-limiting factors in oxidized (aerobic) soils are phosphorus deficiency, iron deficiency on neutral and alkaline soils, and manganese and aluminium toxicity on acid soils fertilized with ammonium sulfate.
- **Weed competition**: Weed competition in upland rice is so serious that total failure of a crop is common if weeds are not controlled
- **Incidence of blast:** The incidence of rice blast disease is more severe for upland than for lowland rice

Table 1: **Nutrient removal of IR-36 to produce one tonne of grain**

Nutrient	Amount removed at harvesting Kg		
	Straw	Grain	Total
N	**7.6**	**14.6**	**22.3**
P	0.5	2.6	3.1
K	**23.7**	**3.7**	**26.4**
Ca	2.7	1	2.8
Mg	1.4	0.6	2.4
S	0.34	0.2	0.94
Fe	0.15	0.06	0.35
Mn	0.31	0.02	0.37
Zn	0.02	0.025	0.04
Cu	0.002	0.025	0.027
B	0.016	0.016	0.032
Si	41.9	9.8	51.7
Cl	5.5	4.2	9.7

(Datta, 1989)

From the above table 1 Datta reported that IR-36 removes maximum quantity of silicon nutrient followed by potassium and nitrogen compared to other essential nutrients to produce one tonne of grain yield

Sources of nutrient for upland rice:

a) Organic sources (FYM, Compost and VC)

b) Inorganic sources (chemical fertilizers)

c) Biofertilizers sources (Azatobacter and Azospirillum)

1. **Organic sources:**

Organic sources are the well decomposed farmyard manure, compost and vermicompost.

Organic farming practices that reduce the pressure on land, water and bio-diversity without adverse effects on agricultural production and nutritive value of food comprise, judicious use of organic manures viz. farmyard manure, compost, vermicompost etc. Integrated in an efficient, nutrient management practice, cropping systems, conjunctive use of rain, tank and underground water, integrated pest management and conservation of genetic resources. Among them, soil fertility is given of attention due to its dynamic action with various physical, chemical and biological properties.

Table 2. Effect of FYM on productivity of rice

FYM (Tonnes/ ha)	Rice yield(q/ha)					
	Grain			Straw		
	1990	1991	1992	1990	1991	1992
0	47.2	57.8	35.6	96.8	118.9	73.6
10	49.5	61.0	38.5	104.6	126.3	76.8
20	53.6	65.5	42.8	110.9	137.5	87.3
CD(0.05)	6.8	6.8	5.2	NS	15.5	10.0

(Singh et. al., 1986)

Above Table 2 indicates that application of farm yard manure increased grain as well as straw yield with increase dose upto 20 tonnes FYM per hectare but there was no significant difference between 10 and 20 tonnes FYM/ha. Therefore 10 tonnes FYM per hectare is the economic dose for getting maximum yield.

2. **Inorganic sources**

i) **Nitrogen:**

Nitrogen is the most important and top ranking essential element for rice plant. It encourages growth of plant and is the main precursor of protein synthesis.

Further, it helps in balanced utilisation of other essential plants nutrients. However, use of N alone or in excess dose can warm the crop and cause soil health problem. This makes it compulsory to know different aspects of N fertilisation to know different aspects of N fertilisation. Upland rice soils are deficient as marginally sufficient in N content, which is the main bottleneck in increasing and stabilizing the yield. Upland rice environment is prone to moisture stress due to its high elevation, uneven topography, and high permeability, infiltration and percolation loss of water. As a result, 20-30 per cent of the applied N fertilizer is utilised by crop due to various kinds of losses. Understanding the N requirement of the crop and adoption of resources to minimize the losses of applied N will help in improving N use efficiency.

Schedule of nitrogen application:

Nitrogen should be applied at the physiological stages based on the appropriate requirement of plant for its efficient utilisation. Adequate supply of N at early tillering and reproductive stage is essential. Application of 50 per cent N at planting on seedling stage and remaining 50 per cent N dose in equal 2 splits at active tillering and panicle initiation has been reported to be superior to a single dose application. The first split of N is 50 per cent dose of N may be applied basaly, if there is adequate soil moisture and proper weed control from the beginning. Otherwise, one first split of N should be top dressed any time within 3 weeks of sowing after weeding (Mishra *et al.*, 1995).

For increasing nitrogen use efficiency by split application of N 1/3 as basal of recommended dose of N, 1/3 at tillering stage and 1/3 at panicle initiation stage (KAU, 1996).

Foliar application of N:

Removal of weed and presence of sufficient soil moisture are the pre-requisites for effectiveness of top dressing of N. In case of dry spell at the time of first or second split application of N foliar spray of N may be preferred over top dressing. As contingency schedule (Mishra,1999). Depending upon the dose of N, the concentration of urea will be 2-3 per cent for high volume, low pressure sprayer as 25 per cent dose of N. Effectiveness of foliar spray can be enhanced by using some sticking agent like triton a.i. 1 ml per 4 litre of spray solution. If any plant protection chemical is to be clubbed with urea solution, it should be mixed just before spray after knowing their comparability. To ensure proper mixing of chemical with urea and prevent clogging of nozzle of the sprayer, solution should be stirred constantly (Mishra, 1992).

Source of Nitrogen:

Under upland condition, ammonium sulphate, ammonium sulphate nitrate, calcium ammonium nitrate and urea are equally efficient (Mahapatra and srivastava, 1983). Among different nitrogenous fertilizers urea is the cheapest and used widely. The current trend of fertilizer consumption indicates that urea will remain predominant source of N. However, there is scope for increasing its use efficiency with modified forms. Moist (non-sticky) cattle dung compost a.i. 0.5 tonnes per hectare mixed with urea followed by conditioning for 48 hours, Karanj (**Pongamia glabra** vent) seed cake coated (30 g powdered cake : 20 ml kerosine oil : 10 g coaltar : 100 g urea) urea and urea super granule of 1.0 g size were found promising modifications (Mishra, 1994). Modified forms yielded better than 3 split of urea (Table 3). Basal application of sulphur coated urea formed better than ordinary prilled urea at the International Rice Research Institute (Gupta and o'toole, 1983). However, if urea and ammonium sulphate were applied in 2-3 splits, they were as effective as sulphur coated urea applied in a single basal dose.

Table 3. Grain yield of upland rice as influenced by forms of urea

Forms of urea	Time and method of application	Grin yield (t/ha)
Control (no nitrogen)	-	0.73
Urea	Single dose,top dressing at seedling stage of rice	1.83
Urea	Three split top dressing	1.99
Urea super granule	Single dose as dibbling at seedling stage of rice	2.44
Urea conditioned with cattle dung compost	Single dose top dressing at seedling stage of rice	2.23
Karnage seed cake coated urea	Single dose top dressing at seedling stage of rice	2.14
C D at 0.05	-	0.49

(Mishra, 1994)

Nitrogen dose:

Dose of nitrogen depends on a number of factors such as native soil fertility status, soil moisture content, soil texture, duration and occurrence of disease. Short statured and long duration variety may respond to high dose of N under low soil fertility conditions traditional varieties tend to lodge at high level of N. For most of upland rice in different parts of country, 40-60 kg N ha^{-1} has been found to be optimum dose (Mishra, 1995).

Quantity of Nitrogen required for short duration upland varieties. The studies conducted at College of Horticulture, Vellayani, have arrived at a recommendation of 60 kg N ha^{-1} in open situation (Thomas, 2000) and 80 kg N ha^{-1} under the shaded situation in coconut garden (Anu, 2001) gives maximum plant height, number of tiller and grain and straw yields.

Nitrogen use efficiency in upland rice is 20-30per cent because of losses of N in several forms, for increasing nitrogen use efficiency according study conducted at College of Vellayani (Table 4) revealed that the varieties were significantly influencing NUE. Nitrogen use efficiency of matta triveni recorded the maximum value of 28 kg grain kg^{-1} N and was significantly superior to swarnaprabha. The application of 80 kg ha^{-1} recorded the maximum value of 28.85 kg grain kg^{-1} N and was significantly superior to 15 and 30 kg N ha^{-1}. Increase in K levels resulted in an increase in NUE application of 45 kg K_2O ha^{-1} recorded the maximum (30.37 kg grain kg^{-1} N) and was significantly superior to lower levels (Anu, 2001).

Table 4: **Effect of varieties, N & K on NUE.**

Treatment (N kg/ha)	NUE kg grain/kg N
Nitrogen levels	
40	25.99
60	26.18
80	28.85
CD (0.05)	1.154
Potassium levels	
15	23.39
30	27.26
45	30.37
CD(0.05)	1.15
Varieties	
Swarnaprabha	25.23
Mattatriveni	28.79
CD (0.05)	0.943

(Anu, 2001)

How to improve NUE?

In upland soil losses of N is more than the lowland condition, to increase NUE several methods as earlier discussed are given below.

1. Split application of N fertilizer
2. Use of slow release fertilizers
   - Coated urea fertilizer
   - Urea super granules and briquettes
3. Application of pre –incubated urea [Urea + Moist soil (1:6)]
4. Use of nitrification inhibitors [Urea + Neem cake (5:1)]
5. Placement of fertilizers
6. Foliar application

Phosphorus:

Phosphorus is the second most important fertiliser nutrient for plant metabolism. Root growth of plant is adversely affected due to 'P' deficiency which is very important for rainfed crop. The availability of P in upland rice soil is lower than flooded soil. Phosphorus deficiency may be a limiting factor in uplands, especially in strongly oxisols (Mahapatra and srivastava, 1983).

Phosphorus management is important because of two reasons. The first problem is it's low availability in the soil solution. The other problem is the fixation of applied phosphatic fertiliser. This is immobile element and hardly moves 3-4 cm away from the site of its application. A rice variety with profuse rooting will have advantage for better uptake of applied phosphatic fertiliser (Mishra, 1991).

Management of fertiliser P:

1. Dose of P:

The optimum dose of phosphorus increase grain as well as straw yield in upland rice. Significant response to application of P in upland rice was observed at Ranchi (Mahapatra ans srivastava, 1983). For upland rice, application of 40 kg ha^{-1} of P_2O_5 was considered as optimum dose (**Table 5**) and for upland rainfed rice 44.66 kg ha^{-1} P_2O_5 gives higher grain yield (Fageria *et al.*, 1982).

Table 5: **Effect of doses of phosphorus on yield of upland rice at Ranchi**

Dose of P_2O_5 (Kg ha^{-1})	Grain yield (Q ha^{-1})			
	1978	1979	1980	Mean
0	18.83	22.63	17.95	19.80
20	18.41	23.38	23.13	21.64
40	19.87	30.53	26.25	25.53
60	22.08	37.71	26.88	28.89
80	21.00	37.37	27.55	28.62
C.D.0.05	2.51	7.73	3.10	

(Mahapatra And Srivastava, 1983)

2. Application schedule of P:

Phosphorus required during initial stages of crop and it is immobile element. Therefore basal dressing of all P through compost treated single super phosphate yielded higher than compost treated mussorie rock phosphate and application of compost treated single super phosphate at active tillering. But statistically these were on par themselves (Mohapatra ans srivastava, 1983). For treating the phosphatic fertilisers with compost, fertiliser and compost should be taken in 1:2 ratio on their dry weight basis. But compost should be moist for incubation with fertiliser. Incubation should be done for 48 to72 hours.

3. Method of P application:

Method of P application increase P use efficiency in case of water insoluble or slightly soluble is powdered form because area of contact will be more, it is better to apply mixing with soil in case of water soluble P best method is granulated form, and in a band placement.

Different forms and methods of P application were compared at Hazaribag for better P use efficiency (Mohapatra and srivastava, 1983). Application of P in the seed furrow just before seeding of rice was found to be better than its broadcasting followed by incorporation into the soil.

4. Sources of phosphorus:

Under upland condition mussorie rock phosphate, single super phosphate and diammonium phosphate are important sources. Among different sources of P in acid upland pH (5.5), use of mussorie rock phosphate(MRP) in place of single super phosphate (SSP) was found to be advantageous per unit cost of P and problem of weed are less with MRP than those with SSP without sacrificing the grain yield (Table 6. As regard, the contact of phosphatic fertilisers with soil, it was reported (Mohapatra and srivastava, 1983) that for water soluble P sources such as SSP 50 per cent contact is needed for optimum efficiency. For water insoluble forms 70 per cent or more contact is required.

Table 6: Grain yield of upland rice as influenced by sources of P application at Hazaribag

P Source	Grain yield (t ha^{-1})			
	1991	1992	1993	Mean
MRP	2.08	2.11	1.95	2.05
SSP	1.86	2.16	1.83	1.95
MRP+SSP (1:1)	1.82	1.99	1.83	1.88
SSP + 1.0 t/ha lime	1.57	1.98	1.78	1.78
SSP + 2.5 t/ha Compost (without incubation)	1.54	2.21	1.85	1.87
DAP in first year and its residual effect in subsequent years	1.62	1.70	1.65	1.66
L.S.D.0.05	NS	NS	0.17	

(Mishra, 1993)

To increase P availability liming is done in upland rice soil to raise its pH near neutrality (6.5), with raise of pH activity of iron and aluminium decreases and thus their reaction with phosphate decreases which results in lower phosphorus fixation and higher phosphate concentration in soil solution.

Potassium:

Information on response of upland rice to potassium application is limited as there has been common notation that Indian soils are sufficient in K. This was there when traditional cultivars were cultivated under low cropping intensities with adoption of improved rice varieties and increased cropping intensities there has been considerable depletion in nutrient status of soil. In co-ordination agronomic trials, the yield increase in improved rice ranged 472-1353 kg ha^{-1} due to K application. But this increase was only in the range of 29-654 kg ha^{-1} with traditional rice (Mahapatra and srivastava, 1983). In recent multi location trial in Bihar plateu there was varietal difference in response of upland rice to K application (CRRI, 1994).

Table 7: **Effect of doses of K under open & shaded conditions**

K kg/ha	Grain yield kg/ha	Straw yield kg/ha
Open		
45	2098	7120 (Thomas, 2000)
Shade		
15	1406	4258
30	1659	5080
45	1854	5538
CD	108.9	177.5

Anu, 2001

In Kerala effect doses of K under shaded condition (**Table 7**). At Vellayani reported that application of 45 kg K_2O ha^{-1} give maximum grain and straw yield under coconut garden (Anu, 2001) while under open situation 45 kg K_2O ha^{-1} gives more yield (Thomas, 2000).

In another study the grain yield of upland rice increased by 62 per cent due to application of 30 kg K_2O ha^{-1}. As basal dressing was found superior to split applications. Significant response to K application was observed in coarse textured upland rice soil of Ranchi (Mahapatra and srivastava, 1983). Usually the best responsive was noted with single dose of basal application of K than other schedules irrespective of its dose.

Application of 20-30 kg K_2O ha-1 at the time of sowing is the recommended dose muriate of potash is the common source of K. Sulphate of potash and potassium nitrate are other fertiliser sources which may be selected in higher of soil reaction.

Secondary nutrients:

Sulphur is reduced to sulfide under submerged conditions wet in upland remains sulphate which is readily available ammonium sulphate, single super phosphate, potassium sulphate are sources of sulphur. A dose of 30 kg S per ha seems to be optimum.

Management of toxicity of micronutrients:

In soils having pH less than 5.5 the problem of nutrient toxicity arises in strongly acidic soils, the problem of toxicity of Mn and Al associated with Ca or Mg may occur. Mn is highly soluble at pH less than 5.5. Mn toxicity can occur with Al toxicity at pH 5.5-6.0 (Gupta and O'Toole, 1983). When concentration of Al becomes around 50 ppm in the soil, it adversely affects the uptake in most of the plant nutrients (Mishra, 1991). At toxicity combined with Mn toxicity results in the stunted plant growth with limited, number of tillers. At toxicity inhibits the root growth and increases drought susceptibility. If available growing of tolerant variety is desirable for such toxic soils alternatively liming should be practised.

Beneficial Element- Silicon (Si):

Beneficial effects of silica (SiO_2) includes maintenance or erect leaves, reduction of water loss, perhaps through cuticular transpiration, increased oxidising power of roots and protection against diseases and insects (Yoshida and Souichi, 1975). A sizeable portion of Si taken up by the crop remains in rice straw. In countries where straw is left in the field, there is no need of silica application. But in country like India where straw is in much need for various purposes, silica application may be desirable. Silica application may be required in highly weathered lateritic and sandy soils having low pH. Beneficial effect of application of silicate material in soil is obtained when SiO_2 content of harvest straw is below 11 per cent (Mahapatra and Srivastava, 1983). Certain phosphatic fertilizers are good source of silica. Basic slag (CaO_5, P_2O_5, SiO_2) in considered as an appropriate source of silica. The dose of silica should be decided in light of the nutritional requirement of crop and pH value of soil. Basic slag should not be mixed with other fertilizer because of its high lime content.

Zinc (Zn):

Zinc deficiency occurs in alkaline soil and its intensity increases with rising pH value of soil. The symptoms of zn deficiency appear during seedling to tillering stage of rice. This occurs when concentration of Zn in leaf blade of rice is less than 15 ppm on its dry weight basis (Datta *et al.*, 1975). In Zn deficient rice plant, the new leaves become chlorotic yellow. Brown blotches and streaks develop in lower and old leaves. Root system appears brown to dirty black in colour. Plant growth is stunted although tillering may continue. Size of leaf is also reduced. This symptoms of Zn deficiency is popularly known as **Khaira disease** in north-western part of India.

Recovery of bronzing has been reported by application of 5 kg $ZnSO_4$/ha in furrows or with 2 sprays of 0.2 per cent $ZnSO_4$ solution sprayed at 20 and 40 days after sowing. Where Zn deficiency is common, $ZnSO_4$ should be applied @ 50 kg/ha as basal dressing. If deficiency symptoms are observed in standing crop, mixture of 5 kg $ZnSO_4$ and 2.5 kg lime/ha should be sprayed. Spray may be repeated at 8-10 days interval if crop has not recovered fully $ZnSO_4$, ZnO and Zncl are the appropriate source of Zn for upland rice (DRR, 1994).

Iron (Fe):

Fe deficiency is found in netural or alkaline soil particularly in calcareous soil with high pH value. However, in certain situations it may occur in acid soils also, particularly when heavy rains followed by periods of drought (Datta *et al.*, 1975). Iron deficiency has been reported in calcareous upland rice soils of Andhra Pradesh and Maharashtra (DRR, 1994). Its deficiency systems appear when its concentration in leaf blade drops below 70 ppm during seedling to tillering phase. In Fe deficient rice plant, newly emerged leaves turn chlorotic followed by scorching and drying of leaf apices. In severe deficiency leaves are bleached, become white and dry. In situation of moderate deficiency chlorisis is mild and restricted to inter veinal area. Foliar spray of 0.5 per cent solution of $FeSO_4$ in recommended practice for deficiency correction. The spray may be repeated at interval of 8-10 days till plant recovers well.

Liming:

Liming is required to ameliorate the adverse effect of soil acidity on plant growth. In acidic uplands Al toxicity reduced both water and nutrient uptake indirectly making the plant vulnerable to the drought stress. Liming under such situation usually increases the availability of P, Ca, Mg, B and Mo for better crop growth. Crop response to lime application is influenced by edaphic factors. As such soils are poor in P, therefore, reasonable grain yield can only be obtained if appropriate quantity of P is applied in conjunction with lime (DRR, 1993). However, overdose of P and lime should be avoided, otherwise this may result in Zn deficiency. Liming should be done to raise the pH of soil up to 6.0. Liming raising pH more than 6.0, sometimes cause more harm than good. It may reduce K availability and cause Zn, B and Mn deficiency (Gupta *et al.*, 1983). Normally 30-35 q/ha of lime once in 3 years is sufficient. Alternatively 0.5 q/ha of lime may be used annually. Liming material should be incorporated into the lower horizon of soil (Mishra, 1991). If lime is applied once in 3 years, it should be applied a month before sowing. But at its lower dose this may be applied at the time of sowing itself in seed furrow. Study on ameliortion of sub soil acidity of upland rice soil was made in Indonesia during 1994-96. Use of calcium nitrate [$Ca(NO_3)_2$] was considered better as it allowed greater downward movement of calcium from surface than calcium carbonate ($CaCO_3$).

Biofertilizers:

Biofertilizers is their characteristic ability to convert the unavailable form of nutrients into forms easily accessible to the plants. They improve soil physical properties and sustain soil fertility by providing aeration, biomass and nutrients. Use of biofertilizers not only make atmospheric nitrogen available but also solubilise and mobilise soil fixed phosphorus and improve phosphorus uptake.

In upland rice use of Azatobactor and Azospirillum increase the 5-15 per cent grain yield and it also supply 25 kg N ha^{-1} (Reddar *et al.*, 1989). Azotobactor and Azospirillum are less efficient N fixers compared to Azolla that we apply in lowland rice.

Before scheduling nutrient management practice for upland rice, we have to near two important points in mind.

1. Higher production from upland rice is not possible by applying organic manure alone.
2. Continuous application of chemical fertilizers alone over years lead to soil degradation.

That is why, now-a-days, scientists as well as farmers focus their attention on Integrated Plant Nutrient Supply system (IPNS) as Integrated Nutrient Management (INM).

Integrated Nutrient Management (INM):

In INM, organic manures are applied in conjuction with chemical fertilizers. Chemical fertilizers supply N, P and K to plants directly while organic manure supplies N, P, S and essential micronutrients through the process of mineralisation. Organic manures maintain soil fertility while chemical fertilizers ensure higher productivity. We can use different sources of organic manure such as FYM, compost, UC etc. provided material should be in well decomposed from otherwise it will take a long time to decompose and release nutrients due to lack of enough moisture in upland soils.

Effect of NPK, lime and manure on the average yield of upland rice (Anwarhar, 1997), reported that application of 90:67:60 kg NPK and 2.35 tonnes of lime either with 10 tonnes of green manure or 10 tonnes of animal manure gives significant yield of upland rice and improve physical properties of soil.

On compilation of the results of more than 1000 experiments in Japan, it was noted that application of compost increased the yield of upland rice by 20 per cent, whereas it was only 1-2 per cent in case of low land rice (Datta, 1975).

Conclusion:

Since the scope of expanding area under low land rice is limited, it is essential to study the possibility of growing upland rice as a component crop in homesteads and as intercropping system especially with coconut garden.

Upland rice farmers face a variety of problems, drought is most important one. Weed control is also a serious problem in upland rice fields because there is no standing water to flood out these unwanted competitions. Similarly, fertilizer needs for upland solution differ from those for lowland. Nutrients such as, Fe and Mn are less available in upland than waterlogged soils.

It is hoped that in time to come better techniques to tackle the problems mentioned above to be found out and the upland rice yields would be increased through the better management of new agro-techniques.

Discussion

Q. How can we reduce P fixation?

A. P fixation can be reduced by adding lime in acid soils and also by a applying organic matter and P solubilising bacteria. Thus P is made available.

Q. Name a cheap organic material that can supply silica.

A. Paddy straw (crop residue) incorporation can provide adequate silica to subsequent rice crop.

Q. Is there micronutrient deficiency in Kerala?

A. In Kerala, since most soils are acidic, micronutrients are generally not deficient. But Zn deficiency is reported widely.

Q. Can green manuring be recommended for upland rice?

A. The major constraints in uplands is lack of adequate soil moisture. For green manures or any organic material to decompose, there should be sufficient soil moisture either through rainfall or irrigation. Then only we can go for application of green manure. Otherwise it is advisable to apply only well-decomposed organic material like compost to upland soils.

Q. Does denitrification occur in upland soils?

A. Yes, denitrification can occur in upland soils too. In upland there may be some low lying areas or ditches, where water stagnates. In such pockets, denitrification may occur.

Q. What is the cost of 10 tonnes of green manure?

A. 10 tonnes of green manure cost is 5,000 rupees.

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Credit seminar on

Phosphorus management in acid- rice soils of kerala

Presented by
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Seminar report

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ABSTRACT

Phosphorus, being one of the important fertilizer element, its management for better crop production assumes practical significance. Further, its immobile nature in soil, high fixing capacity and the formation of various insoluble reaction products makes the management difficult both in acid and alkaline soils. The problem of judicious management becomes more severe under flooded rice system. Of the total 3.8 m ha of land, 3.5 m ha come under acidic reaction and hence the possible and judicious management aspects of phosphorus under acidic rice soils are discussed.

The availability of phosphorus in these soils depend on the p^H, organic matter content of the soil, redox potential, availability of moisture, sesquioxide content, presence of iron, aluminium oxides and hydroxides and silicate minerals .Due to high content of oxides and hydroxides of Fe and Al, the applied phosphorus is converted into insoluble Fe-P and Al-P. Due to chemical fixation and immobility phenomena of phosphorus in acid soil, the efficiency of phosphatic fertilizers and phosphorus status in this type of soil are very low to medium in nature.

The efficiency of phosphatic fertilizer in acid soils depends on the sources of the fertilizers, method and time of application , amendments, etc. To increase the effectiveness of phosphatic fertilizer, phosphatic fertilizers can be mixed with FYM, green manure, lime and phosphate solubilising micro organisms in acid soils

So fertlilizer phosphorus and its management in acid-rice soil is an important aspect to be dealt. In slightly acidic submerged soil, water soluble phosphatic fertilizers are preferable. In acid soils, phosphorus fertilizers containing citrate soluble phosphates like basic slag, calcium phosphate, steamed bone meal etc. are recommended. In highly acidic upland or submerged soils, powdered rock phosphate is most suitable.

Phosphorus Management in acid-rice soils of Kerala

Introduction:

Phosphorus, being one of the important element, it is management for better crop production assumes practical significance. Further,its immobile nature in soil, high fixing capacity and formation of various insoluble reaction products makes the management difficult both in acid and alkaline soils. The problem of judicious management becomes more severe under flooded rice system.

Kerala is one of the smallest states of India occupies a narrow strip of land in the south-western corner of the Indian peninsula. It is located between 8°12' and 12°48' north latitudes and between 74°52' and 77°22' east longitudes. It is bound on the west by Arabian sea, on the north-east by Karnataka; and on the east and south by Tamil Nadu. In the north-south direction Kerala is 580 km long and breadth varies from 30 km in north to 120 km in the central region. The area of the state is 3.8 mha which is about 1.2 per cent of the total area of India. Out of which 3.5 m ha come under acidic reaction and hence possible and judicious management aspects of phosphorus under acidic rice soils are discussed.

Acid soils of Kerala:

Kerala with its small geographical area have immense soil problem. These are mainly due to the undulating terrain, peculiar toposequence, heavy rainfall, high water table in some areas and alternately hot and wet climate in mid land region.

All Kerala soils are acidic in reaction except black soils in the Chittoor taluk in Palghat district. The acid soils of Kerala as classified by the soil survey staff (1978) of the State Department of Agriculture are the following Laterites; Red loams; Forest loam; Coastal alluvium; Riverine alluvium; Greyish onattukara; Brown hydromorphic and Hydromorphic saline, acid saline (including kari, kayal and karapadom soils). (koshyand koran, 1980).The general characteristics, morphological features, mechanical composition and the physiochemical properties of these soils are given below.

Classification:

1.Laterites:

The laterites cover nearly 60 per cent of the land area of Kerala on western ghats, North Kerala. They are acidic in reaction (pH 5.0-6.2). These soils contain fair amount of organic matter and nitrogen, but are deficient in phosphorus, potassium and calcium. Coconut, cassava, banana, vegetables, pulses are grown on the laterite soils in the lower horizons while plantation crops like rubber are grown at higher elevations.

Locations: Slopes of the Western ghats, North Kerala and also in south few below the soil

2. Red loam

These soils are localized in the southern parts of Trivandrum district. The deep red colour of the soil is due to the presence of haematite and are formed by the process of imperfect laterisation.

These soils are highly porous, sandy loam, acidic in reaction (pH 4.0-5.5), low in organic matter and poor in the major plant nutrient elements and lime.

3. Forest loam:
These are found in the eastern parts of the state and the slopes of the western ghats cover approximately 25% of the land area of the state.

They are formed by the weathering of crystalline rocks under the influence of a tropical or subtropical humid climate under a forest canopy. The surface layers are dark in colour due to presence of organic matter.

The reaction in acidic (pH 5-6). They are rich in total nitrogen and phosphorus but poor in bases owing to heavy leaching. Rubber, tea and cardamom are grown in the forest area

4. Coastal alluvium:
These light brown-grey (Aplayer) and light grey soils occur as a narrow strip all along the west coasts. They have developed from marine sandy deposits. They are also highly porous with very little capacity for retaining water and fertilizers. Texture varies from sandy to sandy loam.

They are acidic in reaction (pH 5-6). deficient in organic matter and major nutrients.

5. Riverine alluvium:
These brown soils occur on the banks of rivers. In texture, they vary from sandy loam to clay loam, mildly acid in reaction and are well supplied with organic matter deficient in lime.

The general fertility status in better than that of other acid soils of Kerala.

6.Greyish Onattukara:
These soils occur in the Onattukara region and Alleppey districts. These are formed from marine sandy deposits admixed with laterite material under the influence of high water table. The texture varies from sandy to sandy loam.

They are acid in reaction low in organic matter and nitrogen and deficient in P and Ca.

Coconut major crop, but rice, sesamum, pulses are also grown.

7.Brown hydromorphic:
These soils occur in Trivandrum district of kerela. The reaction in acid (pH 5-5.5), they are well supplied of OM & N & potassium & are deficient in the other plant nutrient elements.

8.Hydromorphic saline
The submerged brown soils of the coastal tracts of Ernakulam. Alleppey. Trichur and Cannanore which are under the tidal influence of the sea.Only one crop of rice is grown during the period August to December and that too using salt resistant varieties.

9.Acid saline:
The acid saline soils are kayal, karappadam and kari soils.

i) Kayal soils: These are found in the rice fields reclaimed from the lake beds in the districts of Kottâyam and Alleppey. The texture of the soil is silly loam to silly clay loam. Rice is the main crop, coconut is also grown on man-made bunds.

ii) Karapadam soils: are the soils of the upper Kuttanad area, developed on river borne alluvium.

The surface soils are generally clay loams and acid in reaction (pH 4.5-5.5). they are fairly well supplied with organic matter and nitrogen, but deficient in other plant elements.

iii) Kari soils: These soils derived from deep-black colour. They occur mainly in the districts of Alleppey and Kottayam. These are high in organic matter, they are extremely acid pH (3.0-4.5) but in the moist conditions, the acidity gets reduced. These are acid sulphate soils in which acidity is generated by the oxidation of sulphur compounds.

Rice is a common crop but due to acidity and salinity crop failures are common.

10.Kole lands:

Kole lands lie continuously along the coastal strips of the two adjoining districts of Trichur and Palghat. These are reclaimed lake beds, acidity, salinity, poor drainage and presence of toxic salts are the characteristics of the soils.

11.Pokkali/Kaipad lands:

These are the low lying and saline marshes found near the mouth of streams and rivers near the Arabian sea. Major portion of the soil lies in the districts of Ernakulam and Cannanore. They are highly acidic (2.1-3.9 a pH). This soil is developed under peculiar environmental conditions such as alternate flooding with saline and fresh water and high acid reaction of soil.

Phosphorus in acid soil:

The forms of phosphorus occurring in acid soils may be divided into two broad categories, organics and inorganic.

Organic form:

The organic forms of phosphorus originate from plant and animal residues and soil organisms. They occur as

- Inositol phosphate
- Phospholipids
- Nucleic acids
- Nucleotids

The organic forms comprise 30-50%, some times, more than 50% of total soil phosph,orus. Inositol phosphates are most abundant. Some of the organic phosphates exists in soil solution, Some organic phosphates (phytin, nucleic and after its break down), may directly, be absorbed by plants. The magnitude of this absorption is very low. Hence the value of organic phosphates as phosphorus sources for plants is negligible. The organic phosphates release inorganic phosphates by mineralization. This released inorganic phosphorus may be adsorbed by plants.

Inorganic Forms The inorganic forms of phosphorus can be classed as

1)Ionic forms,2)Combined forms

Ionic forms

The ionic forms include 1) primary orthophosphate on ($H_2PO_4^-$) and secondary orthophosphate ion (HPO_4^{2-}). These two ions are present in soil solution. Hence they are termed solution phase phosphates. They are derivatives of orthophosphoric acids [$H_3PO_4 \Rightarrow H^+ + H_2PO_4^-$, $H_3PO_4 \Rightarrow 2H^+ + HPO_4^{2-}$]. Their native amount largely depends on pH of soil solution. The primaryorthophosphate ions, $H_2PO_4^-$ and secondary orthophosphate ions, HPO_4^{2-}, are almost equal at pH 7.00-7.22. In strongly alkaline solution, tertiary orthophosphate ions, PO_4^{3}-, dominate. As pH decreases the tertiary orthophosphate ions, PO_4^{3-}, are converted into secondary orthophosphate ions, HPO_4^{2-}.

$$Po_4^{3-} + H^+ \rightarrow HPO_4^{2-}$$

As pH decreases, H^+ concentration increases. This H' reacts with PO_4^{3-} to yield HPO_4^{2-}. With further decrease in pH, the secondary orthophosphate ions, HPO_4^{2-} are converted to primary orthophosphate ions, $H_2PO_4^-$.

In strongly acid solution, primary orthophosphate ions, $H_2PO_4^-$, dominate. As the pH of solution increases, the primary orthophosphate ions, $H_2PO_4^-$ are converted to secondary orthophosphate ions, HPO_4^{2-}.

$$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$$

Hence, in acid soil solution (pH below 7.0) the primary orthophosphate ions, $H_2PO_4^-$, dominate, while in alkaline soil solution (pH above 7.22). Secondary orthophosphate ions, HPO_4^{2-} dominate. Plant uptake of HPO_4^- is much slower than with $H_2PO_4^-$. So the concentration of ionic forms of phosphorus in soil solution is very low.

Combined forms

In acid soils, phosphorus combined with iron and aluminium exists as hydroxy and or hydrated phosphate of iron and aluminium. These compounds are stable in acid soils and are insoluble and less available to plants.

The iron and aluminium phosphate can be classed as

1. Crystalline phosphate
2. Surface precipitated or adsorbed phosphate
3. Occluded or reductant soluble phosphate

Crystalline phosphate Iron phosphate i.e. strengite $FePO_4.2H_2O$, and aluminium phosphate variscite $AlPO_4\ 2H_2O$ are present in the acid soil in the form of crystals. This crystalline phosphate may exist as a constituent of silicate minerals. The native crystalline phosphates are stable and cannot supply phosphorus to plant within a short period. On the other hand, the crystalline phosphates formed in soil upon addition of soluble phosphate fertilizers are unstable and can supply phosphorus to plants. When phosphorus concentration in soil solution decreases for any reason (eg. removal by plant absorption, reaction with soil constituents, diffusion etc.) the recently formed (not native) crystalline phosphates liberate soluble phosphate to the soil solution which is absorbable by plants.

Surface precipitated/adsorbed phosphate

The iron and aluminium phosphates (hydrated /hydroxy) are precipitated or absorbed on the surface of hydrated oxides of iron and aluminium or on clay particles (aluminium silicates) or on clay humus complex. Thus, the iron and aluminium phosphates may form layers or films which are held on the surface of films or layers of hyderabad oxides of iron and aluminium or an clay particles or on clay humus colloids. This precipitated or adsorbed phosphates of iron and aluminium are extremely insoluble and less available to plants.

Occluded or reductant soluble phosphate

The word occluded means closed or locked up or enveloped or coated. Some of the iron and aluminium phosphates are occluded with in iron oxides. These phosphates are termed as occluded phosphates.

There are two fractions of occluded phosphates such as Occluded iron phosphates and occluded aluminium phosphate. The highly weathered soils in tropical region contains large amount of iron oxides. Thus, occluded phosphates predominate in these soils. The soil pH does not change the amount of occluded phosphates in soil. These phosphates are insoluble and unavailable to plants. The iron oxides that coat the iron and aluminimum phosphates can be removed by reduction chelation procedure. Sonsequently the occluded phosphate release.

Phosphorous combined with silicate minerals

The soils contains with silicate minerals. Phosphorus combiners with these silicate minerals by Anion exchange phenomena and formation of silicate mineral - poly valent metal - phosphate linkages.

Forms of phosphorus absorbed by Plants

Plants absorbs phosphorus in ionic forms as follows:

1) Primary orthophosphate ions (or monovalent phosphate ion) $H_2PO_4^-$.
2) Secondary orthophosphate ion (or divalent phosphate ion), HPO_4^{2-}.

The primary orthophosphate ions, $H_2PO_4^-$, are absorbed more readily than secondary orthophosphate ions, HPO_4^{2-}. They are absorbed by plants from solution phase (soil solution). Plant do not absorb phosphorus directly from solid phase.

Plants do not absorb organic phosphorus. But some scientist believe that some soluble organic phosphates (eg. myo-inositol monophosphate, phytin, nucleic acids after their break down etc.) may be absorbed to some extent. The magnitude of this absorption is extremely low compared to that of ionic firms of phosphates, $H_2PO_4^-$ and HPO_4^{2-}. Hence, the absoıption of organic phosphates by plant is less important.

Physico chemical properties of submerged soils in relation to phosphorus availability: Soil fertility in the status of a soil with respect to its ability to supply nutrients essential to plant growth. The ability to supply nutrients depends on the presence in the soil of adequate nutrients in forms the plant can absorb. The soils ability to deliver nutrients by mass flow and diffusion to the root surface, presence of favourable ionic composition, and the absence in the solution of substances that interfere with movement of nutrients into the root. These factors are strongly influenced by the physico-chemical properties of the soils.

In submerged soils the important physco chemical properties or processes that control fertility are negative logarithm of hydrogen ion concentration (pH), redox potential (Eh), specific conductance, ionic strength, ion exchange, sorption and desorption, chemical kinetics and mineral equilibria. Among these, pH, Eh are important one.

PH and soil fertility : The pH values of acid soils increase on submergence whereas the opposite occurs in calcareous and sodic soils. For most soils the fairly stable pH attained after several weeks of submergence is between 6.5 and 7.0.

The pH of a submerged soil exerts a marked influence on the capacity of the soil to supply nutrients through

1) direct effect on nutrient absorption
2) direct effects on the concentration of nutrients or toxic substances in the soil solution,
3) indirect effects on chemical equilibria, and sorption and desorption

4) influence of microbial process connected with the release or loss of plant nutrients and the generation of toxic substances.

Singly or in combination, these effects profoundly influence the rice plants absorption of both macro and micro nutrients in submerged soils.

Effects on chemical equilibria and sorption and desorption

Mineral phosphorus is present in soils mainly as aluminium and iron phosphates at low pH, and as calcium phosphates at high pH, and in found sorbed on the surfaces of clay and oxides of aluminium and iron. An increase in pH values favours the solubilising of aluminium and iron phosphates and desorption of phosphorus, and a decrease in pH favours the solubility of calcium phosphates. Thus the solubility of phosphorus in soils tends to be maximum in the pH range from 6 to 7 (**Fig.1,2**).

The increase in pH of acid soils and the decrease in pH of calcareous and sodic soils increase the availability of phosphorus in submerged soils. This is a benefit of flooding rice soils.

Implication of pH on rice

The pH of the solution of a reduced soil is an important factor determining the fertility of rice soil. In terms of fertility, the optimum pH (measure in the solution of the submerged soil) for rice is about 6.6. At that pH value the microbial release of nitrogen and phosphorus from soil organic matter and the availability of phosphorus are high; the supplies of copper, zinc and molybdenum are adequate; and the concentrations of substances that interfere with nutrient uptake such as aluminium, manganese, iron, carbon dioxide, and organic acids are below the toxic level. However, the rates of denitrification and SO_4^{2-} reduction are higher at pH 6.6 that at lower pH values.

The elements known to be sorbed by clay, organic matter, or hydrous oxides of iron, manganese, and aluminium are nitrogen, phosphorus, silicon, boron, cobalt, copper, zinc and molybdenum. Sorption may be due to electrostratic attraction, covalent bonding, or isomorphous replacement in the crystal lattice. Because of the changes in surface properties brought about by changes in Eh (or) pH ions held by electrostatic attraction or covalent bonding may be released into the soil solution when a soil is flooded.

Thus the concentrations of water-soluble phosphorus, silicon and molybdenum, increase when a soil is submerged.Ravi (2002), reforted that the p^{H} of the soil increased in all the treatments upon submergence.The p^{H} of the soil treated with SSP was slightly higher compored to mono ammonium phosphate at all three intervals measured. The result was indicated in **table 1.**

Redox perennial and soil fertility

The Eh is perhaps the most important physicochemical property controlling the chemical and biochemical characteristics of submerged soils. Eh or the pE (negative logarithm to the base 10 of the electron activity, equal to Eh/0.059), measures the intensing of oxidation or reduction. High and positive Eh or pE values indicate oxidation conditions; low or negative values indicate reduction conditions.

Redox perennial affects

1. the nitrogen status of the soil
2. the availability of phosphorus and silicon
3. the generation of organic acids and hydrogen sulphide

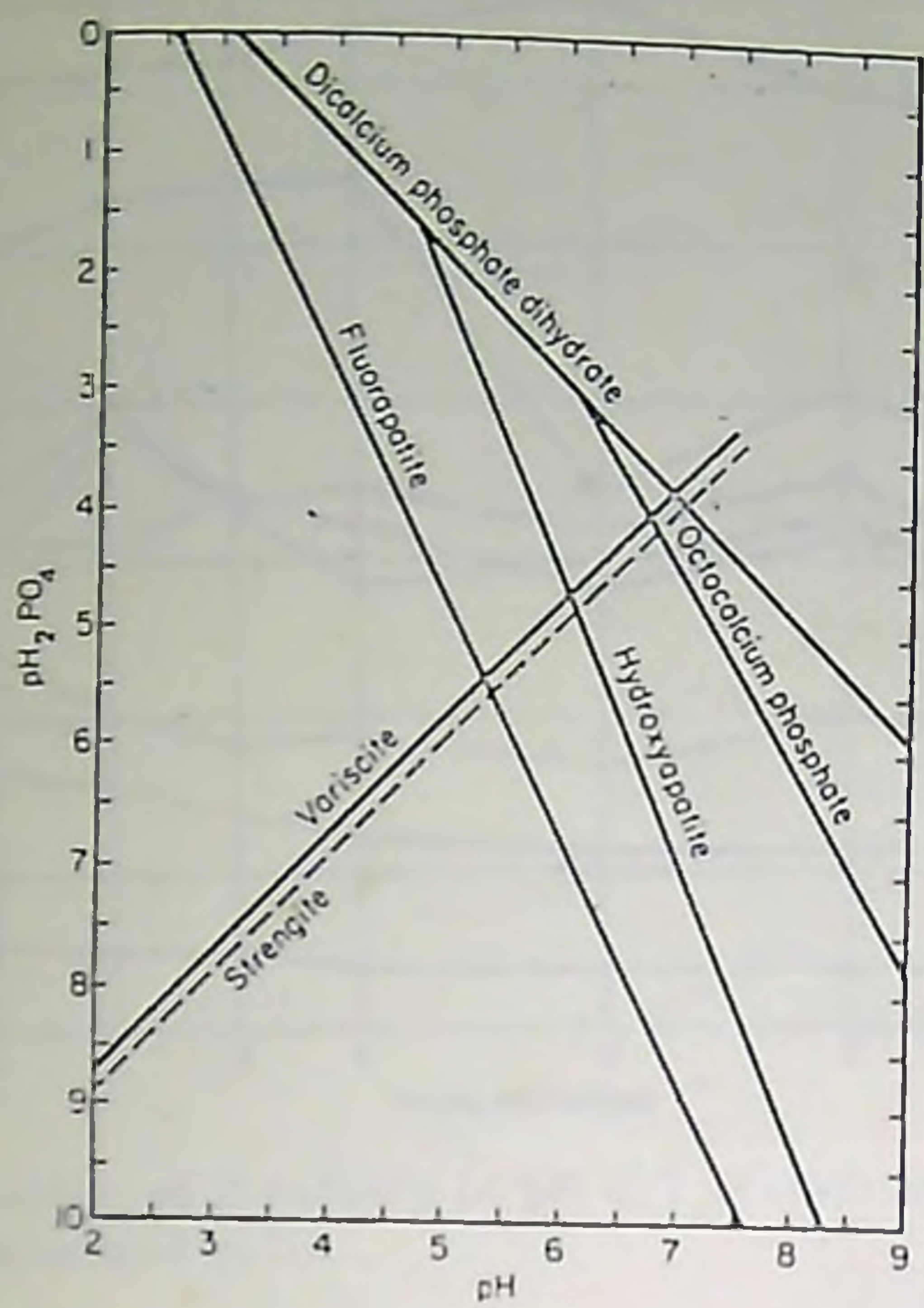

Fig 1 Solubility of phosphate compounds in soils at 25° C and 0.005 M Ca concentrations (Lindsay and Moreno, 1960).

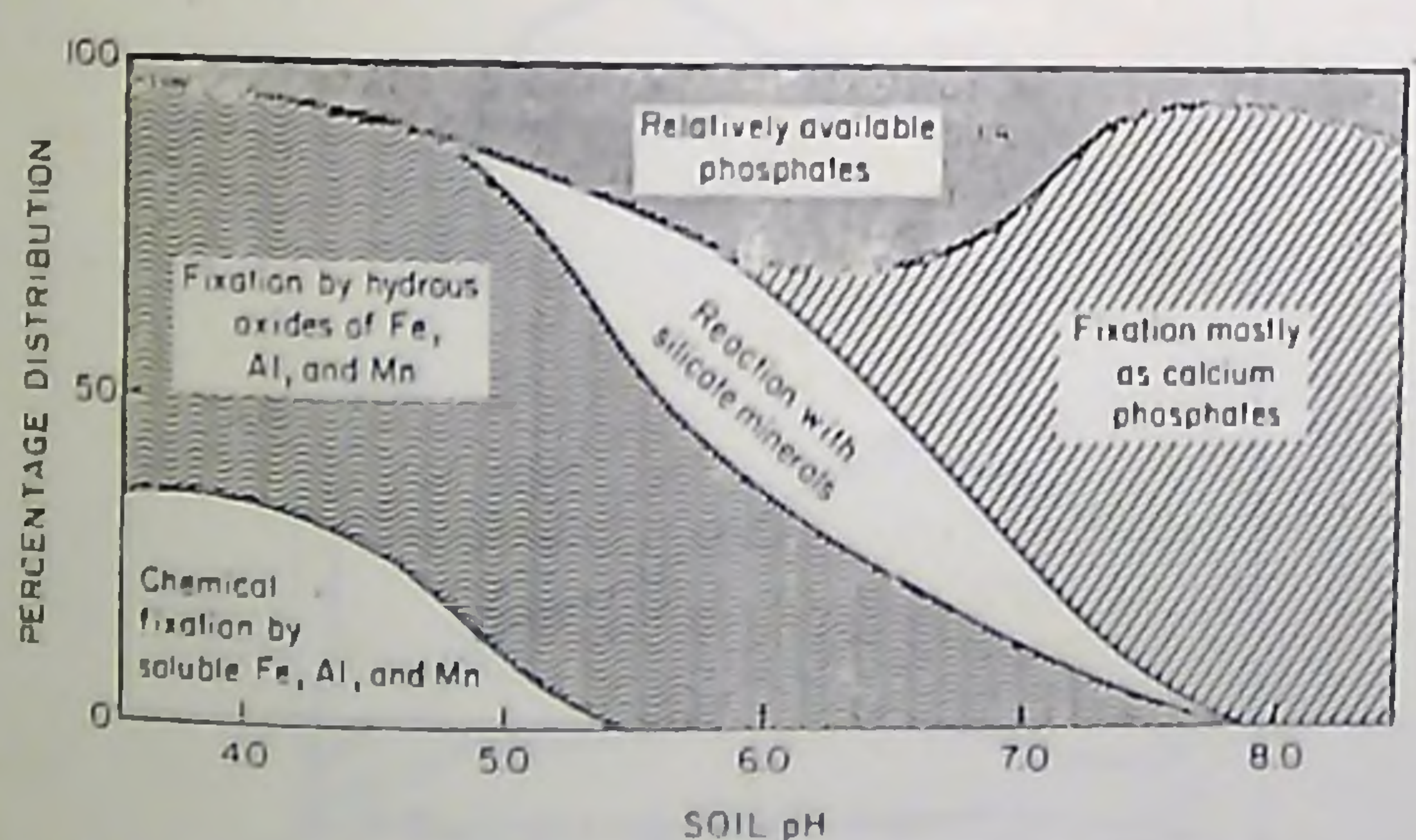

Fig. 2 Inorganic fixation of added phosphate at various soil pH values (Brady, 1974).

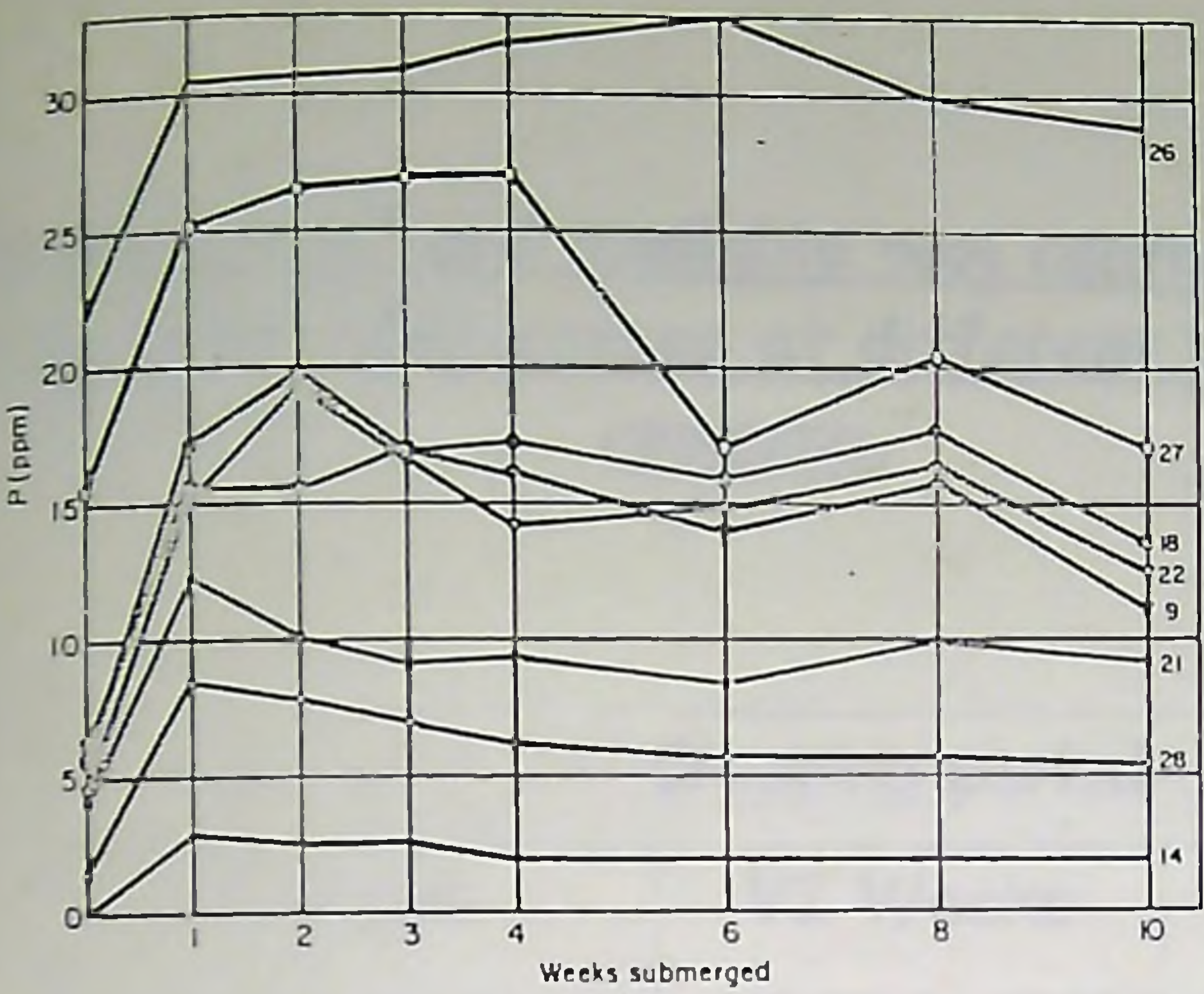

Fig. 3 Kinetics of P soluble in pH 2.7 acetate buffer in eight submerged soils.

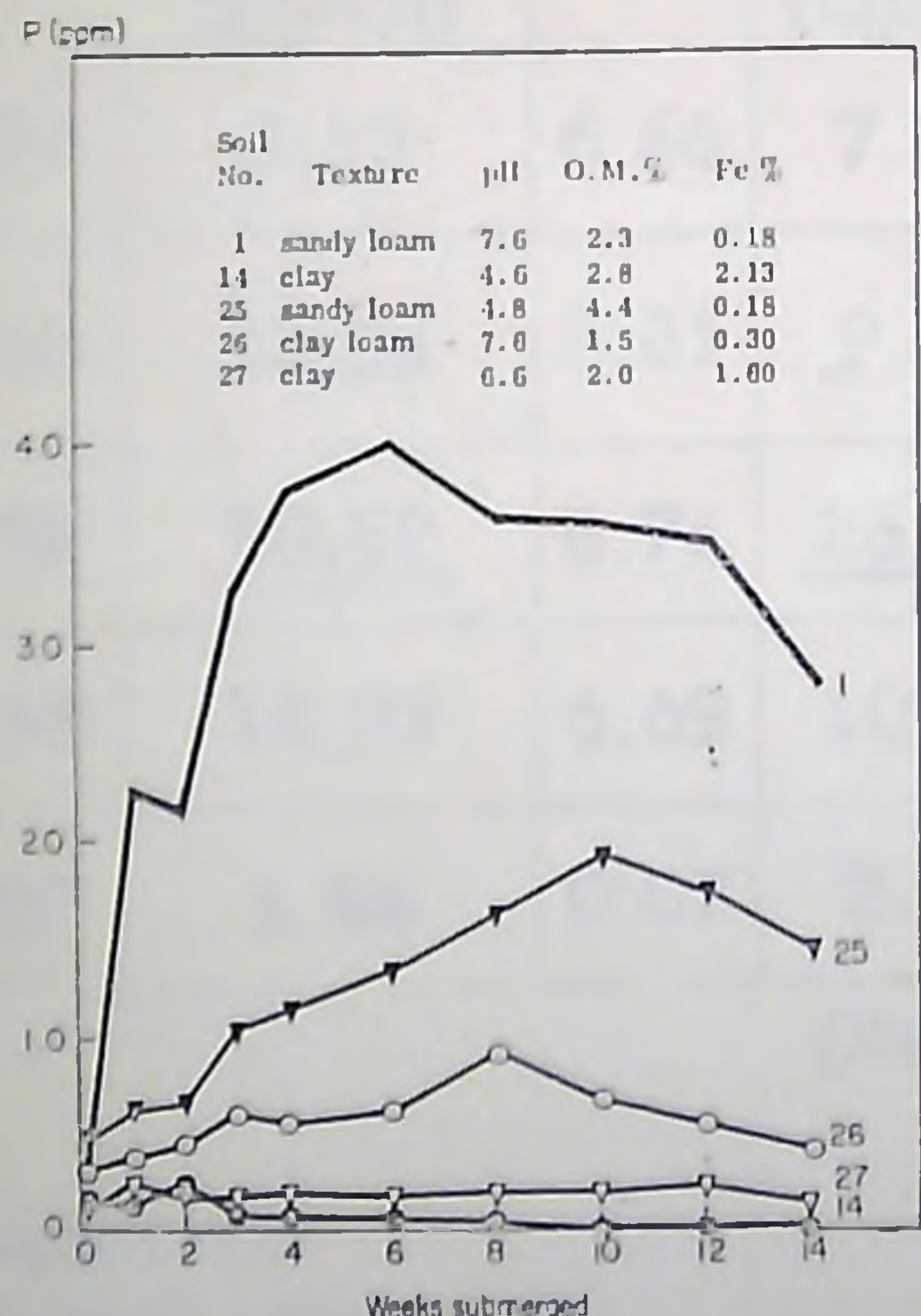

Fig. 4 Kinetics of water-soluble P in five submerged soils.

changes in p^H and available P_2O_5 content of acid soil under submergence at different periods of cropping.

Treatments	Cropping period					
	I Week		VI Weeks		XII Weeks	
	pH	P_2O_5 (Kg/ha)	pH	P_2O_5 (Kg/ha)	pH	P_2O_5 (Kg/ha)
No P	6.51	8.33	6.66	7.05	6.68	6.58
SSP	6.58	23.43	6.81	9.58	6.82	8.94
MAP	6.52	30.52	6.76	26.82	6.78	19.43
MRP	6.63	18.93	6.69	10.58	6.78	9.84
CD (P = 0.05)	0.07	1.86	0.07	2.94	0.07	3.02

(Ravi *et .al.* 2002)

Recommended rate:

Nitrogen @ 60 Kg/ha as urea
Phosphorus @ 75 Kg/ha as SSP, MAP & MRP
Potassium @ 90 Kg/ha as MOP

The availability to rice of original and added phosphorus increases on soil submergence. In acid soils the increase in phosphorus availability is associated with a decrease in Eh or an increase in Iron (II). The increase in phosphorus availability may be due to direct reduction of of iron (III) phosphates of to the increase in pH accompanying soil reduction.

Chemical kinetics and soil fertility

Flooding a soil sets in motion a series of chemical and biochemical changes that profoundly affect the availability and loss of nutrients, and the generation of substances that can interfere with nutrient uptake or that poison the plant directly.

Availability of nutrients:Soil properties, duration of submergence, and temperature strongly influence the concentration of both water and acid soluble phosphorus.

The kinetics of water-soluble phosphorus extractable in a pH 2.7 acetate buffer indicates that the increases are small and short-lived in acid clays, and that available phosphorus after flooding is correlated with available phosphorus before flooding.

Implications for rice: Chemical kinetics of submerged soils has the following implications for the fertility of rice soils.

1. Soil high in available nitrogen need no nitrogen fertilizer
2. Soils medium in available nitrogen need only a top dressing of nitrogen at panicle initiation
3. Soils with low in available nitrogen need both basal application and top dressing
4. Soils whose temperature is below 25°C need more basal nitrogen fertilizer than those whose temperature is 30 to 45°C
5. NH_4^+ toxicity is possible on warm sandy soils high in organic matter
6. Acid clays need phosphorus fertilizer in spite of the increase in availability of phosphorus brought about by flooding
7. To prevent the toxic effects of excess Fe^{2+}, carbon dioxide, organic acids, and hydrogen sulfide, soils should be kept submerged for at least 2 weeks immediately before planning in tropical low lands and longer in cooler areas

P release and transformation in acid soils:

Native P: In general, it is observed that water logging causes release of P due to the following reasons De Datta (1981).

1. Prediction of insoluble ferric phosphate to ferrous form
2. Hydrolysis of AlP and Fe - P ar Z higher pH
3. Desorption of P from clay and oxides of Fe and Al
4. Release of occluded P by reduction of hydrated ferric oxide coating
5. Displacement of phosphate from ferric and aluminium phosphate by organic anions

Sushama *et al.* (1995) observed a continuous in Al-p and Fe-p and available P with period of incubation in water logged coastal laterite soil. Thomas (1997) reported that the available P slightly increased with periods of incubation, reached a maximum and then decreased.

Added P:

Added phosphate in the form of in organic fertilizers was found to be transformed and fixed to Fe-P and Al-P in both rice soils and upland soils. Sushama (1990) observed in Al-P and Fe-P with period of incubation after addition of P.

Phosphorus interaction with other nutrients

Interactions among the plant nutrients are often overlooked eventhough they have considerable influence on plant growth.

An interactions of nutrients takes place when the response of two or more nutrients used in combination is unequal to the sum of their individual responses. There can be both negative and positive interactions in soil fertility studies.

Negative interactions

In negative interactions, the two nutrients combined increase yields less than when they are applied separately, this kind of interaction can be the result of substitution for and or interference of one treatment with the other. Changes in soil pH will result in numerous interactions where one ion or nutrient interferes with or competes with the uptake and utilization of other nutrients by plants. Phosphorus have negative interaction with Zn, Fe, Mn, S and al and B etc.

- High concentration of phosphate in the soil solution produce chlorosis. The high concentration of phosphate hamper the intake and translocation of iron in the plants.

P x Zn interactions:

- High phosphate concentration may also create a zinc deficiency as a result of precipitation of Zinc phosphate in the soil .

A metabolic disorder within plant cells related to an imbalance between P and Zn or an excessive concentration of P interferes with the metabolic function of Zn at some sites in the cells .(Sindhu 2002).

Positiveinterations

Positive interactions are in accordance with Liebig's law of Minimum. If two nutrients are limiting, or nearly 80, addition of one will have little effect on growth, whereas provision of both together will have a much greater influence phosphorus have positive interaction with N, K, Mg, Mo and Si

- Addition of Si significantly increased the available Si in all soil and P in acid soil
- Application of phosphatic fertilizers to acid soil generally associated with increased availability of Mo due to 1) release of molybdate from the anon exchange complex by H_2PO_4 which increases the concentration of Mo in the solution phase of the soil. 2) H_2PO_4 ions in solution phase of soil, promoting the formation of phosphomolybdate ion which in more readily translocated to plant tops ,as compared with molybdate ion alone .(Vijayan,1993)

P x K interactions

Sindhu (2002) reported that P at 17.5 kg/ha and K at 70 kg/ha interacted to produce highest content of 0.23% K and 1182.50 mg/kg S in the kernel. Additional application of 35 kg/ha of K gave the highest Mg content of 0.08%. This value was also produced when P was applied at 35 kg/ha along with K at 70 kg/ha. This combination also gave highest values for N, Fe, and Si which were 17, 36 and 26% higher than P_1K_1 treatment.

Table2: P x K Interaction effects on elemental composition of rice kernal

Treatment	N%		K%		S mg/kg		Fe Mg/kg		Sio₂ %	
	K1	K2	K1	K2	K1	K2	K1	K2	K1	K2
P1 (17.5kg/ha)	1.51	1.65	0.23	0.20	1182.5	417.67	100.0	130.0	1.52	1.91
P2 (35kg/ha)	1.77	1.58	0.17	0.19	482.0	519.67	136.0	81.9	1.92	1.19
CD(0.05)	0.02		0.01		5.09		9.87		0.02	

(Sindhu,2002)

Where K1=70 kg/ha
K2=105 kg/ha

Losses of phosphorus from soils: Phosphorus is lost from soils in many ways as follows.

1. Leaching
2. Volatilization
3. Erosion
4. Plant removal

Leaching: Leaching of phosphates in soil refers to their downward movement along with percolating water. Orthophosphate ions, $H_2PO_4^-$ and HPO_4^{2-}, quickly react with hydrous oxides of ion, and aluminium in acid soils to yield insoluble phosphate compounds of iron aluminium or soluble calcium in alkaline soils or insoluble free calcium carbonate in calcareous soils to yield calcium phosphate compounds leaving a very low amount of orthophosphate ions, in soil solution (not exceeding 1 ppm). Hence the leaching of orthophosphate ions, is extremely low.

If occurs significantly in coarse textured soils (eg. sandy soil) and in organic soil (eg. Muck or pear soil).

Volatilization

In anerobic (reduced) soils orthophosphates are reduced to yield phosphine, pH_3 (which is poisonous and has smell of rotten fish) gas phosphine volatilizes from soils. The addition of high quantities of water soluble phosphorus fertilizers (eg. superphosphates, DAP ere) to a prolonged waterlogged (submerged) rice soil increases phosphorus volatilization. The phosphine, pH_3, reacts with copper in acid soils to form insoluble black copper phosphide Cu_3P_2, that may be precipitated on the surface of roots of rice consequently root respiration and absorption of copper and other nutrients may be indered restricting plant growth. In aerobic (oxidized) soils orthophosphates are not reduced and hence, phosphorus volatilization does not occur.

Erosion Phosphorus is lost by erosion of surface layer of soils.
Plant removal : The orthophosphate ions, $H_2PO_4^-$ and HPO_4^{2-}, present in soil solution are absorbed by growing plants through harvesting, the phosphorus is removed from soils. The magnitude of such removal increases if

1. The crop is high yielding
2. The crop is capable of absorbing high amount of phosphorus
3. The number of harvest per year increases

The removal of phosphorus by crops (plants) is less than removal of nitrogen.

Management of phosphorus fertilizers in acid soil:

Fertilizer phosphorus is an expensive input and its management in soil crop system poses important problems due to several complexities with regard to its behaviour in different types of soil. These often result in poor crop recovery of the nutrient from applied fertilizer.Fertilizer phosphorus is an expensive input and its management in soil crop system poses important problems due to several complexities with regard to its behaviour in different types of soil. These often result in poor crop recovery of the nutrient from applied fertilizer.

Type of phosphatic fertilizer required for different situations:

1. In slightly acidic, neutral or alkaline soils water soluble phosphatic fertilizers are more suitable
2. In submerged rice soils also water soluble phosphatic fertilizers are preferable as pH of most of the slightly acidic soils rises to neutral range on submergence
3. In acidic soils whose pH will not rice above 5.5 to 6 on submergence, phosphatic fertilizers containing citrate soluble phosphates like basic slag, calcium phosphate, steamed bone meal etc., are used.
4. For highly acidic upland soils or submerged soils, powdered rock phosphate such as Rajphos, Hyperphosphate, Ultraphos or powdered mussorie phosphate (100 mesh) are suitable.

How to improve phosphorus use efficiency(PUE) in acid soil?

1).Phosphatic fertilizers should be applied at high rate (dose) to make the soil supersaturated with phosphate ($H_2PO_4^-$). Once the adsorption sites are saturated with phosphate ($H_2PO_4^-$), further adsorption will not occur. Thus excess phosphate ($H_2PO_4^-$) in left in the soil solution which is readily available (accessible) to crops.

2) Surface application or broadcasting is preferred for shallow rooted crops, whereas placement in the root zone is advantageous for deep rooted crops. But in of broadcast application localized application (eg. band placement drill placement, plough-sole placement etc.) of phosphatic fertilizers near the seed or seedling root should be followed. In broadcast application followed by in corporation with soil, more surface area of the fertilizer is exposed for reaction with phosphorus fixing agents (eg. hydrous oxides iron and aluminium) resulting in greater phosphorus fixation (adsorption/precipitation/sorption). On the otherhand, in localized application, less surface area of the fertilizer is exposed and thus, the contact between fertilizers and soil is reduced. Hence the phosphorus fixation decreases. Moreover the phosphorus is within reach of the roots of crops. Thus, the localized application of fertilizers in high phosphorus fixing soils increases phosphorus availability to crops.

3) Sufficient quantity of organic matter should be applied on decomposition, organic matter produces

1. Organic anions such as oxalate, tartarate, citrate, melonate and malate
2. Humus and humate anion
3. Carbon dioxide
4. Nitric acid by nitrogen mineralization process
5. Sulphuric acid by sulphur mineralization process

These products reduce phosphorus fixation (adsorption/precipitation/ sorption) and release phosphorus to the soil solution by mechanisms as follows.

i) The organic anions (eg. oxalate, lartrate, citrate, malonate, malate) form complexes with ion and aluminium

Fe + organic anions -> Fe - anion complex

Al + organic anions -> Al - anion complex

Thus, the reaction of orthophosphate onion ($H_2PO_4^-$) with ion and aluminium is prevented. Furthermore, the organic anions react with ion and aluminium hydroxy phosphates (previously fixed phosphorus) to form complexes of organic anion with ion and aluminium. It may be demonstrated as follows.

$Fe(OH)_2\ H_2PO_4$ + organic onion -> Fe-anion complex + $H_2PO_4^-$

$Al(OH)_2\ H_2PO_4$ + organic onion -> Al-anion complex + $H_2PO_4^-$

Thus, the fixed phosphorus is released to the soil solution ($H_2PO_4^-$).

ii) Humus reacts with phosphate to form phosphohumic complex (organo phosphate complex). This complex can be readily assimilated by plants.Humate anion replaces phosphate anion ($H_2PO_4^-$) adsorbed on soil particles to release phosphate to soil solution. Humus envelops (coats) the hydrous oxides of ion and aluminium particles and thus prevents their reaction with orthophosphate anion ($H_2PO_4^-$). Green manure also increase the availability of P.According to Joseph.p,(1982)P uptake was increased considerably by green manure and amophos applications. Maximum uptake of phosphorus was obtained with the application f 0.2% green manure+ Ammophos.This was significantly superior from rest of the treatments.(Table3.)

- **Bacterial phosphatic fertilizers:**Several organisms in the P supply as for native as well as applied P. Several mechanisms for releasing P. They are

1. Increasing the P mineralization
2. Through the selective enhancement of phosphorus containing organic material
3. Increasing'S' mineralization and production of acids which decreasing pH and increase the availability of P
4. Enhancement of rate of decomposition of organic material

The most bacterial P fertilizers are

1. *Bacillus megathenium* var. phosphaticum which increase the P availability in natural conditions. It increases the availability of P by increasing the decomposition of organic P compounds.
2. *Bacillus polymyxa*
3. *Pseudomonas striata*

Others are *Penicillum digitalium, Aspergillus awamori* and *Trichoderma* sp.

The Bacillus and speudomonas have the ability to bring the insoluble P in the soil to soluble form by secreting organic acids such as cirate, humic, acetic, propionic,

Percentage utilization of phosphorus from fertilizer and green manure by rice.

Treatments	Drymatter mg/pot	Total P µg/pot	%pdff/ %pdfg	%Utilization of P from Fertilizers & Green Manure
T1	171.00	343.75	-	-
T2	211.00	449.90	1.01	7.46
T3	207.00	462.49	1.24	10.55
T4	326.00	731.18	1.11	14.93
T5	195.00	424.27	1.75	6.83
T6	271.50	634.23	1.63	9.51
CD (.05)	56.95	86.17	0.11	1.60

(Joseph.,1982)

T1 Soil alone

T2 Soil + ^{32}P labelled amophos

T3 Soil + ^{32}P labelled green manure at 0.25% by weight of soil

T4 Soil + ^{32}P labelled green manure at 0.25% by weight of soil + unlabelled amophos

T5 Soil + ^{32}p labelled green manure at 0.5% by weight of soil

T6 Soil + ^{32}P labelled green manure at 0.5% by weight of soil unlabelled amophos succinic and humic acids. These acids decrease in pH and by dissolution of bound from of P, increase the availability of P. These bacteria commonly known as phosphobacteria. The artificial culture of bacteria is known as phosphobacterium. This culture is either applied in seed or soil application.

Keeping this view the effect of P solubilising bacterial culture was evaluated for its efficiency in phosphorus utilization under waterlogged condition. An attempt has been made by Anilakumar and Mathew (1996) in Rice at Regional Agricultural Research Station, Pattambi, Kerala.

Table 4: Effect of PSB on P at different % stages of rice growth:

Sl.No.	Treatments	Soil available P kg/ha		
		T_1	P_1	F_1
1	Seedling root dip with PSB + NPK	33.4	36.3	31.3
2	Seedling root dip + Field application of PSB + NPK	34.1	38.4	30.2
3	Field application of PSB + NPK	34.2	35.8	36.9
4	NPK alone	33.7	35.2	30.1
	CD	NS*	NS*	NS*

* Non-significant (Anilakumar and Mathew,1996)

PSB - P solubilizing bacterial culture (*Bacillus mepotheium* var. *phosphaticum*

Ti - Tillering, P_1 - panicle initiation, F_1 - flowering

(Anilkumar and Mathew, 1998)

The table shown that the availability of soil P increased upto tillering stage, then decreased with crop growth. The initial increase might be due to the increased availability of soil P due to submergence and then decrease can be attributed to crop uptake as evidenced from uptake values. On the other hand, the effect of P solubilising bacterial culture on the P availability in soil was marginal. This might be either due to the inability of the bacteria to release more native P over and above the added fertilizers or due to the conversion of water soluble P to Al-P and Fe-P.

Fungi : Vesicular Arbuscular Mycorrhizal (VAM)

VAM fungi from symbiotic association with many commercially cultivated crops and these can be improved the plant growth through the increased nutrient uptake of mainly P and also S, Ca and Zn. This association also resist to diseases and also have ability to absorb more H_2O from the soil during moisture stress condition. Genera are Glomus, Gigaspora, Sclerocystis.

Use of Amendments:

Amendments like time dolomite or magnesium silicate in acid soils may be incorporated in pH and to reduce fixation and increase phosphorus availability before application of phosphatic fertilizers. Overliming should be avoided with rise of pH (upto 6.5) the activity of iron and aluminium decreases and thus their reaction with phosphate ($H_2PO_4^-$) decreases which results in lower phosphorus fixation (adsorption/precipitation) and higher phosphate concentration in soil solution. With further rise of pH (above 6.5), when the soil is overlimed, the activity of calcium increases and thus its reaction with phosphate increases which results in higher phosphorus fixation and lower phosphate concentration in soil solution.

Related to this, one experiment was conducted by Seker (1997), the table shows that the lime influencing in the availability of phosphorus.The result showed in **table 6**

Similar results were recorded by Lakshmi Kanthan (2000) in the laterite alluvium of Manuthy where application of different forms of silicate such as sodium silicate, fine silica as well as rice husk and higher doses of K significantly increased the P content in plants

Table 5 : Residual effects of treatments on nutrient uptake (kg/ha) of rice

Treatments		Phosphorus (kg/ha)	
		with potash	without potash
Overall	Control	1.48	1.4
	Rest	1.69	1.5
	CD (0.05)	NS	NS
Forms of silica	Sodium silicate	1.84	1.6
	Fine silica	1.36	1.4
	Rice husk	1.88	1.4
	CD (0.05)	0.23	NS
Levels of silica	Si 2500	1.66	1.5
	Si 500	1.72	1.5
	CD (0.05)	NS	NS
Levels of potash	K 52.5	1.68	1.6
	K 70	1.71	1.4
	CD (0.05)	NS	NS

(Lakshmikanthan,2000)

In single crop wet lands, where rice in grown in the virippu season (April-May to September-October), application of phosphatic fertilizers can be dispersed with for the rice crop, of the second crop (usually legume or green manure) is given phosphatic fertilizers.

In rainfed or irrigated Agiculture, a cropping system, such as rice-rice-legume, if selected in an acid soil, use of rock phosphate for the pulse crop helps to skip application of phosphatic fertilizers for the succeeding rice crops. But experimental results showed that the skipping of P and K have considerable yield reduction in rice crop. The experiment was conducted by Regional Research Station, Mongumbu ,Kerala (1990). The results showed that skipping of potassium once in two season did not affect grain yield significantly . However skipping of phosphorus once in two season starting with first season and also once in three seasons starting with second season reduced grin yield considerably .

Time of application:

Most of the crops require phosphorus in the initial stages of growth and hence

Table-6 - **Lime influencing on the availability of phosphorus (ppm)**

Treatments	L_0	L_1	L_2	L_3	L_4
S 1	7.77	7.79	7.86	8.38	8.41
S 2	8.03	8.51	8.79	9.50	9.74
S 3	26.17	27.67	28.36	34.64	36.24
Mean	13.99	14.66	15.00	17.51	18.13

(Sekar, 1997)

CD (0.05) for S= 0.432
CD (0.05) for L=0.558
CD (0.05) for SXL =0.967

here,

S1- Exchangeable Al low
S2- Exchangeable Al medium
S3- Exchangeable Al high
L0- No lime
L1- Ca @ 0.5 times of exchangeable Al equivalent
L2- Ca @ 1.0 times of exchangeable Al equivalent
L3- Ca @ 1.5 times of exchangeable Al equivalent
L4- Ca @ 2.0 times of exchangeable Al equivalent

Table - 7

Effect of skipping P and K on grain yield of rice

S.NO	1974-75 punja	1975-76 punja	1975 addl crop	1976 addl crop	Grain yield (kg/ha)
1.	NPK	NPK	NPK	NPK	4050
2.	NPK	N-K	NPK	N-K	3740
3.	N-K	NPK	N-K	NPK	3777
4.	NPK	N-K	N-K	NPK	3835
5.	N-K	NPK	N-K	N-K	3519
6.	NPK	NP-	NPK	NP-	3825
7.	NP-	NPK	NP-	NPK	3968
8.	NPK	NP-	NP-	NPK	3635
9.	NP-	NPK	NP-	NP-	3716
10.	N-	N-	N-	N-	3369
	CD (0.5)				308

(Syriac et al.,1990)

phosphatic fertilizers are usually applied as a basal. But in Kuttanad region, the experiment results showed that the basal application of P_2O_5 as good as split application (Table 7).

Application of rock phosphate two to three weeks before flooding and planting rice makes if as efficient as super phosphate in many acid soils. This is because under acid rice soil conditions, phosphorus or rock phosphate gets converted to iron phosphate which on water logging becomes available for the rice crop.

Permanent manural experiment on Phosphorus in Kerala:

In 1961, a permanent manurial experiment was laid out in Regional Research Station, Pattambi, the treatments included application of cattle manure, greenleaves and ammonium phosphates individually and in combination with and without P and K fertilizers. The trial was aimed to find out the effect of continuous use of inorganic fertilizers and organic manures and to work out the judicious and economic combination of organic and inorganic fertilizers for formulating recommendation to farmers.

Kurumthottical (1982) reported that in the permanent manurial experiment on dwarf Indica.a rice variety at pattambi application of phosphatic fertilizers in combination with organic manures had resulted in higher content of available P as compared to inorganic fertilizers alone. The available P content in soil ranged from 40.5 kg/ha recorded by the treatment which received application of ammonium phosphate alone to 318.5 kg/ha, recorded which involved application of green leaves along NPK fertilizers.

Ill effects of continuous application of phosphatic fertilizers to soil:

Phosphatic fertilizers contained the highest amount of heavy metals. According to Sathya Prakasan (1989), among the phosphatic fertilizers maximum amount of cadmium (7.16 ppm) was found in factomphos, while Nickle (45.19 ppm) and lead (pb) 8.03 ppm were highest in mussoorie rock phosphate. Mulla *et al.* (1980) studied the influence of long term phsophorus fertilization of approximately 178 kg/ha/yr as TSP over 36 years period and found that the total cadmium, Cd in soil was 1.5 ppm, whereas in the control the cadmium concentration was 0.12 ppm. However water soluble cadmium ranged from 0.001 to 0.003 μg/ml which are normal value for most soil. The other heavy metals in P fertilizers are Zn, Cu, Cr, Mn and Va, (Jidesh, 1998).

Conclusion:

The soils of Kerala being under humid tropical climate which are acidic, low in available nutrients with high iron and aluminium content. So the availability of phosphorus in these soils are low in total and available content with high P fixing capacity. Application of insoluble phosphate is found to be more efficient in such soils in conjuction with organic manure. The insoluble forms gets solubilised by releasing organic acids from OM and becomes slowly available. Modification of rhizosphere pH by suitable amendments is also found to improve P availability.

Discussion:

1) What is the pH range of acidic soil?

pH 1-6

2) In Kuttanad, in which season acidity will be more?

Mundakan season, because normally this soils have appreciable quantity of ferrous sulphide. When the soil get dry during second season . The sulphur under goes oxidation producing free sulphuric acid and which is responsible for extreme acidity.

3) Application of phosphorus solubising bacteria in acid soil is not effective, why?

This may be either due to the inability of the bacteria to release more native P over and above the added P fertiliser or due to the conversion of water soluble P to Al-P and Fe-P.

4) What is the pH range for phosphorus availability?

The phosphorus availability is maximum in all soils in the pH range of 6-7.

5) Liming increase the availability of phosphorus in acids soil. What is the effect of overliming?

Overliming reduces the P availability. This is due to the formation of more insoluble Ca-P minerals similar to those occurring in basic soils naturally high in Ca^{2+}.

6) What is the cheapest sources of soil amendments, for acid soils?

According to Lakshmikanthan, rice straw in the cheapest sources of soil amendments for acid soil.

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VERMICOMPOSTING - A REVIEW OF WORK DONE IN KERALA

BY

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SEMINAR REPORT

Ag. Chem. 651 : SEMINAR

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ABSTRACT

Vermicomposting is an emerging technology for recycling of biodegradable wastes. Vermicompost application is also seen to improve the soil health as well as soil fertility status. So it has turned out to be an important component of organic agriculture.

A review of works done on vermi composting in our state have revealed some important findings. Vermi technology using earthworms as biological agents is found to be the best for biodegradation of organic wastes (Zacharia, 1994). Nair *et al.* (1997) have found that population of beneficial microorganisms such as phosphorus solubilisers and Nitrogen fixers are higher in vermi compost compared to ordinary compost.

Vermi compost is seen to be favourably influencing the soil properties such as pH, base status etc. and thus improving the soil environment and overall plant nutrient status (Bijulal, 1994). According to Meera (1997), vermi compost coating on seeds of cowpea showed positive influence on the available Ca, Mg, Zn, Cu and Mn content in the soil.

Studies conducted by Ranijasmine (1996) revealed that in tomato, vermiwash application at 25 and 50% concentration could reduce the inorganic fertilizer dosage to half without any yield reduction. Govindan *et al.* (1995) have found an increase in the yield of Bhindi with increased substitution of Farm yard manure with vermi compost.

Introduction

The potential of organic resources to enrich and sustain the productivity of our arable lands remain untapped in our country. There is a possibility of gathering 750 and 250 million tonnes of cattle and buffalo dung and 100 to 115 million tonnes of crop residues every year. Agroindustry waste, bagasse, pressmud, arecanut waste etc. are also available in large quantities. The organic wastes in India are estimated to supply about 7.1, 3 and 7.6 million tonnes of N, P_2O_5 and K_2O respectively. (Kumaraswamy, 1996). All the available organic waste materials can be converted to value added organic manures or composts by adopting suitable biodegradation process and technology through introducing appropriate microorganisms as well as microorganisms like earth worms (Ramaswamy, 1997).

The recycling of organic resources such as enriched compost, organic mulch etc. is a necessary practise since the chemical fertilizers alone cannot provide all the nutrients in balanced quantities needed for plants (Aruna *et al.*, 1996). Yawalker and Agarwal (1962) opined that because of the high organic matter content and due to relatively higher contents of major nutrients compared to farmyard manure, compost is valuable in crop production.

Of the various types of composting practices, vermitech, the technology of recycling biodegradable organic wastes to compost using earthworms is gaining much importance, now.

Barley (1961) and Gupta (1967) have described the importance of earthworms in enriching the soil with organic matter. According to Palaniappan and Annadurai (1989), earthworms are fertilizer factories, producing fertilizers, which constitutes the earthworm castings. These castings have a balanced proportion of all the nutrients and is also rich in vitamins, enzymes, antibiotics and growth hormones.

The most commonly used earthworms for vermicomposting in India includes exotic species like *Eudrillus euginiae* and *Eisenia foetida*. Commonly used local earthworm is *Perionyx excavatus* (Ismail, 1997).

Eisenia foetida

Eudrilus eugeniae

Vermicompost is brownish black in colour. Earthworms are reported to excrete plant growth promoting substances like hormones as well as vitamins in their castings (Neilson, 1965). Watenake *et al.* (1982) have shown the ability of earthworms in deodorising the organic matter in which they feed, thus making the vermicompost free from bad odours. Kale *et al.* (1987) have reported that the material ingested by earthworms, undergo biochemical changes and the ejected cast contains the plant nutrients and growth regulating substances in plant assimilable forms.

Unlike chemical fertilizers vermicompost is economical. It also increases the productivity, water holding capacity and nutritional value of the soil. Vermiculture and vermicomposting is a potential input for sustainable agriculture. Lot of research works have been conducted on vermicomposting in Kerala.

VERMICOMPOSTING USING DIFFERENT ORGANIC WASTE MATERIALS

In Kerala, mainly three important works are there in thus regard.

VERMICOMPOSTING - USING DIFFERENT TYPES OF ORGANIC WASTE MATERIALS

Sl. No.	Title of the research work	Year
1.	Vermicomposting of vegetable garbage	1993-1995
2.	Vermicomposting using coconut leaves	1997-1998
3.	Vermicomposting of Oushadhi ayurvedic wastes	2002

Vermicomposting of vegetable garbage

Zachariah (1995) in her work vermicomposting of vegetable garbage done at College of Agriculture, Vellayani used 2 species of earthworms, one exotic species and one local species for composting. The raw materials, used for composting included chopped banana leaves and vegetables mixed with cowdung in the ratio 1:1 by weight. It was moistened to a level of 40-50% and was heaped for 2 weeks. After stabilisation of temperature, earthworm species were introduced. Quality parameters of different composts were analysed.

VERMICOMPOSTING OF VEGETABLE GARBAGE

Quality parameters of different composts

Treatments	Time taken for composting (days)	Decomposed/ undecomposed ratio	Humified fraction %
T_1 (Local EW)	56	2.41	33.83
T_2 (Exotic EW)	41	9.43	39.24
T_3 (Ordinary compost)	71	0.31	30.93

The rate of decomposition was higher in exotic earth worm treatment. The rate of decomposition as well as humified fraction percentage were also higher in the same treatment. This is because the actinomycetes and bacteria which are important in waste degradation were more in the gut content of the exotic species used here. Biomass production potential was also analysed for the different treatments.

BIOMASS PRODUCTION POTENTIAL

Treatments	Cocoons/100g	Youngones/100g	Adults/100g
T_1 (Local EW)	3.29	9.0	51
T_2 (Exotic EW)	10.14	22.29	81
T_3 (Ordinary compost)	2.61	3.32	15

The young ones and cocoons per 100 gram were higher in the exotic earthworm treatment. Thus *Eudrillus euginiae* the exotic earthworm used in this work was found to be the superb effective agent for operation of vermicompost technology.

Graff (1981) has reported a reproductive potential of 3-5 cocoons/week/adult in the case of *Eudrillus euginae*.

Prabhakumari *et al.* (1995) have also found *Eudrillus euginae* as the most effective species in converting biowastes into vermicompost at shorter time and the results pointed out the superiority of vermicompost to other organic manure.

Vermicomposting of coconut leaves was a work done at CPCRI, Kasargode and vermicomposting using oushadhi organic waste (wastes from Oushadhi Pharmaceutical corporation) is a work undergoing at present in College of Horticulture, Vellanikkara.

EFFECT OF VERMICOMPOST ON SOIL PROPERTIES

Two important works have been done in this regard in Kerala.

EFFECT OF VERMICOMPOST APPLICATION ON SOIL PROPERTIES

Sl. No.	Title of the research work	Year
1.	Effect of vermicompost application on the electro-chemical and nutritional characters of variable charged soils	1994-1995
2.	Effect of vermicompost or vermi-culture on the physico-chemical properties of soil	1995-1996

1) Effect of vermicompost application on the electrochemical and nutritional characters of variable charged soils

It was a work done by Bijulal during the year 1994-95 at College of Agriculture, Vellayani. The effect of vermicompost in comparison with two other organic manures i.e., farmyard manure and ordinary compost on the electrochemical properties of low activity clay soil was done. For this a soil incubation experiment was conducted.

EFFECT OF VERMICOMPOST APPLICATION ON THE ELECTRO-CHEMICAL AND NUTRITIONAL CHARACTERS OF VARIABLE CHARGED SOILS

Soil - Fine Red Loam Initial pH - 5.1

Changes in pH with time

Treatment	0th day	30th day	60th day	90th day	120th day
T_1 (Control)	5.10	5.13	5.20	5.17	5.23
T_2 (Soil+RP)	5.07	5.30	5.73	6.00	6.17
T_3 (Soil+SP)	5.03	4.43	5.23	5.47	5.83
T_4 (Soil+FYM)	5.23	5.53	5.87	6.30	6.47
T_5 (Soil+FYM+RP)	5.30	5.57	5.97	6.37	6.53
T_6 (Soil+ord.comp)	5.23	5.50	5.87	6.27	6.50
T_7 (Soil+RP+ord.comp)	5.30	5.57	5.87	6.27	6.53
T_8 (Soil+VC)	5.53	5.93	6.37	6.67	6.77
T_9 (Soil+VC+RP)	5.50	5.97	6.40	6.63	6.73

The increase in pH for treatments receiving vermicompost was because on analysis of vermicompost, it showed a neutral to slightly alkaline reaction. Ammonia which forms a larger proportion of the nitrogeneous matter excreted by earthworms is the reason for the rise in soil pH. Other major effects were the reduction in P fixation and increased P solubility in the presence of vermicompost. Contribution to the total base exchange capacity and cation protection was also enhanced in the case of vermicompost. C/N ratio showed stable values in vermicompost treated samples indicating the desirable rate of mineralisation and faster decomposition.

Nitrogen excretion by earthworm was an essential contribution of earthworms to soil fertility (Edwards and Lofty, 1980). Patiram and Singh (1993) have also stressed the positive influence of vermicompost on the pH of the soil. According to Ramaswamy (1996) when the organic waste materials were converted to nutrient rich compost the C/N ratio is narrowed down from more than 100 to less than 30.

2. Effect of vermicompost or vermiculture on the physicochemical properties of the soil

It was a work done by Rajalakshmi during the period of 1995-1996.

In this work, it was seen that treatments in which vermiculture as well as vermicompost application was practised, showed a greater waterholding capacity compared to treatments in which inorganic fertilizers were used. The activity of earthworms in the soil as well as the aggregates formed by the earthworm casts resulted in uniform distribution of micropores and hence increased retention of water.

Studies conducted by Badanur *et al.* (1990) showed that incorporation of organic manures and crop residues in the soil significantly increased the water content upto field capacity as compared with fertilizer treatment.

Works done by Srikanth *et al.* (1995) have revealed a slight decrease in the bulk density of the soil amended with compost compared to inorganic fertilizer treatment.

VERMICOMPOST - USE AS SEED COATINGS

The most important work in this aspect done in Kerala was by Meera during 1997, at College of Agriculture, Vellayani.

VERMICOMPOST - USE AS SEED COATINGS

Sl. No.	Title of the research work	Year
1.	Nutrient economy through seed coating with vermicompost in cowpea	1996-1997

Soil - Red loam
Crop - Cowpea
Variety - Kanakamoni
Package of practice recommendation
FYM - 20 t/ha
NPK - 20:30:10 kg/ha

Analysis of soil at maximum flowering stage showed some significantly higher contents of Ca and Mg, as well as micronutrients in vermicompost coated treatments.

NUTRIENT ECONOMY THROUGH SEED COATING WITH VERMICOMPOST IN COWPEA

Analysis of soil at maximum flowering stage

Treatments	Ca^{2+} (%)	Mg^{2+} (%)	Cu^{2+} (ppm)	Mn^{2+} (ppm)	Zn^{2+} (ppm)
T_1 (Uncoated+POP)	0.87	1.43	1.20	13.47	1.83
T_2 (Br.Rhi+POP)	1.33	2.90	2.57	24.77	2.33
T_3 (VC coat+POP)	1.37	2.90	3.23	27.67	2.50
T_4 (Br.Rhi+VC+POP)	1.20	2.60	2.80	21.27	2.27
T_5 (Br.Rhi+1/2N&P+Full K)	1.07	1.97	2.20	16.50	2.03
T_6 (VC+1/2N&P+Full K)	1.03	2.00	2.33	17.50	1.90
T_7 (Br.Rh+VC+1/2N&P+ Full K)	1.00	2.17	2.13	15.97	1.90
T_8 (Uncoated+POP+ VC 20t/ha)	1.50	3.17	3.63	24.60	2.57
T_9 (Uncoated+POP+ VC 10t/ha)	0.83	1.60	2.23	14.63	1.73

The concentrations of Calcium and Magnesium in the worm casts is much higher compared to the surrounding soil. The active calciferous glands in some species of earthworms can absorb excess Calcium from the diet and then excrete it out. The increase in Magnesium is because of the increased amount of Magnesium in the actual plant material used for composting. Humic acid complex in vermicompost contain appreciable amounts of Fe, Cu, Mn etc.

VERMIWASH AND ITS APPLICATIONS

Vermiwash is a liquid organic manure, which is the aqueous extract of freshly formed vermicompost and surface washing of earthworms. It contains beneficial microorganisms and water soluble fractions of substances present both in vermicompost and body surface of earthworms.

Vermiwash contains 200 ppm N, 70 ppm P, 1000 ppm K, 0.4 ppm Cu, 0.15 ppm Zn, 2.25 ppm Mn and 4 ppm Fe. Auxin and gibberellin like substances are present in Vermiwash (Ismail, 1997).

The important works in Kerala include.

VERMIWASH - IT'S APPLICATIONS

Sl. No.	Title of the research work	Year
1.	Effect of soil and foliar application of vermiwash on growth, yield and quality of TOMATO	1995-1997
2.	The technology for collection of vermiwash in households	1997-1998
3.	Low cost technology for collection of vermiwash developed at COH, Vellanikkara	1999-2000

Effect of soil and foliar application of vermiwash on growth, yield and quality of tomato

This work was conducted at College of Agriculture, Vellayani, by Ranijasmine during the year 1995-97.

The details are given in the table

EFFECT OF SOIL AND FOLIAR APPLICATION OF VERMIWASH ON GROWTH, YIELD AND QUALITY OF TOMATO

Crop - Tomato Variety - Sakthi Soil - Red loam Package of Practice Recommendation FYM - 20-25 t/ha, NPK - 75:40:25

Treatment	Fruit yield (g/plant) Foliar application	Soil application	
T_1 - (V_0f_1)	485.4	49.8	
T_2 - (V_1f_1)	611.1	781.6	
T_3 - (V_1f_2)	768.3	876.3	
T_4 - (V_1f_3)	622.0	494.5	V_0 - Water spray
T_5 - (V_2f_1)	1075.1	1015.6	V_1 - Vermiwash 100%
T_6 - (V_2f_2)	899.0	901.1	V_2 - Vermiwash 50%
T_7 - (V_2f_3)	507.9	1142.8	V_3 - Vermiwash 25%
T_8 - (V_3f_1)	1009.7	649.4	V_4 - Vermiwash 12.5%
T_9 - (V_3f_2)	982.0	1149.9	f_1 - Full NPK
T_{10} - (V_3f_3)	861.5	1001.5	f_2 - 1/2 NPK
T_{11} - (V_4f_1)	1045.0	980.4	f_3 - 0 NPK
T_{12} - (V_4f_2)	968.0	994.3	
T_{13} - (V_4f_3)	529.9	1168.0	

Vermiwash was sprayed to the crop 2 weeks after transplanting and at weekly intervals. Foliar spraying was done using Knapsack sprayer and soil application was done by pouring 50 ml of vermiwash to the base of each plant.

The highest concentration of vermiwash produced the lowest yield. In the 50 and 25% concentrations of vermiwash, it was seen that the inorganic fertilizers could be reduced to half of the recommended dose without any reduction in the yield.

As the 100% vermiwash application was undesirable, a field experiment was conducted by skipping it. Salient finding regarding the shelf life of tomato was obtained.

EFFECT OF SOIL AND FOLIAR APPLICATION OF VERMIWASH ON GROWTH, YIELD AND QUALITY OF TOMATO

Treatments	Shelf life (Days)	
	Foliar	Soil
T_1 - (V_0f_1)	15.5	15.5
T_2 - (V_0f_2)	10.5	11.0
T_3 - (V_0f_3)	11.0	14.0
T_4 - (V_1f_1)	11.5	13.0
T_5 - (V_1f_2)	9.0	10.0
T_6 - (V_1f_3)	10.0	10.0
T_7 - (V_2f_1)	12.5	15.5
T_8 - (V_2f_2)	10.5	14.0
T_9 - (V_2f_3)	11.5	10.0
T_{10} - (V_3f_1)	15.5	12.5
T_{11} - (V_3f_2)	13.0	11.0
T_{12} - (V_3f_3)	10.5	12.5

V_0 - Water spray
V_1 - Vermiwash 50%
V_2 - Vermiwash 25%
V_3 - Vermiwash 12.5%
f_1 - Full NPK
f_2 - 1/2 NPK
f_3 - 0 NPK

Soil application of vermiwash produced fruits with more shelf life compared to foliar application. When the foliar application alone was considered, it was seen that lower concentrations gave tomato fruits with better shelf life. But in soil application, it was just the reverse higher concentrations of vermiwash produced fruits with better keeping quality.

Shanmughavelu (1989) reported that application of a combination of inorganic fertilizers and farmyard manure was the best form firmness, storage life and keeping quality of tomatoes for a long time.

Technology of vermiwash collection developed at College of Agriculture, Vellayani

It was developed by Padmaja *et al.* (1998) at College of Agriculture, Vellayani.

Lowcost technology for collection of vermiwash developed at College of Horticulture, Vellanikkara

It is a much simple and economical technique for collection of vermiwash. The earthern pot consists of pieces of stores upto 10 cm height, above that coir fibres, then 1500 to 2000 worms in humus. The hole situated at the bottom of the pot has a tap through which vermiwash is collected. Everyday kitchen waste is put into the container. After brownish black mass of the compost in obtained, pour about 2 litres of water. After 24 hours, collection of 1½ litre of vermiwash is possible.

VERMICOMPOST - ITS EFFECT ON DIFFERENT CROPS

Thampan (1993) recommended onfarm recycling of organic wastes and application of bulky organic manure such as farmyard manure and compost as the most popular agronomic measure to sustain good soil health.

In Kerala, works are there regarding the influence of vermicompost on different crops.

VERMICOMPOST APPLICATION IN DIFFERENT CROPS

Sl. No.	Title of the research work	Year
1.	Influence of vermicompost on the field performance of Bhindi in laterite soil	1993-1994
2.	Effect of vermicompost on the yield and quality of Tomato	1994-1995
3.	Vermicompost as a potential organic source and partial substitute for inorganic fertilizers in Sweet Potato	1995-1996
4.	Vermicompost enriched with rock phosphate on Cowpea	1997-1998

Influence of vermicompost on the field performance of Bhindi in laterite soil

The work was conducted at RARS, Pilicode during the period 1994-95, by Govindan and coworkers. They could find out that the yield of bhindi recorded was increasing in the order of increased substitution of farmyard manure with vermicompost.

Effect of vermicompost on the yield and quality of tomato

The work was conducted by Pushpa during 1994-95 period. The results revealed that the protein and carbohydrate percentage of the fruits showed a greater increase in the treatments where vermicomposting and vermiculture was practised.

Ravignanam and Gunathilagaraj (1994) investigated the effect of earthworms on mullberry biochemical characters such as increasing the protein and chlorophyll content of leves.

Phebe (1998) reported that substitution of vermicompost for chemical fertilizers showed highest ascorbic acid content and lowest level of acidity in snakegourd.

Vermicompost as a potential organic source and partial substitute for inorganic fertilizers in sweet potato

It was a work undertaken at Vellayani during 1995-96. There were some significant results regarding the K content in plants.

Vermicompost as a potential organic source and partial substitute for inorganic fertilizers in Sweet Potato

Soil - Brown hydromorphic Package of Practice Recommendation
Crop - Sweet Potato Cattle manure - 10 t/ha
Variety - Kanjangad local NPK - 75:50:75 kg/ha

Treatments	Soil analysis Available K (kg/ha)	Plant analysis (K content in %)		
		Leaf	Vine	Tuber
T_1 - Inor. fert. (Full NPK)+ org. fert.(cattle manure)	79.66	1.80	2.43	2.37
T_2 - Inor. fert. (Full NPK)+ org. fert. (VC)	78.33	2.12	2.81	2.48
T_3 - Inor. fert. (3/4 NPK)+ org. fert. (VC)	78.95	2.05	2.65	2.47
T_4 - Inor. fert. (1/2 NPK)+ org. fert. (VC)	78.93	1.99	2.62	2.38
T_5 - Inor. fert. (Full NPK)+ org. fert. (3/4 org.fert. as VC)	85.54	1.80	2.37	2.23
T_6 - Inor. fert. (Full NPK)+ org. fert. (1/2 org.fert. as VC)	82.88	1.62	2.22	2.13
T_7 - Inor. fert. (N as VC)+ org. fert. (VC)	84.59	1.62	2.25	2.12

K is a nutrient which shows luxury consumption when applied in excess amounts.

In this experiment, it was seen that on leaf, vine as well as tuber analysis, the Potassium content was maximum in the treatment T_2, that receiving full dose of inorganic fertilizers as well as organic fertilizers as vermicompost. Vermicompost showed higher amounts of potassium on analysis. That may be the reason for higher Potassium content in various plant parts for this treatment.

In the case of soil analysis after harvest, the available Potassium was least in treatment T_2. This is because maximum amount of Potassium was taken up by the plants in this treatment.

Vermicompost enriched with rockphosphate on cowpea

This was another work done at College of Agriculture, Vellayani by Shylajakumari during 1998. The results revealed that inorganic phosphate could be reduced to half of its recommended dose by priming vermicompost with rock phosphate. Joshi *et al.* (1985) have reported that blending of urea and rockphosphate with pith resulted in immobilisation of urea nitrogen and controlled release of nitrogen.

Mishra and Banager (1986) also emphasized that the phosphorus enriched compost was comparable to single superphosphate in crop response and phosphorus uptake.

Raghuwanshi *et al.* (1996) have found that rate of decomposition, earthworm population, fungal and bacterial count were all higher in treatments, where single superphosphate, cowdung earthworm and azotobacter were added to the material to be composted.

Manna and Ganguly (2000) have shown that rockphosphate enriched compost at 5 t/ha yielded soyabean grain at par with recommended doses of mineral fertilizers.

VERMOCOMPOST AND ASSOCIATED MICROBES

The presence of a large number of microorganisms including nitrogen fixing bacteria as surface and gut microflora of earthworms has been reported earlier by Hutchinson and Kamel (1956).

Karsten and Dnike (1995) found that the ratio of microbes capable of growing under obligate anaerobic condition to those capable of growing under aerobic condition was higher in the worm intestine than in the soil. Earthworms encourage mutualism and biodiversity in soil. Mobilisation of nutrients and organic resources through mutualism with soil microflora was encouraged by earthworms (Lavelle *et al.*, 1995).

Indira *et al.* (1996) reported that population of beneficial organism like Phosphorus solubilising bacteria, nitrogen fixing organism and entomophagous fungi was in the range of 10^5 and 10^6 in vermicompost.

In Kerala, two major works have been undertaken in this regard.

VERMICOMPOST AND ASSOCIATED MICROFLORA

Sl. No.	Title of the research work	Year
1.	Microflora associated with earthworms and vermicompost	1995-1996
2.	Influence of microflora associated with earthworm (*Eudrilus eugeniae*) and vermicompost on growth and performance of chilli	1997-1999

Microflora associated with earthworms and vermicompost

In the first experiment which was undertaken at College of Agriculture, Vellayani the important findings included,

MICROFLORA ASSOCIATED WITH EARTHWORMS AND VERMICOMPOST

Sample	Bacteria	Fungi	Actinomycetes	Azotobacter
Surface wash				
E. eugeniae	$1.3x10^7$	$22.7x10^4$	$8.3x10^6$	$0.7x10^3$
Megascolex sp.	$1.6x10^7$	$13.3x10^4$	$1.0x10^6$	$3.0x10^3$
Gut				
E. eugeniae	$20.5x10^7$	$223.3x10^4$	$94.7x10^6$	$1.3x10^3$
Megascolex sp.	$2.9x10^7$	$88.7x10^4$	$19.3x10^6$	-
Vermicompost				
E. eugeniae	$5.7x10^7$	$22.7x10^4$	$17.7x10^6$	$2.3x10^3$
Megascolex sp.	$2.0x10^7$	$4.3x10^4$	$1.0x10^6$	-
Ordinary compost	$2.6x10^7$	$4.0x10^4$	$4.3x10^6$	$0.3x10^3$

For determining the microflora in the surface wash, the earthworm were gently washed in 5 ml sterile water for 5 minutes and the resultant supernatant after serial dilution was plated on a specific medium.

The surface washed earthworms were killed by brief exposure to 95% ethanol and hind gut was dissected and the gut content was transferred and after serial dilution, plated on the medium and then counted.

On comparison of vermicompost and ordinary compost, it can be seen that a very higher amount of microflora is there in the case of vermicompost.

The second work was done by Suja (1999) at College of Agriculture, Vellayani.

FUTURE LINE OF WORK

The areas related to vermicomposting where not much research works have been done in the State include,

- **Staggered application of vermicomposting**

Instead of applying the vermicompost as full basal dose, a staggered application at optimum growth stages of the plant will be advantageous. As vermicompost can retain sufficient moisture and thus avoid dispersal by wind, topdressing would not cause any problem. Moreover all the nutrients in vermicompost are in available form to the plants.

- **Standardisation of the dosage of vermicompost for different crops.**
- **Pelletising of vermicompost**

Digested organic supplements, which are packed as tablets and briquettes after elimination of pathogens by pasteurisation, fortification with essential micronutrients and immobilisation with nitrogen fixing and phosphate solubilising organisms is of great use to farmers (Ramarethinam, 1996).

- **Vermiwash can be used as effective foliar spray for anthuriums and orchids**

It contains 200 ppm Nitrogen, 70 ppm Phosphorus and 1000 ppm Potassium. It contains growth hormones like auxins, gibberellins etc.

- **Influence of vermicompost on soil borne pathogens needs further study.**
- **Maintenance of VEMP (Vermicompost-earthworm-mulch-plant root) interaction.**

The interaction of root hairs of green manure plants with nitrogen fixing organisms is enhanced by VEMP interaction. Population of vesicular arbuscular mycorrhiza is increased as the earthworms are vectors of viable propagules of VAM.

Vermicompost can be used as carrier medium for Azospirillum, rhizobium and Phosphorus solubilisers. In systems, where azolla is applied as organic input, decomposition and release of nutrients are hastened by application of vermicompost.

- **Impact of chemicals on earthworms**

Large number of chemicals like insecticides, herbicides, fungicides etc. applied to the soil will affect the earthworm population, thus resulting is an imbalance of the normal functioning of various components of ecosystem.

- **Impact of heavy metals**

Earthworms may accumulate heavy metals in their tissues, thus acting as biomagnifiers, trasnferring the metals in their tissues to higher organisms through the food chain.

CONCLUSION

Minimising of environmental pollution and the demand for safe disposal of domestic and industrial wastes have resulted in an increased interest in the process of vermicomposting. Vermicomposting as well as vermiculture has much to do with the soil formation, soil turn over and soil fertility, also.

It is a well known fact the "soil is the placenta of life". A healthy agriculture can spring up only from a healthy soil. A soil in turn is said to be healthy and living, only with the right combination of soil flora as well as soil fauna such as earthworms. Soil, the precious natural resource is not something which we have inherited from our ancestors, but it is something which we have borrowed from our children.

The tapping of this resourceful technology, vermitech, is of utmost important as it protects our soils for future generations to enjoy.

DISCUSSION

1) Do vermicompost has any effect on controlling plant diseases?

Not much research works have been done in this regard. However, it is seen that vermiwash, which is prepared from vermicompost has got some effect on controlling amaranthus leaf blight.

2) From where a farmer of Kerala can get this vermicompost? Is it available in packets?

All, research stations coming under Kerala Agricultural University, then Krishi Vigyan Kendras, a lot of private enterprises etc. are involved in this vermicompost preparation and sale. They are available in small packets of 1 kg; usually.

3) What is the nutrient content of vermicompost? Can we fully substitute it for the chemical fertilizers?

Vermicompost contains 1.6% N, 0.8% P and 1.8% K. It can very well be substituted for the FYM, recommended in the package of practices. But full substitution of the recommended chemical fertilizers with vermicompost cannot be advised, because it takes more time for supply of nutrients from vermicompost. Moreover, large quantities are required for providing even a little amount of nutrients. So abruptly switching on to full vermicompost is not good. A judicious use of vermicompost along with chemical fertilizers is needed.

4) Why are we adding along with vegetable garbage, some cowdung also, during composting?

Usually cowdung is mixed with vegetable garbage to ease the decomposition process, so that compost is got in lesser time. Not only that, some vegetables may contain pungent substances harmful to earthworms. So they are to be mixed with cowdung, so that a partially decayed material is available for composting.

5) Why this Fe, Mn content more in vermicompost?

The humic acid complex formed out of this vermicomposting has got these metal ions, in chelated form, so their content is more in vermicompost.

6) Is there any growth promoting substance present in vermiwash?

Auxin and gibberellins have been detected on chemical analysis of vermiwash.

7) What are the advantages of vermicompost compared to other composts?

Vermicompost is odourless. The time taken for vermicomposting is less. Beneficial microorganisms like nitrogen fixers, phosphorus solubilisers etc. are more in vermicompost. Secretion of enzymes and hormones by the earthworm gut can act as plant growth regulators.

8) What are the substances, on which earthworms cannot feed?

They usually feed on all biodegradable substances. They cannot feed on metals, plastics etc. and other oily substances. Also they avoids pungent materials.

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RECYCLING OF AGRICULTURAL WASTES FOR SUSTAINABLE PRODUCTION

BY

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SEMINAR REPORT

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ABSTRACT

Sustainable agriculture is the system of raising crops for greater human utility through utilization of resources with better efficiency without disturbing, imbalancing or polluting the environment. (Ramaswamy, 1996) The most important consideration of this kind of agriculture is keeping the environment of the region harmonious and balanced through appropriate cropping and farming systems and by using resources judiciously. In this context recycling of agriculture wastes assumes importance since most of the wastes which when burnt or disposed as such has serious impact on environment in terms of pollution of land, water and atmosphere. The recycling of crop residues and organic wastes through composting methods is the key technology for disposal and production of organic manure.

The recycling of agriculture wastes has an important role in sustainable agriculture since the application of these wastes helps to improve physico-chemical and biological properties of soils. Infact the current aim of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment and enhance health and safety in long-term perspective.

INTRODUCTION

"Since for the last 25 years this rice field has not been ploughed. Even a single fraction of chemical fertilizers were not applied to this land rather than crop residue incorporation. Pesticides and fungicides were not allowed in the vicinity of the land. The only operation done was broadcasting of clay coated seeds to the land. After adopting this practice per hectare yield was found to be more than 4000 kg" (Fukuoka, 1978). This has been taken from the famous book "One Straw Revolution" by Fukuoka which is considered as the Bible of nature lovers. In this book he emphasized the need of recycling of crop residues for sustainable production.

Aryan's agriculture was basically organic farming as revealed by the trusted history of Aryan civilization. They had combined together the husbandry of various crops of various animals. There was a real blend of interdependence for allround benefits to crop, soil and animals. But in the wake of 21st century due to technological growth waste accumulation enhanced and disposal has assumed serious dimensions not only in western world but also in Third world countries. The wastes are of different kinds including crop residues, vegetable wastes, domestic wastes, city garbages, sewage effluents, industrial effluents and sludges etc., which affect the environment and harmonious relationship between the biotic and abiotic components of ecosystem.

To achieve sufficiency in food production and in maximizing crop yield potential, many developing countries will need to accelerate efforts to halt the declining in the soil productivity of toresort to the productivity of degraded soils in shortest possible time. Much of this goal can be achieved through proper management and utilization of organic matter such as agricultural residues to protect agriculture soil from wind and water erosion and to prevent nutrient losses through runoff and leaching. Efficient and effective use of these materials as soil conditioners also provides one of the best means for maintaining soil productivity. The beneficial effects of organic wastes on soil physical properties are increasing water infiltration, water holding capacity, water content, aeration and permeability, soil aggregation and rooting depth and decreasing soil crusting, bulk density, runoff and erosion.

The greatest challenge in 21st century is to feed the ever increasing population. Eventhough the use of mineral fertilizers provides the way to achieve this, the limitation in the availability of fossil fuel creates energy crisis and makes the cost of fertilizers high. Complementary use of available renewable resources of plant nutrients like organics and biofertilizers along with fertilizers is of great importance. Use of inorganic fertilizers alone in the intensive cropping system creates infertility and unfavourable soil physical conditions and biological systems. Soil health is deteriorating year after year. It can be overcome by the use of recycled agriculture wastes for health and sustainable crop production. The conventional farming is not sustainable due to loss of soil productivity and excessive dependence on chemical inputs, neglection of recycling of organic matter resulted in soil erosion, depletion of ground water and loss of biodiversity. But sustainable agriculture is ecologically sound, viable and society acceptable.

SUSTAINABLE AGRICULTURE

Sustainable agriculture is the system of raising crops for greater human utility through utilization of resources with better efficiency without disturbing, imbalancing or polluting the environment (Ramaswamy, 1996). The most important consideration of this kind of agriculture is keeping the environment of the region harmonious and balanced through appropriate cropping and farming systems and by using resources judiciously sustainable farm minimizes their purchased inputs, viz. fertilizers, energy and equipments and rely as much as possible on the renewable resources of farm itself. Thus sustainable agriculture doesn't mean a return to the farming methods of earlier agriculture rather, it combines traditional techniques with modern technologies such as improved seeds, modern equipment for low tillage practices, integrated pest management that relies heavily on biological control principles and weed control that depends on crop rotation (Rammohan *et al.*, 2001). The trash of one component will become input feed for another component, thus raising the utilization ratio of substances, increased productivity of agriecosystem and enriching the diversity of system as well.

RECYCLING OF AGRICULTURAL WASTES

Agricultural wastes include rice bran, rice husk and rice straw (106 MT), wheat and other cereal straw (140 MT), sugarcane trash (18.2 MT), bagasses (44 MT), Molasses (3.7 MT), tobacco waste (62,000 t), wool waste (2.0 MT), coir waste (33,000 t) etc. All the available organic wastes from different sources could be recycled, reprocessed and put to productive use. Nearly 100 to 114 Mt of crop residues are either wasted or burnt. The organic wastes available in India are estimated to supply about 7.1, 3.0 and 7.6 Mt of N, P_2O_5 and K_2O respectively. The crop residue alone can supply about 1.13, 1.41 and 3.54 Mt of N, P_2O_5 and K_2O respectively. All the available organic waste materials can be converted into value added organic matter/compost by adopting suitable biodegradation process and technology (Ramaswamy, 1996).

Recycling of agricultural wastes can be broadly classified into

Application of agricultural wastes as such or Stubble mulching

Composting

(a) STUBBLE MULCHING

Efficacy of plant nutrition can be increased if the soil is covered by organic mulches. Most of the areas of our country receives high intensity rainfall and due to the less infiltration rate it results in heavy run off leading to plant nutrient loss. Here lies the importance of crop residue management. Crop residues will act as good organic mulches when incorporated into the soil and thus increases the infiltration capacity of soil. The new trend towards thicker planting, narrow rows and heavy fertilization not only causes increase in yield but also results in production of finer stemmed crop plants which are easy to manage as surface residues.

A field experiment done at Kovilpetty research station reveals that application of Bajra straw as mulch increases the available N, P, K and organic carbon (OC) of the soil and also increases cotton yield.

Table 1. Effect of Bajra straw as mulch on cotton field.

	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)
Bajra straw	130.4	8.40	348	0.279

(Solaiappan, U., 1998)

Increase in available soil N and organic carbon content is due to suppression of weeds, build up of organic matter and increased microbial activity. All these favoured rate of mineralisation and release of available N in greater proportion. Build up of organic matter, release of organic acids during decomposition, solubilization of minerals, change over from non exchangeable form to exchangeable form under mulched condition etc. are reasons for increased availability of K and P.

Advantages of mulching

1. Increased crop yield
2. Application of crop residues result in soil conservation, weed control and improvement of soil structure.
3. It improves soil water by reduction of evaporation, run off, weeds and increase in infiltration.
4. It decreases splash erosion and thus protects the breaking down of soil aggregates.
5. It reduces soil salinity.
6. It adds to mone soil humus and also helps in build up of desirable soil microbial fauna.

Disadvantages of mulching

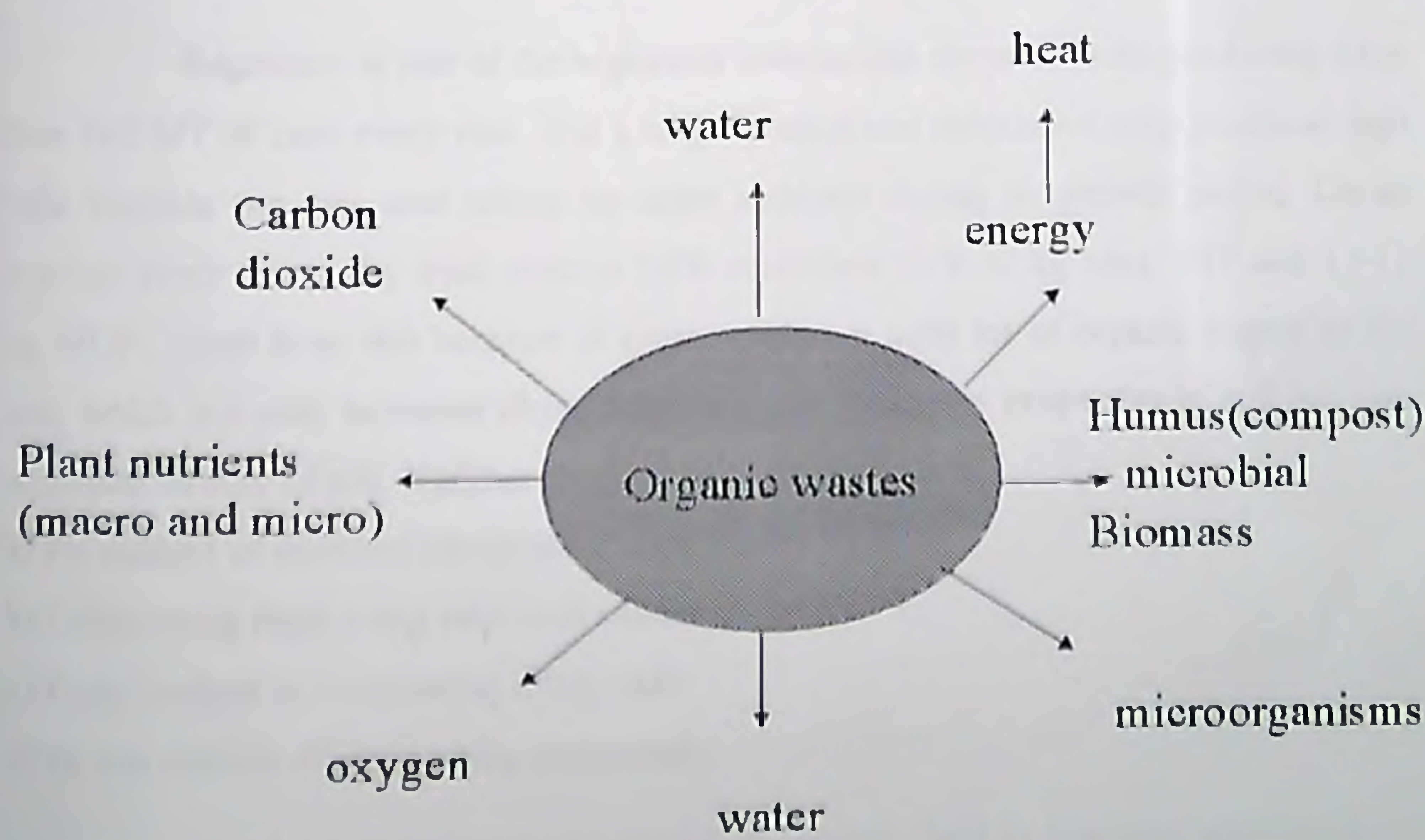
Direct incorporation of crop residues has its own limitations as

1. There are more chances of incidence of insects, diseases, weeds and rodents.
2. There will be more difficulty in getting good seed soil contact resulting in a non uniform stand.
3. It affects young seedlings through liberation of toxic substances like alkaloids and phenols.
4. Incorporation of fresh crop residues delay the transplantation of some crops mainly rice.
5. Immediate immobilization of available plant nutrients.
6. More wetness and coldness in soil surface resulting in slower germination.

Moreoever if we apply crop residues as such it will take a longer time to release the nutrients in its available form into the soil and hence it is more advantageous to long duration crops only. Hence we can go for recycling of crop residues through composting methods which is the key technology for the disposal of agricultural wastes.

(b) COMPOSTING

Composting is a microbiological process accomplished by cumulative action of bacteria, fungi actinomycetes and protozoa which are present in raw materials or introduced into the system by the use of inoculum. The finished material is crumby, dark brown to black, has a pleasant earthy smell, will not attract flies, rich in humus substances and contains both micro and macro nutrients. This can be carried out both under aerobic and partially anaerobic conditions. Aerobic composting is usually preferred since we get good quality composts within a short time. The principle of aerobic composting was standardized as the best formulation technique for the production of organic meals. Good quality composts could be produced within a period of 90 days by open heap method using materials like sludge, neemcake, Mussorie rock phospate and urea (Thomas, 2001).



Dung slurry and biogas spent slurry was found to be good additives for improving the rate of decomposition of crop waste composts (Gaur and Mathur, 1990). Composting of wide C/N ratio materials such as bark wastes, rice straw, sawdust with low C/N ratio material such as poultry manure resulted in a more favourable ratio for composting and compost produced had high nutrient content (Rynk, 1992).

Srikanth *et al.* (2000) noted that composts contains macronutrients such as P that contributed to greater yield of different crops. A field experiment was conduct to study the direct and residual effect of enriched compost on soil properties in comparison with FYM, vermicompost and inorganic fertilizers. The soil nutrient value was found to be high in enriched compost amended soil after the harvest of first and second crops. There was a light decrease in bulk density of soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment.

Eventhough almost all of the agricultural wastes can be converted into good quality composts, composting of some of the agricultural wastes are discussed below.

1. Compost from sugarcane wastes (Patil, 2001)

Sugarcane is one of the important commercial crops of India producing more than 300 MT of cane every year. It is a long duration and exhaustive crop produces high total biomass per unit area taking up more nutrients during its growth period. On an average every ton of dry trash contain NPK equivalent to 8-10 kg urea, SSP and 11-12 kg MOP. Apart from this because of great volume, it adds lot of organic matter to the soil, which not only increases physicochemical and biological properties of soil but also increases fertility of soil. Various methods of composting are:

a) Pit method of enriched composting using trash

b) Composting trash using microbial culture

c) Heap method of composting using trash

d) In situ method of composting using trash

Based on experiment conducted in farmers field in Madurai application of cane trash compost was found to improve the nutrient content of soil as well as the crop yield. Compost obtained from the 2nd method is found to have a significant effect on increasing wheat grain yield physicochemical and biological properties of soil also showed marked improvement. In situ method of composting is an economically viable focus which enhance the accelerated growth of rattoon crop.

Table 2. Composition of canetrash and cane trash compost in %

Nutrients	Canetrash	Canetrash compost
N	0.50	1.60
P	0.13	1.10
K	0.40	0.50
Ca	0.55	1.00
Mg	0.30	0.60
S	0.12	0.48

(Karthikeyan, S., Ramesh, P.J., Nagamani,B, 2002)

A study was conducted to assess the effect of biodegraded sugarcane trash on yield and nutrient uptake by wheat crop. The shredded trash was inoculated with three mesophilic actinomycetes and a thermophilic actinomycete singly or in combination and allowed to decompose. Application of compost produced by coinoculation of 3 mesophilic actinomycetes with and without 80 kg N effected a significant increase in grain yield over that with 120 kg N ha^{-1} (Mathur and Shukla, 2000).

2. Characterization and utilization of N contained in sweet corn waste (Fritz *et al.*, 2001)

Sweet corn waste accounts for 61-73% of harvest yield. It comprise of husk leaves, cobe, discarded kernels and small amounts of stalk. The waste was transformed into enriched compost which contains larger quantities of mineralized N. When sweet corn waste was applied to field, grain yield and N uptake of sweet corn were increased with increase in sweet corn waste application rate. Post harvest Nitrate-N concentration in soil were also greater and were significantly increased by increase in sweet corn waste rate. N availability also arrived about 16-18% of total sweet corn wastes - N applied. Soil P was increased 2.6 mg/kg with each 112 kg/ha sweet corn waste and soil K was increased 14.2 mg/kg with each 112 kg/ha sweet corn waste.

Table 3. Nutrient content in sweet corn waste (% dry matter)

Dry matter	Total C	N	P	K	C/N
170	456	12.3	2.9	10.5	37.1

3. Compost from coir pith and its effect on maize (Surya Rao *et al.*, 2001)

Composting of coir pith was done with various organic and inorganic additives in various combinations. Coir pith has high CN ratio (93.77) and LN ratio (106.0) could be converted to good quality composts with 21.91 to 34.07 CN ratio of 18.78 to 25.49 LN ratio. The organic carbon, lignin, cellulose and total phenol content decreases while contents of major, minor and micronutrients increased upon composting of coir dusts in all composts. So it is used as a effective compost in integrated nutrient management.

In a field trial done by Surya Rao *et al.* (2001) composting of coir pith was carried out with different organic and inorganic additives like *Pleurotus sajorcaju* @ 1 kg/T of coir pith, cowdung, garden weeds of glyricidia, @ 5, 10 and 15% of fresh weight basis. Urea was used as N source in C_4 compost. Micronutrients Zn, Fe and Mn are added @ 200 ppm and Cu @ 20 ppm.

Table 4. Chemical and biochemical properties of coir pith and matured compost

Parameters	Coir pith	C_1	C_2	C_3	C_4
pH	6.25	6.80	7.20	6.83	6.81
N (%)	0.47	1.18	1.02	1.06	1.38
P (%)	0.02	1.14	1.08	1.06	1.28
K (%)	0.62	0.98	0.96	0.94	1.00
CEC (C mol kg-1)	70.12	76.81	86.90	75.94	73.99
CN ratio	93.77	27.37	34.70	31.93	21.91
LN ratio	106	22.38	22.23	25.47	18.78

(Surya Rao, P. Suseela Devi, L., Amlan Datta, 2001)

C_1 - Coir dust + Pleurotus + cowdung + garden weeds + glyrycidia + Rock phosphate + micro nutrients

C_2 - Coir dust (L) + Pleurotus + cowdung + garden weeds + glyrycidia + Rock phosphate + micro nutrients

C_3 - Coir dust + Pleurotus + cowdung + garden weeds + glyrycidia + Rock phosphate

C_4 - Coir dust + Pleurotus + cowdung + urea + Rock phosphate + micro nutrients

The pH of lime pre treated compost was high due to alkali treatment and all other values are in acceptable limits. In C_4, CN ratio was drastically reduced due to increase of N due to incorporation of urea and also due to omission of Carbon rich garden weeds and glyrycidia. The CEC of coir pith composts in general is high compared to composts from other wastes due to high lignin content and which in turn is rich in functional groups.

These composts were applied @ 10 t/ha along with 50% recommended doze of fertilizers (RDF) for maize crop and dry matter yield of maize was noted 60 DAS. It was quite comparable with 100% RDF. The quality of composts can be arranged as $C_1 > C_4 > C_2 > C_3$. Thus it is evident that it is possible to save 50% of inorganic fertilizer without sacrificing the yield with addition of coir pith enriched composts. Application of compost also resulted in significantly high N, P_2O_5 and K_2O contents of post harvest soil. Hence it can be successfully introduced into integrated nutrient management systems to sustain productivity.

Another field experiment was also conducted to study the effect of composted coir pith on growth and yield of rice-ragi cropping sequence at Paiyur (Andani Gowda and Suresh Babu, 2001).

Table 5. Effect of composted coir pith on growth and yield of rice-ragi cropping sequence

Treatments	Rice		Ragi	
	Grain yield (kg/ha)	Straw yield (t/ha)	Grain yield (kg/ha)	Straw yield (t/ha)
Control	4421	6.1	1758	2.5
Recom. inorganic fertilizer	5865	8.2	2285	2.9
Raw coir pith	4202	5.8	1486	2.3
Coir pith compost	4895	6.4	1726	2.6
Compost + 50% inorganic fertilizer	5796	8.0	2200	2.8

From the results also it is evident that we can sacrifice 50% inorganic fertilizer and get a yield which is almost comparable to the yield obtained by adopting 100 % RDF

4. Effect of enriched compost prepared from chopped and unchopped organic materials on crops (Gaur, 1999)

The effect of enriched composts was compared with recommended dosages of fertilizer on crop yields. The enriched composts was applied @ 10 t/ha before sowing with and without recommended dozes of chemical fertilizers. The application of enriched compost, produced from either chopped or unchopped straw wastes, increased the grain yield of crops.

Table 6. Effect of enriched rice straw compost on grain and straw yields of wheat crop

Treatments	Enriched rice straw compost		
	Grain yield (kg/ha)	% increase over control	Straw yield (kg/ha)
Control	1753	-	3067
Chopped straw compost	2486	41.8	4440
Chopped straw compost + N_{60} P_{30} K_{30}	3995	127.9	7552
N_{60} P_{30} K_{30}	3080	75.9	5778
Unchopped straw compost	2400	36.9	3711
Unchopped straw compost + N_{60} P_{30} K_{36}	3888	121.8	6849

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5. Vermi composting - an emerging technology for waste management

Vermi composting is the process of composting suitable wastes with the help of earth worms (Gaur, 1999). Earth worms can consume practically all kinds of organic matter. One worm, weighs about 0.5-0.6 g eats wastes as their own body weight per day and produces cast of same weight per day. It is estimated that 1000 tonnes of moist organic matter can be converted by earthworms into 300 tonnes of compost (Tapaidor, 1981). Organic materials undergo complex biochemical changes in the interstines of earth worms. Vermi composting is an appropriate technique for disposal of non toxic solid and liquid organic wastes. In South East Asia, Vermi composting is being practised in Philippines (Gaur, 1982) and of late it is gaining popularity in Western India where production of vermicultures is coming up as a commercial activity.

Earthworms can be divided as surface living (epigeic) and burrowing (epianecic) worms. Epigeic or compost worms are found on surface and are reddish brown. Of many species of earthworms tested for mass culture all over the world, *Eisenia foetida*, *Eudrilus eugenia* come in the order of preference for their ability to compost organic wastes. Local species such as *Lampito mauritie*, *Octochartona* and *Perionyx excavatus* were used in vermi composting. Frequent harvesting of worms brings down density pressure and enables continuous growth of worm population. Mass rearing and maintaining worm cultures and vermi composting has a good scope for developing it as a cottage industry.

Vermi composting process

After separating and sorting the non compostable materials like plastics, stones, glass, ceramics, metals etc. the compostable material should be separated and exposed to the sun for a day or two. Agricultural wastes should be heaped and then beaten with sticks to break into smaller pieces. Composting bed under the shade is very important where water is not stagnated during rains. The flow diagram of vermin composty pit is given below.

With 2000 adult earthworms about 200 kg of vermicompost can be obtained every month. The moisture content of pit should be maintained between 30-40% optimum temperature is 20-30°C. pH of substrate should be between 6.8-7.5.

Table 7. Average nutrient content of vermi composts and other manures

Manure	Nutrient content (% of dry matter)		
	N	P_2O_5	K_2O
Vermicompost	1.60	2.20	0.67
FYM	0.80	0.41	0.74
Rural compost	1.22	1.08	1.47
Urban compost	1.24	1.92	1.07
Sugarcane trash compost	1.6	1.10	0.50
Paddy straw compost	0.90	2.05	0.90

Poonam Gupta and Dwivedi, C.P. (2001)

Benefits of vermi composts

1. It enhance the physical, chemical and biological properties of soil
2. It improves water holding capacity of soil
3. It acts as a buffer in maintaining soil pH
4. It influences the availability of micronutrients by chelating them as complexes
5. It possess high CEC of phosphate solubilising actinomycetes which in turn influences soil fertility
6. It possess vitamins and growth hormones which have a direct role on plant growth
7. It acts as a mine for various plant essential nutrients such as N, P, K, S and trace elements

Recent trends in composting

Bokashi

Many Japanese organic farmers utilise a novel system of decomposition of agricultural wastes called 'Bokashi' which in Japanese means 'Obscuring the direct effectiveness'. Bokashi is prepared by composting briefly the commercially available organic manures like rapeseed or soybean meal. In this the organic manures are inoculated with specific aerobic microorganisms and water is added to give a moisture content of 50-55%. It is then heaped into a pile. When the temperature of pile reaches 50-55°C it is mixed and spread out. After the compost has cooled down, again it is heaped into a pile. This type of restricted microbial decomposition and cooling is repeated 3-4 times. The final product is air dried for further storage or use. The overall aim of this process is to decompose substances which attract pests and also to create a slower activity organic fertilizer.

Compost tea:

Brewed water extract of compost. During the brewing cycle all the soluble organic and inorganic nutrients and a large % of decomposting organisms in the compost are extracted into tea. The organisms grow, increase in number depending on the nutrient in tea since it contains a good amount of active growing aerobic microorganisms, it will result in disease suppression, retention of nutrients, increased availability of nutrients in roots and foliage of plants, detoxification of many residues and improvement in soil structure.

6. Organic recycling of coffee pulp (Korkanthimath and Hosmani, 1998)

The out turn of every 100 kg of ripened arabica fruits was 16.0 kg dry pulp or fruit skin. Substantial quantity of nutrients were obtained from arabica coffee pulp compost, which can be advantageously recycled in coffee based cropping system to enrich the soil fertility and to substitute part of chemical fertilizers. Coffee pulp can be very well organically recycled to enrich the soil fertility by safe disposal of effluents without causing environmental hazards. The manurial value of coffee pulp is valued higher than cattle manure and for this reason, its primary usage as an organic manure and soil conditioner is attractive.

Compost was made out of coffee pulp by placing the pulp with trash material of cardamom alternatively length wise. Compost was kept moist by frequent watering, turned over the heap once or twice to blend it in order to obtain a homogenous product. The compost material can be used 3-4 months after fermentation.

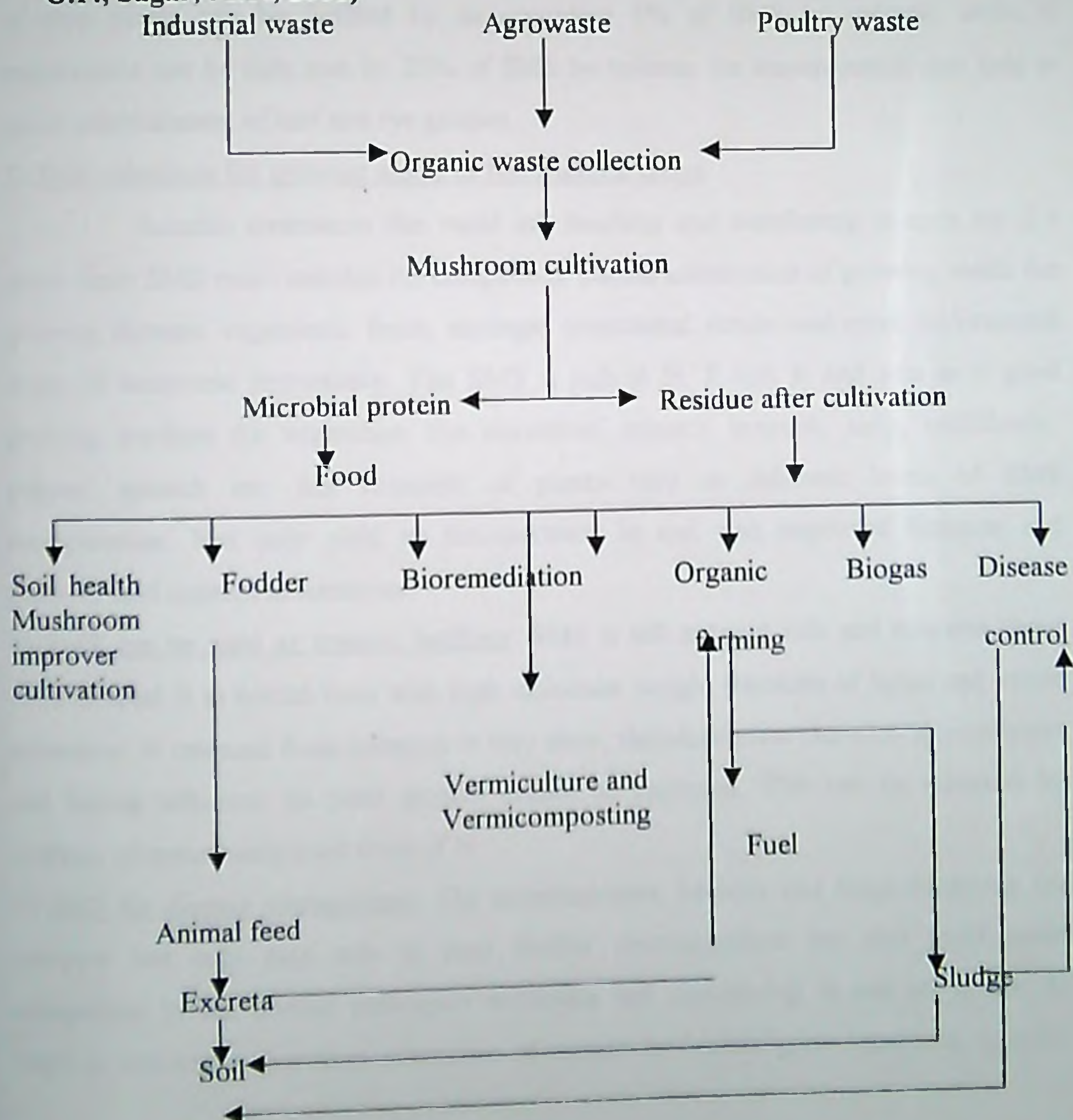
Table 8. Manurial value of coffee pulp compost Vs cowdung

Manures	Nutrient content (% of dry matter)		
	N	P_2O_5	K_2O
Coffee pulp	2.38	0.55	4.2
Cow dung	0.3-0.4	0.1-0.2	0.1-0.3

Korikanthimanth,V.S., Idosmani, M.M. (1998)

Thus the coffee pulp which is rich in plant nutrients has a great scope in efficient utilization of large quantity of farm waste of coffee pulp to recycle the same.

7. Recycling of Spent Mushroom Substrate (SMS) for beneficial purpose (Ahalwat, O.P., Sagar, M.P., 2001)



1) Bioremediation of contaminated soil and water

SMS has ability to chemically absorb the organic and inorganic pollutants and in addition it also contains diverse category of microbes having capabilities of biological break down of organic Xenobiotic compounds present in soil and water like Pentachlorophenol (PCP). The microbes especially Actinomycetes present in SMS also have strong PCP catabolizing capabilities which result in decreased level of PCP in contaminated soil after incubation with SMS.

2) Reclamation of soil: Addition of SMS in nutrient poor soil leads to an improvement in soil health by improving soil texture, water holding capacity and nutrient status. Its amendment in soil leads to increase in organic carbon content. The P and K requirement of crop plants can be fulfilled by incorporating 5% of SMS by volume, while N requirement can be fully met by 25% of SMS by volume. Its incorporation also help in quick establishment of turf and rye grasses.

3) SMS substitute for growing media of horticultural crops

Suitable treatments like rapid salt leaching and weathering in open for 2-3 years make SMS more suitable for complete or partial substitution of growing media for growing flowers, vegetables, fruits, saplings, ornamental shrubs and other horticultural crops of economic importance. The SMS is rich in N, P and K and acts as a good growing medium for vegetables like cucumber, tomato, braccoli, tulip, cauliflower, pepper, spinach etc. but response of plants vary at different levels of SMS incorporation. Not only yield its incorporation in soil also improved firmness and ascorbic acid content in tomatoes.

4) SMS can be used as organic fertilizer: SMS is still nutrient rich and contains about 80% of total N in bound form with high molecular weight fractions of lignin and humic substance. N released from compost is very slow; therefore plant nutrition is insufficient and lasting influence on plant growth cannot be expected. This can be achieved by addition of some easily avail form of N.

5) SMS for disease management: The actinomycetes, bacteria and fungi inhabiting the compost not only play role in their further decomposition but also exert some antagonism to the normal pathogens surveying and multiplying in soil ecosystem. It helps in restricting root knot infestation of tomato by *Meloidogyne incognita*, conidial

germination of *Venturia inequalis* causal agent of apple scab, *Cochliobolus carbarum* causing disease on maize and *Spharcopsis supine* cause in red pine disease.

6) SMS as animal feed: Cellulose made available during oyster mushroom cultivation can act as energy source for animals as they have enough quantity of enzymes or microbes in rumen which can degrade it effectively.

7) SMS can also be used for biogas production

8. Sericulture waste management system: (Nair,S.K. *et al.*, 1999)

Being a highly remunerative labour intensive agro industry, sericulture is fast expanding in rural India. Sericulture is practised in around 59,200 villages providing employment to 63 lakh people. Cocoons always been primary transactable produce in Indian sericulture. Now efforts are under way to develop some systems and methods where by enormous amount of sericulture waste produced can either be utilized for the production of some useful and immensely valuable materials or be recycled.

Table 9. Details of valuable products synthesized from sericulture wastes and its uses

Source	Products	Used in
Silk worm litter	Compost	Recycling of organic matter
	Biogas	Domestic purpose
Silk worm excreta	Chlorophyll	Pharmaceutical field, food products and cosmetics
	Pectin	Pharmaceutical field, food products and cosmetics
	Carotene	Synthesis of vitamin A and medicines
	Phytol	Synthesis of vitamin E and K
	Triacontanol	Plant growth regulator
Silk worm pupa	Lysine	Pharmaceutical field
	Proteace	Food, beverage and leather industries
Pupa cuticle	Chitin	Pharmaceutical field, food and paper adhesive industry, chelating

		agent in waste management
Silk moth	Chitin	Pharmaceutical field, food and paper adhesive industry, chelating agent in waste management
Egg shell	Chitin	Pharmaceutical field, food and paper adhesive industry, chelating agent in waste management

Advantages of recycling of agricultural wastes

1. It serves as slow release source of N, P, S for plant nutrition and microbial growth
2. It possess considerable waterholding capacity and thereby helps to maintain water regime of the soil
3. It can be used as a buffer against changes in pH of soil
4. Its dark colour contributes to absorption of energy from the sun and heating of soil
5. It acts as a cement for clay and silt particles together thus contributing to the crumb structure of soils
6. It finds micronutrients in soil that otherwise may leached out

Role of recycled waste in sustainable agriculture

a) **Physical effects**: It is the humus fraction which improves the soil physical condition. The addition of compost improves soil structure, texture and tilth (Biswas *et al.*, 1971, Gaur *et al.*, 1972 and Hesse and Misra, 1982). Sandy soils become more compact and clayey soil become more open. The better soil structure provides better environment for root development and aeration. The water holding capacity of soil increases.

b) **Chemical effects**: Compost adds nutrients to the soil thus reducing total dependence on fertilizers which involves greater energy expense (Katyal *et al.*, 1979).

The major plant nutrients namely nitrogen, phosphorous, potassium, calcium and magnesium in organic combinations are made available to plants due to decomposition process. The important micronutrients viz. iron, sulphur, manganese, boron, molybdenum etc. can be contributed through compost in small amounts. The humic substances increase P availability as it has a very high CEC (Gaur, 1990).

c) **Biological effects**: Composts contain bacteria, actinomycets and fungi. Hence the fresh supply of humic material not only add millions of microorganisms but also stimulate them (Balasubramanian *et al.*, 1972, Gaur *et al.*, 1975). The incorporation of organics helps the microorganics to produce polysaccharides which build up better soil structure. N-fixation and P-solubilization are also increased due to improved micro-biological activity in organic matter amended soil.

CONCLUSION

Thus the complementary use of available renewable resources of plant nutrients along with fertilizers can be used to overcome the deterioration of soil health and thus accelerating sustainable crop production. This also emphasizes management practices involving substantial use of these manures which is environmentally sound and economically viable and is an important key for sustainable production. Infact the current aim of sustainable agriculture is to develop farming systems that are productive and profitable, consume the natural resource base, protect the environment and enhance health and safety in long term perspective. The entire nutrient requirement for crop production can be obtained from proper bioconversion of wastes. Since India is a country with a lot of natural resources and many of resources are not fully utilized, there is a great potential and scope for ecofriendly management for sustainable agricultural production.

DISCUSSION

1) How mulching reduces soil salinity?

By mulching infiltration rate increases and it decreases evaporation thus preventing accumulation of salts in surface layers.

2) What is the harm in applying the ayurvedic wastes as such in soil?

When the ayurvedic wastes are applied as such it will undergo decomposition process in soil. At first the temperature of this process will be in mesophilic range i.e. (40-50°C) and then it will rise to thermophilic range (60-65°C) which will hill the soil beneficial microbes and thus decomposition rate will slow down. The development of this higher temperature is detrimental to plant roots also. More over these ayurvedic wastes also contains numerous alkaloids, phenols and resins which is harmful to beneficial microbes in soil if applied in large amounts.

3) What are the other components of sustainable agriculture?

a) Biological diversity, b) Genetic diversity, c) Crop rotation, d) Multiple cropping, e) Integrated nutrient management, f) Integrated pest management, g) Judicious use of irrigation resources, h) Mixed farming, i) Post harvest technology etc.

4) Characteristics/Quality parameters of a good compost?

a) CN ratio - 25 to 40%

b) Moisture content - should be 50-60%

c) Aeration - 0.6-1.8 m^3 air/day/kg volatile solids during thermophilic stage

d) Temperature - 50°-60°C held for 3 days

e) Particle size - 10 mm for agitated systems and forced aeration 50 mm for long heaps and natural aeration

5) What is bioremediation?

Bioremediation is the process of curing the soil using biological agents. SMS contains diverse category of microbes having capability of biological break down of organic xenobiotic compounds present in soil and water like pentachloro phenol (PCP).

6) Is compost tea is a pesticide?

Compost tea is not a pesticide. Pesticide will kill pests but compost tea is probiotic i.e. it prevents disease organisms from finding space, food or infection site.

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ROLE OF BIOFERTILIZERS IN FLORICULTURE

By

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SEMINAR REPORT

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ABSTRACT

Today floriculture has emerged as a lucrative business since it provide more returns per unit area than other horticultural crops both for domestic market and export. In view of this competitive advantages any technological innovation towards reduction in cost and improvement in quality is a welcome measure to provide an identity for Indian flowers in the global scene. Thus the need of the hour is a comprehensive nutrient management along with biofertilizers to get the maximum output in a cost effective manner.

The various research works conducted have revealed the effect of biofertilizers on flowers. Manonmani (1992) have observed significant increase in leaf area and yield in *Jasminum sambac* inoculated with 20 g of *Azospirillium* and *phosphobacteria*. *Azospirillum* application significantly increased the overall growth and yield in Edward rose. Graded dose of NPK along with *Azospirillum*, *phosphobacteria* and AM has increased the flower diameter and flower yield in Marigold. There was a significant improvement in the growth and yield of Chrysanthemum cultivars inoculated with AMF-*Glomus fasciculatum*. Thus the role of biofertilizers can be well exploited to obtain maximum output with an appropriate benefit cost ratio.

INTRODUCTION

Horticulture is rapidly claiming its place in the world of business and floriculture trade is all set to conquer an important niche, with exports worth Rs.69 crores in 1995-96 to a projected target of Rs.400 crores in 2005-2006. Although there is good scope for floriculture export, India do not have even a peripheral presence in the international market. In India with an estimated high investment of Rs.2 to 2.5 crores per hectare under protected cultivation the returns from international markets are at present low and growers look only towards the domestic market for support. In this context any technological innovation towards reduction in costs minimising the incidence of dreaded pests and diseases, along with improvement in quality would be a welcome measure to provide an identity for Indian flowers in the global scene.

INDIAN SCENARIO OF FLOWERS

Karnataka is the leading state in area of cultivation of flowers with 19,161 ha followed by Tamil Nadu 14,194 ha and West Bengal 12,285 ha. In India mainly two categories of flowers are cultivated namely traditional flowers and modern flowers.

Traditional flowers	**Modern flowers**
Aster	Anthurium
Chrysanthemum	Carnation
Crossandra	Gerbera
Jasmine	Gladiolus
Marigold	Orchid
Tuberose	Rose

Traditional flowers account for an area of 24,000 ha with a return of 105 crores and modern flowers occupy an area of 10,000 ha with 100 crores of return.

Thus eventhough a high return of 205 crores is obtained from floriculture industry the position of India in the export angle is very meagre <0.6%. So it was estimated that the best alternative method with a high benefit cost ratio is the path of comprehensive nutrient management. This brings out the total potential for exhibition of quality of flowers in terms of improved stalk length, colour, bloom size, keeping quality and resistance against pathogens etc.

CHANGING STYLE: CHEMICAL FERTILIZERS → BIOLOGICAL FERTILIZERS

The need of the hour is a balanced nutrient management and pace by pace chemical fertilizers are slowly replaced by biological fertilizers. The main reasons for this are

1) ENVIRONMENTAL POLLUTION

The indescriminate use of chemical fertilizers has resulted in serious damage to the ecosystem, particularly soil health rendering it often times saline and less suitable for cultivation.

2) HIGH COST

The heavy cost of production or procurement of nitrogenous and phosphatic fertilizers is another factor to be reckoned with for a developing country like ours. Moreover in India most of the farmers comes under small and marginal category and the use of heavy dose of chemical fertilizers are not affordable.

3) LEACHING LOSS

Chemical fertilizers applied to crop undergoes 50% loss due to natural process of leaching and denitrification. It is estimated that 5-6 million tons of P, applied to soil is carried away to sea each year.

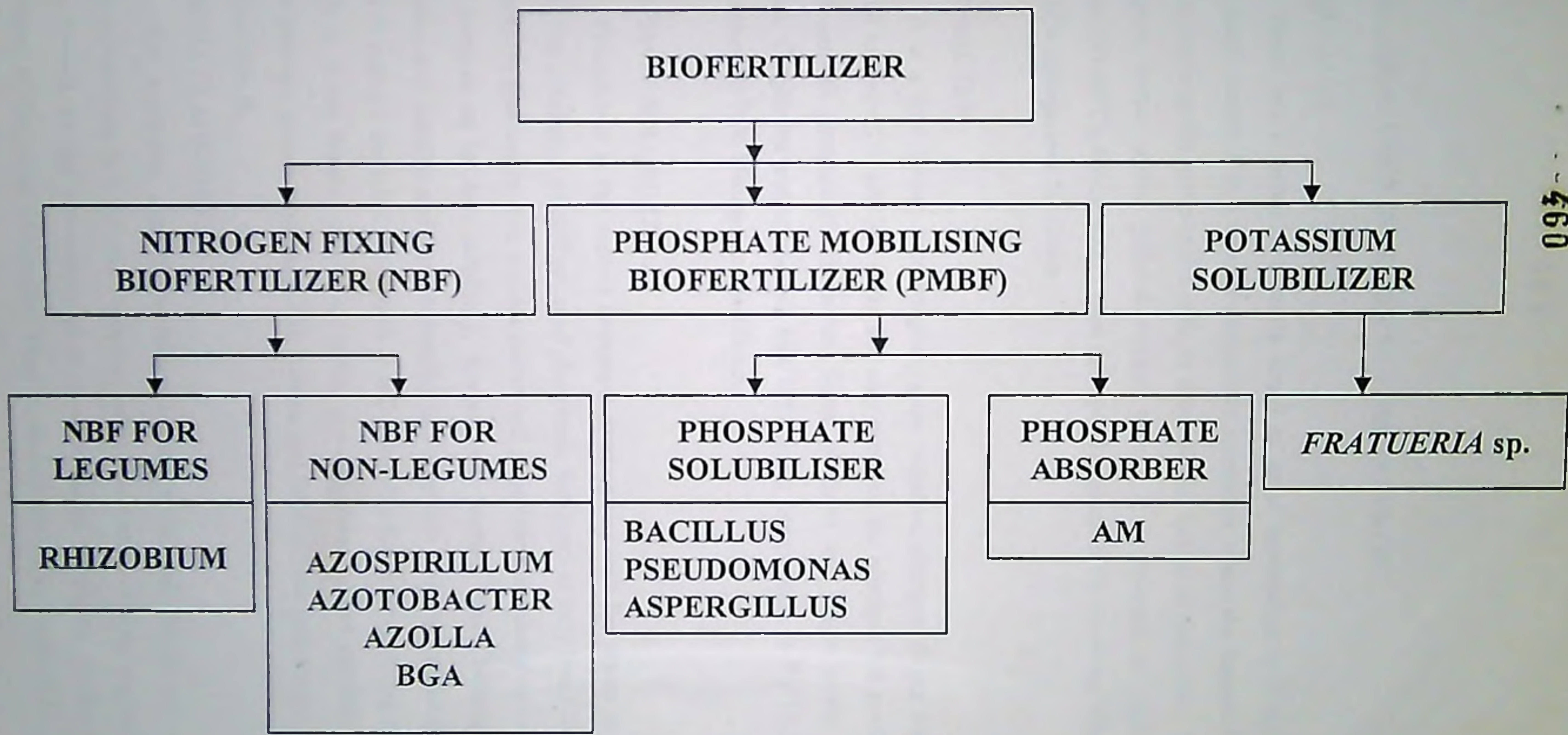
Thus the use of biofertilizers, which are microbial in origin, offer themselves as viable alternative to these problems.

BIOFERTILIZERS

Biofertilizers are biologically active products containing active strains of specific bacteria, algae, fungi alone or in combination which may help in increasing crop productivity by way of helping in the biological nitrogen fixation, solubilization of insoluble fertilizer materials, stimulating plant growth or in decomposition of plant residues (Verma and Bhattacharya, 1972).

First report on biofertilizers in India was given by Joshi (1920). He identified and isolated strains of Rhizobium from different leguminous crops.

CLASSIFICATION OF BIOFERTILIZERS



BIOFERTILIZERS USED IN FLORICULTURE INDUSTRY

I. AZOSPIRILLUM

These are a group of bacteria found in loose association with the root system of many plants. It is a type of associative symbiosis where the bacterial cells are found colonizing the root cortical cells or inter cellular spaces in the cortex. These bacteria grow better under reduced oxygen levels. It is tolerant to high soil temperature (30-40°C), hence widely used in tropical regions. It fix 10-40 kg N/ha and saves 25-30% nitrogenous fertilizers.

II. AZOTOBACTER

It is a free living, heterotrophic, gram negative nitrogen fixing bacteria encountered in neutral to alkaline soils, not only provides the nitrogen but produce a variety of growth promoting substances. Some of them are Indole acetic acid, Gibberelins, Cytokinins and antibiotics like Tetracyclin compounds. It fix 15-20 kg N/ha and saves 10-20% Nitrogenous fertilizers.

III. PHOSPHATE SOLUBILIZERS

Phosphorus is the second important nutrient required for plants in large quantities. The efficiency of utilization of phosphatic fertilizers is very low (20-25%) due to chemical fixation in soil, besides native soil phosphorus is mostly unavailable to crops because of its low solubility. Several soil bacteria those belonging to *pseudomonas* and *bacillus* and fungi belonging to *Pencillium* and *Aspergillus* possess the ability to convert insoluble phosphates in soil to soluble forms by secreting organic acids such as acetic formic, propionic, lactic, glycolic, fumaric and succinic acids. They also produce growth regulators like Auxins and Gibberellins and certain amino acids and vitamin B.

IV. PHOSPHATE ABSORBERS

The symbiotic association between plant roots and fungal mycelia is termed as mycorrhiza. It is the most common fungal association among angiosperms. They are formed by the non-septate phycomycetes fungi belonging to the family Endogonaceae of the order Mucorales. They produce vesicles and arbuscules inside the root system. Arbuscules are the site of phosphorus translocation. It also help in mobilization of micro nutrients like Zn, Cu, S, improves soil structure by polysaccharide secretions and controls soil pathogens.

AM sp. effective for flowers

Glomus mosseae

G. etunicatum

G. intraradius

G. fasciculatum

Acaulospora laevis

A. scrobiculata

Gegospora margarita

Sclerocystis dassci

APPLICATION OF BIOFERTILIZERS

Biofertilizers are applied in various manner

1) SEED TREATMENT

A thick slurry of biofertilizer is made using water and any adhesive material, seeds are mixed in this slurry, shade dried and used for sowing.

2) SEEDLING TREATMENT

A dilute slurry of biofertilizers are made using water and the seedlings are dipped in it for an hour before transplantation to main field.

3) DIRECT APPLICATION

Biofertilizers are applied directly in the field either immediately after planting the crop or after establishment of the crop.

4) PRE-CULTIVATION OF A DEPENDENT CROP

In the case of AM fungi, the pre-cultivation of a highly mycorrhizal dependent crop in the previous year improves soil conditions by highly mycorrhizal innoculated soil. The crops cultivated are Cassava, Cowpea, Sorghum, Stylosanthus etc.

BENEFITS OF BIOFERTILIZERS

Nutrient mobilization

It helps in mobilization of nutrients like phosphorus by secreting certain organic acids. These organic acids lower the pH and bring about dissolution of the nutrient and can be utilized by crops.

Ecofriendly

It does not produce any toxic substances to the environment and helps in improving soil health.

Productive soils

These microorganisms secrete certain polysaccharide like substances which improves soil structure by increasing aeration, water periolation etc. by forming soil aggregates.

Sustainable nature

It does not require any non-renewable form of energy during their production.

Produce growth promoters

Produce various growth promoting substances like Auxins, Gibberlins, Cytokinins, certain aminoacids, Vitamin B etc.

Less expensive

Since the number of applications and quantity required is less when compared to chemical fertilizers, the overall BC ratio is beneficial in the case of biofertilizers.

STUDIES REGARDING THE EFFECT OF BIOFERTILIZERS ON FLOWER CROPS

CARNATION - *Dianthus caryophyllus*

The field application of *Glomus intraradius* has shown an increase in flower yield along with decrease in disease severity caused by *Fusarium oxysporum* in carnation (St. Arnaud *et al.*, 1997).

Gayathri (1997) reported that 30:20:10 NPK + Azospirillum + Phosphosphobacteria has given the highest plant height, 22.5:15:10 NPK + VAM showed an improvement in first flowering, 22.5:15:10 NPK + Phosphobacteria has shown an increase in flower diameter and 30:20:10 NPK + Azospirillum + Phosphobacteria + VAM has shown an increase in yield.

CHINA ASTER - *Callistephus chinensis*

Field trial conducted with AM fungi *Gigaspora margarita* with phosphorus has shown an increase in plant height, number of branches and flower yield with a cost benefit ratio of 1:6.3 (Naik *et al.*, 1998).

Soroa *et al.* (1998) observed an increase in plant growth in *Callistephus chinesis* inoculated with *Scutellospora pellucida* by seed pelleting.

CROSSANDRA (*Crossandra undulaefolia*)

Nagesh *et al.* (1997) reported that use of oil cake 15 g/plant along with *Glomus mossae* (1000 clamydospores/plant) in pot experiments promoted better plant growth and reduce nematode multiplication rate.

A study on crossandra cv. Dindigul Local at Annamalai University found that application of 100% NPK + Azospirillum + Phosphobacteria each incorporated at 2 kg/ha gave the highest flower yields (41.72 g/plant) with maximum returns per rupee invested (1:3.50) (Raju and Haripriya, 2001).

Field experiment conducted at Agricultural College and Research Institute, Madurai in crossandra variety Delhi revealed that 120 kg N/ha + 70 kg K_2/ha + Azospirillum 2 kg/ha + FYM 30 t/ha proved to give an increased in plant height, number of branches, leaves, leaf area, number of spikes, number of flowers/spike and flower yield (Swaminathan and Sambandamurthi, 2000).

Bhavanisanker and Vananganudi (1999) revealed that 75% N + Azospirillum and 75% P + Phosphobacteria has given the highest flower yield (0.738 kg/plant) at 10 months after planting.

CRYSANTHEMUM (Crysanthemum sp.)

Three cultivars of chrysanthemum namely Bangalore white, Local yellow and Shymal were inoculated with 3 types of AM fungi, *Acaulospora laevis*, *Glomus mosseae* and *Glomus fasiculatum* shown that plants inoculated with *Glomus* *fasciculatum* has given an increase in plant height, number of flowers/plant and flower yield in all the three varieties (Gnanadevi and Haripriya, 1999).

GERBERA - *Gerbera jamesonii*

Wang *et al.* (1993) observed an increase in shoot number and root dry weight in plants inoculated with *Glomus intraradices* and *Glomus vesiculiferum*.

Micropropaguled plantlets of gerbera cultivar Tennussee and Regina were inoculated with *Glomus etunicatum* which showed an increase in K, Zn and Cu uptake. Application of *Glomus mossea* along with *Glomus etunicatum* induced an increase in lateral shoots, cut flower yield and advance flowering (Chang and Wen, 1994).

Application of *Glomus mosseae* and *Asaulospora scrobiculata* inoculated plants showed an increase in plant height, P, K, Cu and Zn content in leaves, N, Ca, Cu and Zn content in roots (Pedraza *et al.*, 2001).

GLADIOLUS (*Gladiolus* sp.)

An experiment was conducted in gladiolus was Melodie in IARI, New Delhi on the effect of biofertilizer along with NAFED super culture. Gladiolus corms were dipped in 3 l of water containing 0, 50, 150 and 300 g Nafed Super (culture (NSC) containing *Azotobacter* sp., micronutrients and vitamins. All biofertilizer treatments significantly increased the number of florets per spike of gladiolus plants and NSC at 300 g/3 litre of water significantly increased the number of cormels per plant, compared to control (Misra, 1997).

JASMINE (*Jasminum* sp.)

Experiment conducted by Bhavanisanker and Vanangamudi (1999) revealed that 75% N + Azospirillum and 75% P + Phosphobacteria registered the highest flower yield in *Jasminum sumbac*.

Manonmani (1992) observed an increase in plant height, leaf area and yield in *Jasminum sumbac* treated with Azospirillum and Phosphobacteria along with N and P.

An increase in leaf area, stalk length and flower diameter was observed in *Jasminum grandiflorum* by Vasanthi Gnanasekar (1994).

LILY (*Lilium* sp.)

Wu *et al*. (1999) conducted an experiment with oriental lily inoculated with AM fungi and it was observed that it was helpful in increasing bulblet size of plants.

In Asian hybrid lily dual inoculation of AM fungi and phosphate solubilizing bacteria showed the best promotion of growth (Lin *et al*., 1999).

MARIGOLD - *Tagetes erecta*

In an experiment conducted in *Tagetes erecta* with biofertilizers along with chemical fertilizers shown an increase effect on plant height, 100 flower weight and yield at 45:90:120 NPK + 20 gm Azospirillum and 20 gm Phosphobacteria (Velmurugan, 1998).

Pot culture experiments were conducted at Department of Horticulture, Annamalai University in African Marigold treated with NPK and biofertilizers. Application of NPK at 45:45:37.5 mg/kg along with combined inoculation of Azospirillum and VAM exhibited increases growth with respect to plant height (144.50 cm), number of leaves (156.20), laterals per plant (28.30) and early flowering (Rajadurai *et al*., 2000).

Gupta *et al*. (1999) reported that treatments with 100% nitrogen along with azetobacter and phosphobacteria has given increased growth and highest flower yield.

Experiment conducted at Akola, Maharashtra by Chandrikapure *et al*. (1999) reported that application of NPK along with Azospirillum, phosphoacteria has given highest plant height, flower weight and flower diameter.

NARCISSUS - *Narcissus sp.*

Results of pot experiments investigating the effect of inoculation with strains of *Azospirillum brasiliense* and *Azospirillum lipoferum* at different N levels showed that it increased flower yield and bulb productivity particularly in sandy loam and sandy clay loam soil (El Naggar and Mahmoud, 1994).

PETUNIA - *Petunia* sp.

Wang and Ling (1997) reported that inoculation of AMF along with phosphate solubilizing bacteria has increases fresh weight, number of branches and number of flowers in petunia along with an advanced flowering of 20-30 days.

Application of AM culture - Glomus, Gigaspora and Scutellospora sp. has marked improvement in height of plants, number of flowers and an early flowering of 15 days in Petunia hybrida (Gaur *et al*., 2000).

ROSE - *Rosa barboniana*

A field experiment conducted to determine the individual and combined effect of 37.5 kg N/ha + Azosperillum 2 kg/ha + 1000 ppm of ascorbic acid spray applied in 6^{th} month after planting gave highest number of total and flowering shoots, lowers number of blind shoots, highest value for pedicel length, flower weight, flower diameter, concrete recovery and nutrition content of plant (Prethi *et al*., 1998). Scagel (2001) reported that application of VAM inoculum into the rooting medium has increased the number of rooted cuttings and number of roots/cutting for three miniature rose cultivars (*Rosa* sp.).

Studies regarding the effect of VAM on *Rosa* sp. is undergoing in Kerala Agricultural University, Vellayani (Shivaprasad, 2002).

SNAP DRAGON - *Antirrhinum majus*

Experiment conducted by Soroa *et al*. (1998) observed that *Antirrhinum majus* treated with *Glomus mosae* (seed pelleting) showed and increase in growth.

The effect of phosphorus and mycorrhizal colonization on ethylene production by snapdragons were studied and it was observed that phosphorus + AM fungi decreased the ethylene production there by increasing vase life (Besmer, 1999).

TUBEROSE - *Polanthus tuberosa*

A Mexican single cultivar of Polianthus tuberosa treated with 120:65:62.5 kg NPK/ha along with Azospirillum and Phosphobacteria showed an increase in number of flowers/spike, flower weight and number of tubers and highest spike length and yield of 3.08 t/ha (Swaminathan *et al*., 1999).

Applicationof Azotobacter + Azospirillum mixture significantly increased the number of flowers/stalk, flowering shoots and bulb yield (Wange and Patil, 1994).

Field trials conducted with 50 kg N along with Azospirillum increased bulb yield whereas application of 150 kg N along with azospirillum increased cut flower yield 26,288 dozen/ha in tuberose var. Single petaled (Wange *et al*., 1995).

ZINNIA - *Zinnia elegans*

Experiments conducted by Duke *et al.* (1994) observed that inoculation with *Glomus intraradix* for increased the number of flower buds in Zinnia.

Plants inoculated with *Glomus etunicatum* showed a faster flowering rate when compared to control in *Zinnia elegans* (Abourl Nasr, 1996).

Different effects of biofertilizers in combination with inorganic fertilizers are presented in a tabular form

Crop	Biofertilizer	Effects	Institute
Carnation	AM - *Glomus intraradius*	↑ Flower yield ↓Disease severity (*Fusarium oxysporum*)	University de Montreal, Canada
	30:20:10 NPK+ *Azospirillum*+ Phosphobacteria	↑ Plant height ↑ Yield	Department of Horticulture, TNAU, Coimbatore
China Aster	P+ *Glomus margarita*	↑ Plant height ↑ No. of branches ↑ Flower yield	Dept. of Horticulture, Univ. of Agriculture Sciences, Dharwad
	AM - *Scutellospora pellucida*	↑ Plant growth	Dept. of Biofertilizers and Nutrition, La Habana, Cuba
Crossandra	AM - *Glomus mosseae* + oil cake (15g/plant)	↑ Plant growth ↓ Nematode multiplication	IIHR, Bangalore
	100% NPK + *Azospirillum* + Phosphobacteria (2 kg/ha)	Highest flower yield	Dept. of Horticulture, Annamalai University, Tamil Nadu
	120 kg/ha N + 70 kg/ha K_2O + *Azospirillum* 2 kg + FYM	↑ Plant height ↑ No. of branches ↑ Leaves, Leaf area ↑ No. of spikes ↑ No. of flower/spike ↑ Flower yield	Dept. of Horticulture, AC & RI, Madurai, Tamil Nadu
	N + *Azospirillum* + P + Phosphobacteria	Highest flower yield	FC & RI, Mettupalayam, Tamil Nadu
Chrysanthemum	AM - *Glomus fasciculatum*	↑ Flower height ↑ Flowers/plant ↑ Flower yield	Dept. of Horticulture, Annamalai University, Tamil Nadu
Gerbera	AM - *Glomus intraradius* + *G. vesiculiferum*	↑ Shoot number ↑ Root dry weight	Dept. of Phytology, Universite Laval, Canada
	AM - *Glomus etunicatum* *Glomus mosseae* *G. etunicatum*	↑ K, Zn & Cu uptake ↑ No. of lateral shoots ↑ Cut flower yield Advance flowering	Division of Botany, Taiwan Endemic sp. Research Institute, Taiwan

Crop	Biofertilizer	Effects	Institute
Gerbera	AM - *Glomus mosseae* *Acaulospora scrobiculata*	↑ Plant height ↑ P, K, Cu & Zn content in leaves ↑ Ca, Cu & Zn content in roots ↑ P content in leaves ↑ N content in roots	IREGEP, Mexico
Gladiolus	Nafed super culture (300 g/3 litre) + *Azotobacter* sp.	↑ No. of florets/spike ↑ No. of cormels/plant	Division of Floriculture & Landscaping, IARI, New Delhi
Jasminum sambac	N + *Azospirillum* + P + Phosphobacteria	Highest flower yield	FC & RI, Mettupalayam, Tamil Nadu
	N + P + *Azospirillum* + Phosphobacteria	↑ Leaf area ↑ Yield	Dept. of Horticulture, TNAU, Coimbatore, Tamil Nadu
Jasminum grandiflorum	N + P + *Azospirillum* + Phosphobacteria	↑ Leaf area ↑ Stalk length ↑ Flower diameter	Dept. of Horticulture, TNAU, Coimbatore, Tamil Nadu
Lily (Oriental lily)	AM	↑ Bulblet size	Dept. of Agri. Chemistry, TARI, Taiwan
Asian hybrid lily	AM + Phosphobacteria	↑ Growth	Dept. of Agri. Chemistry, TARI, Taiwan
Marigold	NPK 45:45:37.5 + *Azospirillum* + AM	↑ Growth ↑ Leaf No. ↑ Laterals/plant Early flowering	Dept. of Horticulture, Annamalai University, Tamil Nadu
	N 100% + *Azetobactor* + Phosphobacteria	↑ Growth ↑ Flower yield	Dept. of Horticulture, Akola, Maharashtra
	NPK + *Azospirillum* + Phosphobacteria	↑ Plant height ↑ Flower weight ↑ Flower diameter	Dept. of Horticulture, TNAU, Coimbatore, Tamil Nadu
Narcissus	*Azospirillum brasilense* + *Azospirillum lipoferum* + N	↑ Flower yield ↑ Bulb productivity	Dept. of Horticulture, Assiut University, Egypt
Petunia	AM + Phosphobacteria	↑ Fresh weight ↑ No. of branches, leaves ↑ No. of flowers Advanced flowering (20-30 days)	National Pingtung University of Science and Technology, Taiwan

Crop	Biofertilizer	Effects	Institute
Petunia	AM - *Glomus* + *Gigaspora* + *Scutellospora*	↑ Plant height ↑ No. of flowers Advanced flowering (15 days)	University of Pretoria, South Africa
Rose	37.5 kg N/ha + *Azospirillum* + Ascorbic acid spray	↑ Flowering shoots ↓ Blind shoots ↑ Pedicel length ↑ Flower weight ↑ Concrete recovery	HC & RI, TNAU, Tamil Nau
	AM	↑ No. of rooted cuttings ↑ No. of roots/cutting	USDA ARS Horticultural Crops Research Laboratory, Corvallis, USA
Snap dragon	AM - *Glomus mosseae*	↑ Growth	Institute of National Agriculture, Cuba
	P + AM	↓ Ethylene production ↑ Vase life	Pennsylvania State University, USA
Tube rose	120:65:62.5 NPK + *Azospirillum* + Phosphobacteria	Highest spike length ↑ No. of flowers/spike ↑ Flower weight ↑ No. of tubers	HRS, Pechiparai, Tamil Nadu
	Azetobactor + *Azospirillum*	↑ No. of flowers/stalk ↑ Flowering shoots ↑ Bulb yield	Regional Fruit Research Station, Ganeshkind, Pune
	50 Kg N + *Azospirillum* 150 kg N + *Azospirillum*	↑ Bulb yield ↑ Cut flower yield	NARP Ganeshkind, Pune
Zinnia	AM - *Glomus intraradius*	↑ Flower buds	ENEA, Italy
	AM - *Glomus etunicatum*	↑ Faster flowering	Faculty of Agriculture, Alexandria University, Egypt

CONSTRAINTS IN USE OF BIOFERTILIZERS

1) Raw material

Peat and lignite are considered as the ideal carrier material for biofertilizers. Non-availability as well as high cost involved for raw material procurement is a real constrain.

2) Specificity of strains

Most of the biological strains of biofertilizers are soil and agroclimatic specific. This limits their wide spread and fool proof use with expected performance.

3) Economics of production

For the production of quality product, use of hi-tech instruments and equipments are desirable. However, the low pricing structure and low offtake of biofertilizers do not permit the use of sophisticated facilities in a factory or unit.

4) Short shelf life

It has a short shelf life of often less than 6 months. The best results are rather possible if the material is used in 3-4 months time, provided the material is not subjected to very high temperature above 40°C during movement and transportation.

5) Limited demand

Demand is limited because of inadequate awareness among the extension workers, dealers and farmers regarding the cost effectiveness and usefulness of biofertilizers.

CONCLUSION

Biofertilizers offer an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal resources. They are never alternatives for inorganic fertilizers, but are useful in increasing quality and yield of crop when used in combination with organic manures and inorganic fertilizers in a balanced proportion.

The success obtained hitherto with the use of biofertilizers in floriculture crop production would definitely give an impetus to their continued use. Therefore development of newer eco-friendly methods of nutrient management in flower crops is need of the hour. What is equally important is the successful integration of these inputs with other technologies resulting in a wholistic approach to nutrient management. In our anxiety to sustain the green revolution, we should not forget to maintain a greener environment for our future generations. Biofertilizers are our tools to achieve the goals of not only higher yields but also a cleaner environment.

VARIATION IN LEAF AREA FOR DIFFERENT BIOFERTILIZER TREATMENT IN JASMINE

T2 - 45:70:120 NPK + 20 g *Azospirillum* + 20 g phosphobacteria

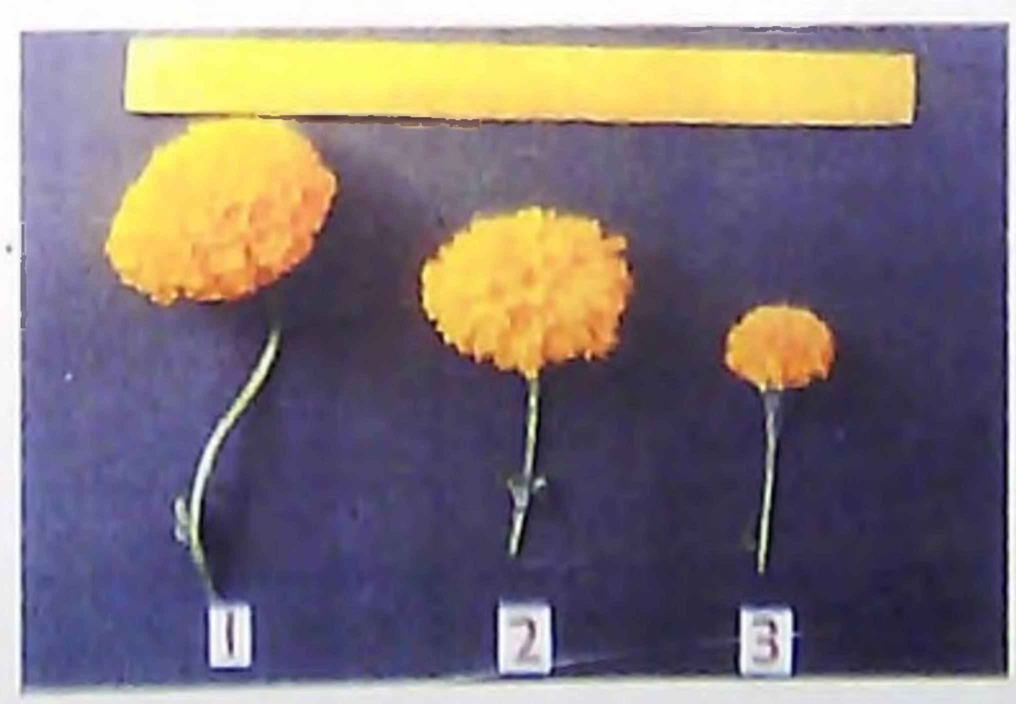
EFFECT OF *AZOSPIRILLUM*, PHOSPHOBACTERIA & VAM ON GROWTH OF MARIGOLD

1- 33:75:67.5:75 NPK/ha
2 - 45:90:75 NPK/ha + *Azospirillum* + Phosphobacteria
3 - 45:90:75 NPK/ha + *Azospirillum* + Phosphobacteria +VAM

EFFECT OF *AZOSPIRILLUM*, PHOSPHOBACTERIA & VAM ON PEDICEL LENGTH OF MARIGOLD

1 - 45:90:75 NPK/ha + *Azospirillum* + Phosphobacteria +VAM

EFFECT OF *AZOSPIRILLUM*, PHOSPHOBACTERIA & VAM ON FLOWER DIAMETER OF MARIGOLD



1 - 45:90:75 NPK/ha + *Azospirillum* +Phosphobacteria +VAM+GA3 @ 200 ppm
2 - 45:90:75 NPK/ha + *Azospirillum* +Phosphobacteria+VAM+GA3+CCC @ 2000 ppm
3 - 33.75:67.5:75 NPK/ha

DISCUSSION

Q.1. Is lime application necessary before the use of biofertilizers?

A. Lime application is very essential in the case of biofertilizers because biofertilizers can sustain only at a pH of 6.5 to 7.5. So in acidic soils lime application is very important or else it may deteriorate the microbial population.

Q.2. Is fertigation possible for biofertilizers?

A. Yes, biofertilizers also can be used for fertigation purpose i.e., applying fertilizers along with irrigation water but for this special liquid broth cultures should be used which is available at Maharashtra. Commercially available biofertilizers in packets should not be used for fertigation purpose.

Q.3. Can biofertilizers be applied along with chemical fertilizers or pesticides?

A. No. Biofertilizers cannot be used along with chemical fertilizers or pesticides. Because the microorganism may get killed if used in combination. But chemical fertilizers or pesticides can be applied either before or after biofertilizer application leaving a gap of 1 or 2 days.

Q.4. Can biofertilizers be applied in combination?

A. Biofertilizer interaction seems to offer an synergistic effect on plant growth and yield hence they can be used in combination.

Q.5. What are the commercial formulations of biofertilizers?

A. Azophos, Rhizoplus, Vamplus, Symbiont, Azoplus etc. marketed by Stanes, Coimbatore.

Q.6. What is the cost for biofertilizers?

A. Azospirillum, Azotobacter and Phosphobacteria costs Rs.30/kg and VAM Rs.50/kg.

Q.7. Why biofertilizers are not used in large scale?

A. Mainly unawareness among farmers due to adequate extension activities, less publicity for the produce and slow effects when compared to inorganic fertilizers.

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EXPLOITATION OF MICROBIAL ANTAGONISTS AND BIOFERTILIZERS IN THE MANAGEMENT OF MAJOR SPICES OF KERALA

A78

By

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ABSTRACT

There is a growing interest in the exploitation of naturally occurring micro-organisms as biofertilizers and biocontrol agents in spices. Black pepper responded well to continued inoculation of biofertilizers (Kandiannan *et al.*, 2000). Dual inoculation with Azospirillum and Azotobacter increased curcumin content in both mother and finger rhizomes in turmeric (Jena and Das, 1994). Efficacy of biocontrol agents like *Trichoderma* spp. in checking foot rot in black pepper (Anandaraj and Sarma, 1995), capsule rot in cardamom (Thomas *et al.*, 1996) and rhizome rot in ginger (Usman *et al.*, 1996) has been established under field conditions. Plant growth promoting rhizobacteria have also been reported to have suppressive effects on root pathogens of black pepper (Jubina and Girija,1998). *Glomus fasciculatum* was the predominant Arbuscular Mycorrhizal fungi associated with black pepper (Sivaprasad *et al.*, 2000). Agro wastes like coconut water and coffee husk offer ideal carrier media for mass multiplication of bioagents (Anandaraj and Sarma, 1997). Future research thrusts include identifying chitin degrading proteins in microbial antagonists and the genes encoding them, which could be used to develop resistant crop varieties.

INTRODUCTION

Indian spices are unique and valued world over for their highly intrinsic attributes. Globally India holds prime position in production, area, consumption and export. Being export-oriented crop, Indian spices should be geared up to meet the increasing stringency of quality standards in the importing countries. Its obvious that unless innovative practices are reinforced in spice production technologies, our prime position in global spice market may face serious set backs. Low productivity and biotic stresses forms major constrains in production of spices.

Effective crop husbandry like implementing biofertilizer programmes & exploiting naturally occurring microorganisms for controlling debilitating pests and diseases in spices have generated considerable interest, since they offer possibilities of growing spices in environmentally safe agricultural systems. They also form major components of organic farming concept, currently popular in spice production technology. Hence the topic selected ''Exploitation of microbial antagonists and biofertilizers in themanagement of major spices of Kerala" proposes to update the status of the use of microbial antagonists and biofertilizers in major spice crops.

Mode of action of major microbial antagonists and Biofertilizers

Microbial antagonists	Biofertilizers
Trichoderma → Mycoparasitism → Antibiosis → Competition → Solubilization & Sequistration → Induced resistance → Tolerance to stress	*Azotobacter* → Nitrogen fixation → Produce B-group Vitamins, IAA, Gibberlline → Synthesize antibiotics & Antifungal products → Cause mineralization of fixed phosphorus
AM fungi → Anatomical alternations → Physiological & biochemical alternations → Biological alternations	*Azospirillum* → Produce hormones → Maintains soil fertility → Enhancement of growth
PGPR → Antibiosis → Competition	AM fungi → Phosphorus uptake → Uptake of Fe, Mn, Zn, Ca → Growth enhancement → Uptake of Nitrogen → Production of auxins, cytokinins etc. →Recovery from water stress

CLASSIFICATION OF MICROBIAL ANTAGONISTS

Microbial antagonists are classified in to two sections. They includes bacterial antagonists and fungal antagonists. The classification is as follows.

Microbial antagonists in spices

Fungal antagonists

1. *Trichoderma*
   - *T. harzianum*
   - *T. viridae*
   - *T. hamatum*
   - *T. virens*
   - *T. longibracheatum*
   - *T. koningi*
   - *T. polysporum*
2. AM fungi
   - *Glomus*
   - *Acaulospora*
   - *Scutellospora*
   - *Sclerocystis*
3. Others
   - *Verticillium dahliae*, *Aspergillus minitans*
   - *Gliocladium* sp., *Cladosporium herbarum*
   - *Fusarium* sp., *Sporidermium sclerotivorum*

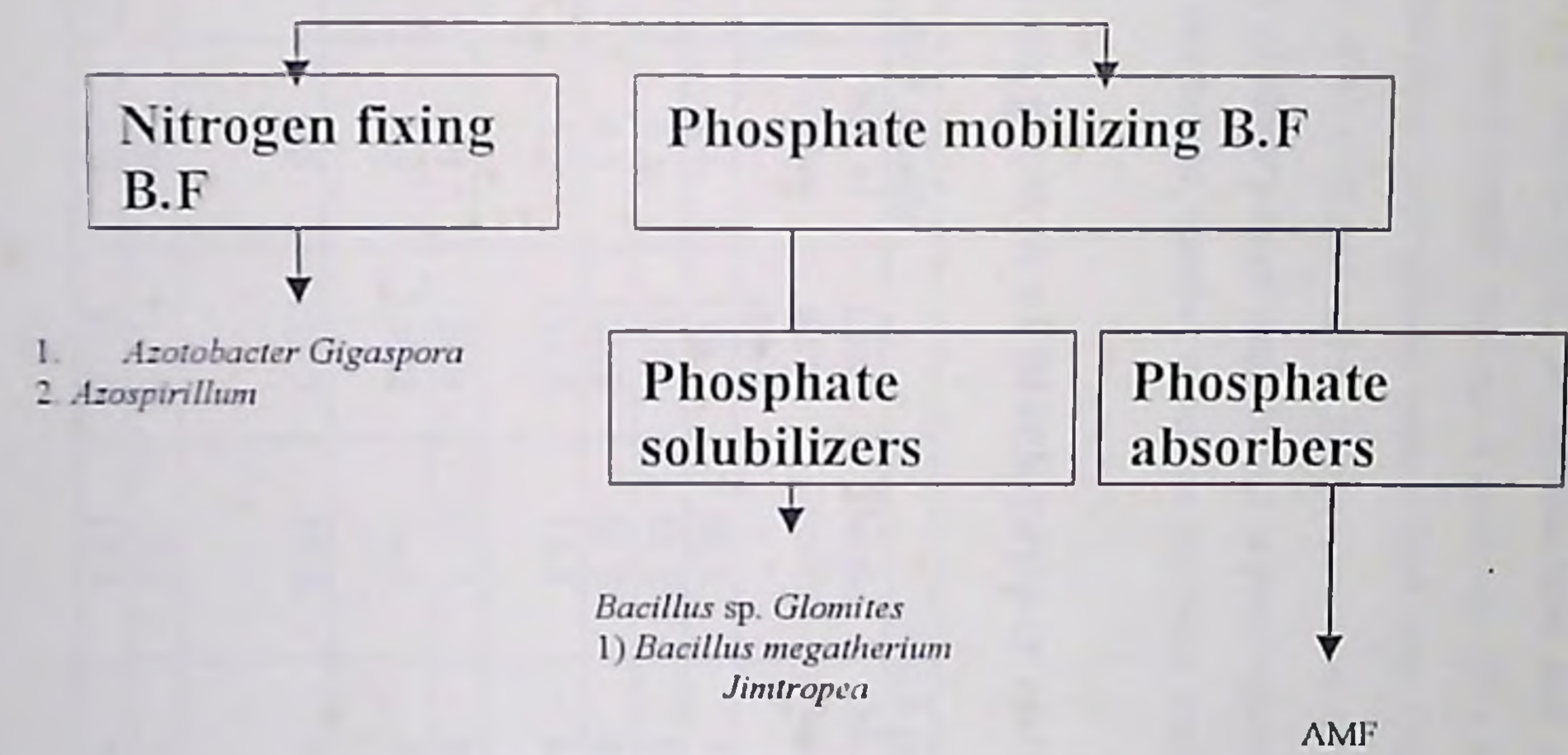
Bacterial antagonists

- *Bacillus scibtilis*
- *Pseudomonas fluorescence*

BIOFERTILIZERS

These are of microbial origin and can be more appropriately called microbial inoculants ., which are products containing living cells of microbes that mobilize nutritionally important elements from non usable form to usable form through biological processes.

Microbial Biofertilizers in spices



Black pepper which is the front runner in terms of value in spices is highly influenced by microbial antagonists and biofertilizers. Impact is discussed under 3 divisions. 1)Nursery management 2)Disease management 3)Improvement of growth parameters.

Effect of inoculation of Azospirillum, phosphobacteria and AMF on growth and nutrient content in rooted pepper cuttings is analysed. This study was carried out at IISR, Calicut. The three biofertilizers were mixed with 5 kg potting mixture and filled in polybags of 45 x 30 cm^2 and 30 gauge thickness. Single node cuttings of Shubhakara a variety of black pepper was planted in polybags and grown in nursery. Growth parameters like height, number of leaves etc. were analysed at 3 and 6 months after planting.

Effect of biofertilizers on growth of black pepper cuttings (Kandiannan et. al)

Treatment	At 3 months			At 6 months		
	Height (cm)	No. of leaves	Leaf area (cm^2)	Height (cm)	No. of leaves	Leaf area (cm^2)
Azospirillum	23	4.1	116.6	50.9	7.7	244.7
Phosphobacterium	23.6	4.1	119.8	51.5	8.2	255.7
AMF	25.5	4.3	120.2	53.2	8.6	279.3
Azospirillum+phosphobacterium	25.7	5.1	134.3	54.7	8.7	280.5
Azospirillum+AMF	28.3	5.1	134.8	61.3	9.1	290.4
Phosphobacterium+ AMF	30.2	5.3	150.2	66.6	93	309.9
Azospirillum+Phosphobacterium+ AMF	32.9	5.3	155.9	77.0	9.4	343.5
Control	18.9	3.9	111.7	45.6	7.7	235.0
CD	7.7	1.0	30.0	17.6	NS	66.3

It was observed that black pepper responded well to combined inoculation of fertilizers. Plant height, leaf area, biomass etc. were higher in inoculated plants as compared to control. Growth was significantly higher when three biofertilizers were inoculated together. Among individual inoculation maximum growth was observed with AMF followed by phosphobacteria and Azospirillum. In dual combinations phosphobacteria + AMF was effective followed by Azospirillum along with AMF and Azospirillum along with phosphobacteria.

The same trend was visible with respect to biomass, dry matter production and nutrient content of treated cuttings.

Effect of biofertilizers on biomass, dry matter production and nutrient content of black pepper cuttings

(Kandiannan et. al)

Treatment	Biomass (g/plant)	Dry matter (g/plant)	Nutrient content (%)		
			N	P	K
Azospirillum	61	23	2.80	0.15	1.53
Phosphobacterium	73	24	2.87	0.16	1.57
AMF	74	24	2.98	0.16	1.63
Azospirillum+ phosphobacterium	89	27	3.10	0.17	1.66
Azospirillum+ AMF	92	27	3.15	0.17	1.70
Phosphobacterium+AMF	132	31	3.17	0.18	1.80
Azospirillum+ Phosphobacterium+ AMF	146	34	3.27	0.21	1.94
Control	57	19	2.70	0.13	1.52
CD	22	5	0.17	0.05	0.30

Relative efficiency of Nitrogen fixing bacteria Azospirillum, Azotobacter and AMF on growth of pepper cutting has been studied

Influence of biofertilizers on growth and nutrient status of black pepper.

(Bopaiah and Abdul Kader, 1989)

Treatment	Plant height (cm)	Weight (g)		Total N (%)		Total P (%)		Total K (%)	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Azotobacter	119.0	40.4	3.61	0.85	0.85	0.38	0.38	0.68	0.53
Azospirillum	129.0	41.3	3.68	0.90	0.89	0.30	0.37	0.62	0.57
AMF	135.5	43.8	3.70	0.88	0.84	0.38	0.42	0.59	0.58
Azotobacter+ *Azospirillum* + AMF	161.7	49.5	3.70	0.90	0.88	0.38	0.45	0.65	0.58
Control	108.4	35.8	3.40	0.80	0.28	0.28	0.36	0.54	0.53
CD (0.05)	14.5	4.4	0.20						

It is evident from the table that biofertilizer inoculation increased plant height, shoot and root weight and NPK status of plant compared to uninoculated control. Combined inoculation exhibited better response in plant growth and nutrient status.

Selection of effective AMF is a major step in developing mycorrhizal inoculation programmes in black pepper. Growth stimulating effect in black pepper cuttings varied with the AMF employed has also been demonstrated. Studies were conducted at College of Agriculture, Vellayani to evaluate the performance of different strains of AMF. Inter specific differences in effectiveness of AMF in promoting growth and nutrient uptake in black pepper cuttings has been proved in various instances. Growth responses in cuttings inoculated with introduced endophytes and native isolates have been observed to be different.

Percentage root colonization was found higher in *Glomus Fasciculatum.* Plant height, number of leaves, dry weight etc.were found higher in case of *Glomus epigium*. Such variation in efficiency could be attributed to their intrinsic ability to explore more soil area, plant fungal compatibility and interaction between endophytes and soil environment. In general inoculated plants showed better growth than uninoculated control. *G. epigium* is found to be most effective followed by *G. fasciculatum* and *G. margarita*.

Introduced fungi like *G. macrocarpum* and *Acaulospora* sp. were less effective. With respect to percentage root colonization *G. fascicalatum* proved to be the most efficient colonizer of black pepper roots with 88 %colonization followed by *G. macrocarpum* 70%. Thus it is evident that maximum benefit of mycorrhizal symbiosis is achieved only of plants, which are inoculated with the most efficient AMF under a particular set of conditions. From this its also clear that beneficial effect is not always correlated with the extend of root infection caused by the organism.

The synergistic and growth promoting effects of efficient isolates of AMF and Trichoderma were studied in black pepper nursery in 2 varieties. Karimunda and Panniyur-1. Results showed that Karimunda responded better than Panniyur-1 to AMF and *Trichoderma*. Combination of AMF with *T. harzianum* enhanced sprouting and root growth in both the varieties.

Relative effect of the AMF, *Glomus fasciculatum* to improve rooting of runner shoots and laterals also have been investigated. Percentage of roots, number of roots and length of roots were found maximum in cuttings treated with AMF alone, in both runner shoots and laterals. When AMF and hormones were used together, rooting was effected especially in runner shoots, which are meant for propagation. The endogenous hormone level must be sufficiently high and hence addition of seradix (rooting hormone) and AMF must have had a negative effect. In laterals since the level of endogenous growth hormones is low, better response to the combined treatment is noticed especially with respect to rooting percentage.

Effect of AMF on rooting percentage of runners and laterals in black pepper

(Shivaprasad et. al)

Treatment	Rooting percentage		No. of roots		Maximum length (cm)	
	Runner shoots	Laterals	Runner shoots	Laterals	Runner shoots	Laterals
AMF + soil	71.3	68.8	4.71	2.60	4.07	7.69
AMF + Sand	61.8	63.3	4.79	2.37	2.78	7.19
AMF+ Sand+ Seradix B	43.7	63.0	3.49	2.44	2.64	3.89
Sand + Seradix B	32.4	61.5	3.23	2.36	1.72	3.82
Control	48.8	36.5	3.89	1.57	2.73	3.67
CD (0.05%)	17.3	18.5	0.85	1.35	6.64	1.78

Among biotic stresses 2 major problems i.e., foot rot caused by *Phytopthora capsici* and slow decline by *Radopholus similis* forms major constraints in production of black pepper.

Field trials conducted in Wynadu on the efficiency of biocontrol aspects viz., Trichoderma and Gliocladium on foot rot suppression showed that *Trichoderma hamatum* and *T. harzianum* were found more effective in reducing foot root as compared to *Gliocladium virens*. *Pseudomonas* isolated from the rhizosphere of black pepper from Eastern Ghats of Andhra Pradesh were highly inhibitory to P.capsici.

Effect of biocontrol agents (BCA's) on wilt incidence was studied in selected plots of 6 districts in Kerala namely Idukki, Ernakulam, Kottayam, Kollam, Pathanamthitta and Thrissur.

Effect of biocontrol treatments in the incidence of phytophthora footrot of back pepper in different locations of Kerala during 2000-2001 (Jubina et. al)

Treatments	Idukki	Ernakulam	Kottayam	Kollam	Pathanamthitta	Thrissur
T_1 (control)	42.0	48.0	42.1	30.1	28.0	32.0
T_2	8.6	11.2	9.2	24.4	23.4	29.5
T_3 TH+PP(1)	26.4	31.2	27.6	27.2	34.3	32.4
T_4 TH+PP(2)	23.4	21.3	21.3	23.4	23.4	22.4
T_5 TH+BM(2)	23.4	28.3	24.4	19.4	26.2	29.2
T_6 TL+PP(1)	24.4	25.2	19.2	21.8	18.4	18.4
T_7 TL+PP(2)	38.8	29.6	29.6	12.4	14.4	16.4
T_8 TL+BM(2)	28.6	27.2	24.7	28.4	29.4	29.7

In Idukki Ernakulam and Kottayam districts where control plots have more footrot incidence minimum disease incidence was found with Fytolen and BM spray as recommended by package of practices. In Kollam, Pathanthitta and Thrissur districts where disease incidence was moderate (28-32%) treatments which received post planting application of Trichoderma local isolates and potassium phosphonate twice showed minimum wilt incidence (12.4-16.4%).

The same treatments were incorporated in newly planted pepper gardens with the following results. Percentage wilt incidence in control plots of newly planted pepper gardens revealed a moderate disease incidence (18%). Among the treatments T_7 (*Trichoderma* local isolate and potassium phosphonate (twice) showed minimum wilt incidence in all the districts.

MODE OF APPLICATION OF *TRICHODERMA*

At the onset of monsoon apply *Trichoderma* around the base of vine @ 50 g/vine, followed by a foliar spray of 1% BM or 0.3% potassium phosphonate. Repeat during September-October. *Trichoderma* is applied by broadcasting it over the entire root zone of the vine and then heavily mulched. Three points to be remembered are

1. In phytopthora sick soils, use only chemical control measures.
2. Ensure that isolates of *Trichoderma* were obtained from pepper gardens alone.
3. When disease incidence is negligible *Trichoderma* application @ 50 g/vine with neemcake 1 kg is enough.

Extensive investigations were carried out at College of Agriculture, Vellayani to develop a microbial inoculants based technology, involving fungal antagonists and AMF for foot rot disease management in black pepper. Among the 10 AMF isolates tested, IS-6, Pi-11 and Pi-9 isolated from Kerala soils and identified species *G. fasciculatum* and *Gijaspora margarita* were very effective in reducing disease incidence.

Characterisation of AMF inoculated with different genotypes of black pepper grown in various types of soils indicates definite influence of soil type on AMF colonization. Sandy soils harboured maximum root colony while forest soils had the lowest. *Glomus sp.* particularly *G. fasciculatum* was the predominant AMF associated with black pepper irrespective of soil types. An exception noticed was the presence of *Acaulospora* and Gigaspora *sp.* in sandy soils. The potential native isolates Is-6, Pi-11 were identified as Glomus. Positive changes in aminoacids, total and reducing sugars and orthodehydroxy phenol contents and acidity of cellulose and chitinase enzymes were observed with AMF colonization, particularly Is-6, Pi-11 which could be correlated with disease tolerance.

Phytonematodes like *Melidogyne incognita* and *Radopholus similis* also contributes to low productivity. A large number of BCA's have been identified to have good potential for suppressing nematode population. The fungal antagonists *Trichoderma harzianum, T. viridae, T. longibracheatum, T. koningi* and *Gliocladium virens* are good colonizers of eggs of the root knot nematode *Melidogyne incognita* and suppress nematode multiplication.

AMF also offer increased host tolerance to nematode infection due to improved Phosphate status of host by competition or antagonism between nematodes and fungi. Studies have been carried out to evaluate the effect of artificial inoculation with AMF. Suppressive effect of AMF on nematodes has been observed to be comparable to that of phorate and its clear from the table.

Effect of AM fungi and pesticides on *M. incognita*

(Jeba Kumar et. al)

Treatment	Root-knot index
G. mosseae + M. incognita	1.25
Acaulosporalaevis + M. incognita	0.75
M. incognita + Phorate	1.00
M. incognita	3.50

Suppressive effects of AMF *Glomus fasciculatum* on root damage caused by *P. capsici, Radopholus similis* and *Melidogyne incognita* have been investigated in Karimunda variety. *Verticillium chalmydosporum, Pasteuria penetrans,* *Paecilomyces lilacinus* etc. are also having inhibitory effects on nematodoes. *P. lilacinus* is having suppressive effect on burrowing nematodes also.

Limited attempts have been made on biocontrol of foot rot disease of pepper, with bacterial antagonists. An investigation was attempted to isolate bacteria from rhizosphere of pepper with the ability to suppress foot rot and to assess the effect of bacterial antagonists on growth of pepper. Native isolates were tested for antagonism to *P. capsici*.

Efficiency of bacterial antagonists in the management of foot-rot and promoting growth in black pepper

(Jubina et.al)

Isolate number	Mortality (%) Days after inoculation		Shoot growth of rooted cuttings
	30	90	
B3	71.4	85.7	54.3
B5	42.9	71.4	74.2
B6	85.7	100.0	56.9
B7	42.9	71.4	82.7
B12	57.0	100.0	80.7
B13	42.9	57.1	58.0
P. flourescence	42.9	85.7	48.3
T. harzianum	42.9	100.0	50.2
Control	71.4	100.0	41.3

Isolates B_5, B_7 and B_{13} were effective in reducing lesion size and delaying of symptom initiation in excised shoots. Isolate B_{13} proved to be most effective with mortality remaining at 57% even after 90 days of inoculation. *Pseudomonas fluorescens* standard culture could suppress the initial disease symptoms, but the effect gradually decreased as time after application increases. Studies on growth promotion of pepper showed that B_4 and B_7 were effective in promoting growth of rooted cuttings. Thus B_7 is having dual role in diseases suppression and also in growth improvement. B_7 isolates belongs to Bacillus series.

GROWTH PARAMETERS

No significant increase in plant height, number of laterals, canopy spread etc. was noticed when Azospirillum + phosphobacteria + AMF were given to black pepper. When these 3 combined with inorganic FYM, it has been revealed the following results.

Yield in P_1 - 01.355 kg/unit P_2 - 2.077 kg/unit

Value of essential oil

P_1 - 2.8% P_2- 2.7%

Oleoresin content

P_1 - 11.8% P_2 - 12.9%

P_1 - Panniyur-1 P_2 - Panniyur-2

Another study pertaining to 6 locations, no significant increase in plant height, fresh weight, yield etc. were noticed in mature gardens, but biometric characters like plant height, rate of growth etc. were increased in newly planted pepper gardens when treated with Trichoderma local isolates + Potassium phosphonate.

MASS MULTIPLICATION OF MICROBIAL ANTAGONISTS.

Present day contexts shows that use of microbial antagonists and biofertilizers are increasing day by day. So mass multiplication is followed for large scale production. Coconut water is used as a media for this. Mature coconut water autoclaved at 15 psi for 20' is used as an effective medium for this especially for *Trichoderma* and *Gliocladium virens*. Growth of mycelia was highest in undiluted coconut water and when diluted up to 50%, it is resulted in reduction in weight of mycelium.

A simple incoulation technique by growing certain highly mycorrhizal and annual plants with AMF inoculation to achieve better colonization by introduced AMF in established pepper gardens is reported.

For highly mycorrhizal plants cowpea, sorghum, green gram and Italian millet were raised at 10 spots around pepper plants at 50 cm radius. 10 g of inoculum was mixed with 5 cm soil and seeds are sown and it is observed that sorghum was more efficient in colonization i.e., up to 63.33-78.33%. A plant with higher root length will be more efficient to carry the inoculum to root region of pepper, that is why sorghum with good root length ensures better penetration in to root zone of black pepper introducing higher amount of AMF propagules.

CARDAMOM

Regarding cardamom, whatever be the system of planting, the main objective is to produce maximum number of field plantable seedlings with in the shortest period.

In this context application of bioagents have much significance. Use of AMF has thus become vital in the management of cardamom nursery to produce healthy and vigorous seedlings. Studies were conducted to assess the role of AMF in cardamom. A collaborative project of UAS, Bangalore and ICRI, Myladumpara to evaluate the role of AMF in cardamom revealed that, cardamom seedling inoculated with exotic strains gave encouraging results such as early vigour, resistance to Fusarium infection, rot incidende etc. and these promising strains belongs to *Glomus mosseae*, *G. microcarpum* and *G. fasciculata*.

METHOD OF APPLICATION

Nursery beds prepared for seed sowing is first sterilized by solarisation, so that temperature inside the sheet rises to 45-50°C. After 30-50 days, AMF inoculum is added to sowing burrows in beds or spread over surface layers. As seeds germinate radicles comes in contact with AMF inoculum and roots get infected with AMF. If polybags are used made a small pit in the center of soil mix, and transfer 5 g of AMF inoculum in to this pit and transplant germinated seedlings such that their roots touch the inoculum. If we are using unsterilised soil, natural AMF with in soil and other fungi infect cardamom and later mycorrhizal inoculum may not give expected results. Hence seedling inoculation in cardamom has to be done at very early stage of seedlings.

As a part of the nursery management in cardamom, application of bioagents with *Trichoderma harzianum* along with coffee husk as a delivery medium was undertaken by 5 nurseries in Karnataka. The percentage recovery of seedlings varied, but was found effective. The cultivars varied in their efficacy from place to place.

Response of 3 cultivars of cardamom namely Malabar, Mysore and Vazhukka to AMF application were studied. This study was undertaken at ICRI Myladumpara to assess the frequency and level of AMF colonization on improved selections of cardamom. Nine improved selections viz. MCC-49, MCC-40,Mudigree (Malabar), MCC-61, MCC-12 and Mysore Local (Mysore) and MCC-21, MCC-16 and Clone 57 (Vazhukka) were collected from 3 locations.

AMF colonization was observed in all cardamom selections. Selection MCC-49 exhibited highest amount of colonization. MCC-49 has maximum root length and number of vesicles in roots. This variability in response is because of difference in soil fertility, soil moisture, and natural variability i.e., AMF exhibited specificity according to locations. Malabar selections showed maximum response, followed by Vazhukka. Mysore cultivars had less response to native AMF (Bhai *et al.*.)

Effect of soil application of Trichoderma on incidence of Azhukal disease and population levels of *P. meadii* in cardamom was studies by Thomas *et al.* (1996). In control, disease incidence was up to 45% and its lower in the case of Trichoderma applied seedlings and plantations. DPI is also found highest in control plots. In the case of plantation sick plot 1 and 2 also application of Trichoderma strains *T. viridae* and *T. harzianum* reduced the disease incidence and DPI level.
Effect of Entomogenic fungi on cardamom aphid

Effect of soil application of *Trichoderma* on incidence of azhukal disease and population levels of *P. meadii* in cardamom

Thomas *et al.*, 1996

Antagonist	Seedling/ plantation	Disease incidence (%)	DPI
T. viridae	Seedlings	22	2
T. harzianum	Seedlings	23	2
Control		45	16
T. viridae	Plantation - Sick plot I	14	1
T. harzianum	Plantation - Sick plot I	18	2
Control		32	16
T. viridae	Plantation - Sick plot II	23	4
T. harzianum	Plantation - Sick plot II	40	4
Control		50	32

Among these 2 strains *T. viridae* is found most effective protective measure. *Laetisaria* sp. is also found to be a good BCA for controlling Azhukal disease.

Comparative efficiency of native isolates of *Trichoderma* collected from Tamil Nadu and Kerala has also been selected as a focus of interest. It was observed that native isolates from Tamil Nadu were mostly inhibitory to *Rhizoctonia solani* only while those from Kerala were inhibitory to both *R. solani* and *P. meadii*. This may be because Azhukal disease is less prevalent in Tamil Nadu leading to paucity of the pathogen in that zone which accounts for the lack of inhibition of isolates on *P. meadii*.

Effect of *T. viridae* and *T. harzianum* as seed dressing, 1 week prior to transplanting reduces damping off and mortality. Therefore time of application is also an important factor.

Viral diseases like Katte and Kokke Kandu transmitted by *Pentalonia nigronervosa* can be controlled by certain endomogenous fungi (1) *Metarhizium anisopliae*, (2) *Beauveria bassiana*, (3) *B. brongniarti*, (4) *Verticillium chalmydosporium*.

B. bassiana is found to be most effective, causing 96% mortality. In cardamom *Paecilomyces liticinus*, *G. fasciculatum* and *Trichoderma* sp. have suppressive effect on root knot nematode.

Test fungus	Percentage mortality in aphids	
	Adult	Nymph
Beauveria bassiana	94.6	78.4
Verticillium chalmydosporum	84.6	75.4
B. brongniartii	60.2	56.2
Metarhizium anisopliae	55.1	70.2

GINGER

An investigation was carried out at College of Horticulture, Vellanikkara about the influence of organic manures and Azospirillum on growth, yield and quality of ginger.

Effect of different sources of organic manures and *Azospirillum* on yield and quality of ginger rhizome (Usman et .al)

Treatments	Green ginger (kg/ha)	Dry ginger (kg/ha)	Drying %	Oil %	Oleoresin %
Control	19890.42	3563.51	18	1.14	10.90
Azospirillum with 50% Neemcake	20448.97	3994.11	19.54	1.41	8.37
Azospirillum with 75% Neemcake	20114.55	4169.62	20.85	1.51	9.63

In treatments supplemented with Azospirillum green and dry ginger recovery was higher. Oleoresin content did not show any improvement, but oil content was higher. Though oil content is primarily governed by the cultivar, its considered that the conditions during growth can contribute some amount of variability (Perseglove *et al.*, 1981). The content of oleoresin in ginger was not influenced. This may be due to the fact that synthesis of components of oleoresin is governed by level of nutrients and plant tissues.

Potentiality of Trichoderma, Gliocladium, Pseudomonas fluorescens, Bacillus etc. in combating soil borne diseases of ginger is well demonstrated.

In vitro antagonistic effect of Trichoderma against *Rhizoctonia solanacearum* causing soft rot of ginger has been reported as early as in 1939. Disease incidence was less and yields higher in treated beds compared with Dithane M-45.

Field trials conducted to evaluate biocontrol of soft rot by *Rhizoctonia solanacearum*. Pythium sick soils were treated solarised and treated with BCA's. *T. harzianum, T. viridae, T. hamatum, Gliocladium* etc. were applied as seed or soil treatment and found that disease incidence was less in solarised oils and non solarised soils than untreated plots.

Trichoderma is applied at the rate of 250 g in 20 kg FYM or neemcake. Dissolve 250 g Trichoderma in 5 lit of water and soaked and drenched in beds @ 3 l/m² is done.

Attempts were made to isolate native antagonists to control *Pythium aphanidermatum*, the causal organisms of rhizome rot of ginger.

Pure cultures of isolated native fungi, bacteria and actinomycetes from soils of rhizosphere of healthy ginger plants within rhizome affected fields have been analysed for their antagonistic properties against *Phythium aphanidermatum* by employing dual culture method and cell free culture filtrates. The microflora belongs to *A. niger, A. flavus* and *T. viridae* were found antagonistic against the pathogen. Maximum contribution was noted in *T. viridae* followed by *A. niger*. Actinomycetes (*Streptomyces* sp.) and bacterial isolates failed to inhibit the pathogen. As a strategy to enhance the efficiency of management of rhizome rot of ginger, the bacterial biocontrol agent *Pseudomonas fluorescens* was evaluated individually and with combination to *T. harzianum* and also with fungicidal rhizome treatment colonization of both BCAs resulted in better germination and plant stand which reduced disease incidence and increased yield.

Fungal and bacterial BCAs have different modes of antagonism and then integration is likely to enhance not only the antagonism but also the biological efficiency and provide more competition to pathogens by better rhizosphere competence. Here soil application of BCA's was found superior to seed treatment. Since they have natural soil inhabitants and have better chances of survival and fast muluplication when applied to soil *Bacillus* and *Pseudomonas* are used as BCAs against Bacterial wilt, which is an important diseases in ginger.

TURMERIC

Evaluation of role of Biofertilizers in curcumin content in turmeric is conducted with 12 treatments and 3 nitrogen levels (0, 30 and 60 kg/ha). Here each level is integrated with inoculants of Azotobacter and Azospirillum in single and dual inoculation.

Effect of biofertilizers and nitrogen in curcumin content in turmeric (Jena et.al)

Treatment	Finger rhizome	Mother rhizome	Mean	Protein content (%)
N_0	4.10	4.61	4.36	7.85
N_{30}	5.00	5.36	5.18	7.97
N_{60}	4.82	5.10	4.96	8.28
N_0 + *Azotobacter*	4.33	5.00	4.67	8.13
N_{30} + *Azotobacter*	4.80	5.37	5.09	8.26
N_{60} + *Azotobacter*	4.75	5.33	5.04	8.34
N_0 +*Azospirillum*	4.36	5.16	4.76	8.26
N_{30}+ *Azospirillum*	4.85	5.45	5.15	8.35
N_{60}+*Azospirillum*	5.32	6.00	5.66	8.41
N_0+*Azotobacter* + *Azospirillum*	4.47	5.13	4.80	8.26
N_{30} + *Azotobacter* + *Azpspirillum*	5.48	6.12	5.80	8.38
N_{60} + *Azospirillum* + *Azotobacter*	5.30	5.75	5.53	8.47

Inoculation increased curcumin content and dual inoculation had showed better cucurmin content. Curcumin content was more in mother rhizome than the finger rhizome. Curcumin content increases with increase in level of Nitrogen application irrespective of the microbial inoculums used.

TREE SPICES

In tree spices like nutmeg effect of microbial inoculants like Azospirillum and Azotobacter proved beneficial and resulting in increased growth parameters and fruit number.

VANILLA

Combined application of Azospirillum and phosphobacteria significantly increased growth parameters.

CONCLUSION

Research and development activities in spices need to provide outcomes of interest with a particular shift to organic and sustainable farming in order to comply with the regulations prescribed by the importing countries. Policy changes are required to achieve this and for subsequent effective delivery to the farmers. As a safe guard for the protection of nature and human health ecofriendly practices should be applied to the field to save our earth and its dwellings.

DISCUSSION

1 Is there any bio control lab near our university ?

Yes. Bio control lab Mannuthy is situated near our university .

2 How AMF is applied in field?

AMF is applied in the field mainly by three methods.

Seed treatment

Soil application

Seed pelleting

3 What is the difference between microbial antagonists and biofertilizers?

Biofertilizers involves only microbes which are having growth stimulating effect, but microbial antagonists also involves other organisms which are not microbial eg, insects.,which are having antagonistic effect.

4 Which are the two newly identified AMFsp?

Glomites and *Jimtropea*

5 How much will be the cost of one kg of Pseudomonas fluorescens?

Rs. 46 per kg

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USE OF BIOREGULATORS IN VEGETABLES

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ABSTRACT

Plant growth and development is influenced by various physiological and biochemical factors. Plant bioregulators are an important class of chemicals which can alter these physiological and biochemical reactions. Plant Bioregulators are defined as organic substances other than nutrients which in small quantity are capable of quantitatively and qualitatively modifying the plant growth and development. Broadly they are classified into growth promoters and growth retardants. Now many of them are produced synthetically and are classified as auxins, gibberellins, cytokinins, ethylene, dormins, growth retardants and others (Purohit, 1993).

The growth regulators modify metabolic processes and improve the physiological effects such as plant height, flower number, Relative Growth Rate (RGR), Dry Matter Production (DMP) when applied in definite concentration and time (Singh and Arora, 1994). The use of bioregulators can bring about increased yield in many crops like bell pepper by use of triacontanol (Thakur *et al.*, 1999), in potato by CCC (Bama *et al.*, 2000) and in yard long bean by CCC (Resmi, 2001).

In the present situation where the production of vegetables cannot be further increased in a horizontal plane bioregulators have emerged as the magic chemicals which can be profitably exploited for inducing stress resistance, reducing flower drop, increasing fruitset and ultimately our final goal, the yield. It also finds its place in increasing storage life, breaking dormancy, inducing parthenocarpy and in hybrid seed production.

USE OF BIOREGULATORS IN VEGETABLES

INTRODUCTION

The growth and development of a plant is influenced by the genetic makeup, its environment and a number of internal factors like growth substances. The growth substances alter the physiological activities of the plant and improve the physiological effects including photosynthetic ability of the plants and increase productivity of crops.

It has been widely demonstrated that entirely minute concentration of plant growth substances have the potential to regulate several feets of plant growth and development spanning from seed germination, plant growth, flowering, fruiting, seed formation through senescence and finally death of the plant. Auxins were the first class of plant growth substances, which were discovered six decades ago. Since then four additional groups of plant growth substances have been isolated namely, gibberellins, cytokinins, abscissic acid and ethylene. Quite recently aliphatic alcohols, brassinosteroids, phenolics especially, salicylates, jasmonates are being accepted as the added novel class of plant growth substances.

Undoubtedly exogenous applications of growth substances significantly effect plant responses. Synthetic bioregulators produce their effects through changing the endogenous levels of naturally occuring plant hormones resulting in improvement of yield and quality in desired direction and to the desired extent.

This presentation discusses the contribution of plant bioregulators, their physiological effects and their role in vegetable crop improvement including yields.

BIOREGULATORS

Bioregulators were formerly known as plant growth regulators (PGRs). In 1991, in International Plant Physiology Conference, the term PGR was replaced by plant Bio regulators (PBRs) since the term covers the broader spectrum of effects on plants than PGRs.

Plant Bioregulators are defined as the organic substances other than nutrients, which in small quantity is capable of quantitatively and qualitatively modifying plant growth and development.

CLASSIFICATION OF BIOREGULATORS

Broadly bioregulators are classified into growth promoters and growth retardants.

Purohit (1993) classified bioregulators into,

1. Auxins - IAA, IBA, NAA, 2,4-D, etc.
2. Gibberellins- GA
3. Cytokinins – Kinetin, Zeatin
4. Ethylene – Ethrel
5. Dormins- ABA, Phaseic acid
6. Synthetic growth retardants– CCC, AMO 1618

PHYSIOLOGICAL EFFECTS AND MODE OF ACTION OF PBRs

Auxins

These are the first discovered plant growth substances.The group includes Indole – 3-Acetic Acid (IAA), Indole Butyric acid (IBA) Naphthalene Acetic Acid (NAA), etc.

- They are produced in shoot and root apices.
- They stimulate cell division and cell enlargement.
- They induce shoot and root growth.

Mode of Action

Auxins maintain the cell wall p^H at 4 by activating the proton pump which results in loosening of cell wall components. As a result the wall pressure is reduced and water enters the cell, accompanied by increase in cell volume. Therefore to balance the increased volume cell wall materials become necessary, resulting in cell elongation.

Auxins also act by activating the enzymes involved in synthesis of cell wall materials.

Gibberellins

- These are the second important group of plant growth substances isolated from a fungus.(*Gibberella fujikuroi*)
- They are synthesized by young seedlings and immature seeds.
- They induce seed germination, flowering in long day and low temperature requiring plants.
- They promote cell elongation and shoot growth.
- They increase DNA, RNA and Protein synthesis.
- They break apical and bud dormancy.

Mode of action

- Gibberellins exert their physiological effects by altering the auxin status in the tissue.
- They act at gene level by causing de-repression of specific genes resulting in increased RNA and Protein synthesis.
- They stimulate the formation of hydrolytic enzymes like alpha amylase protease,beta glucanase, phosphatase and ribonuclease which break complex substances to simpler substances necessary for germination.

Cytokinins

- They are produced in root tip, cambial tissue and developing seeds.
- Along with auxins they induce cell division in non-meristematic cells also.
- They break dormancy, delay senescence and induce morphogenesis.

Mode of action

- Cytokinesis i.e., cell division is the main action of cytokinins.
- They induce DNA synthesis.
- They delay protein degradation and loss of chlorophyll there by delaying senescence.

Ethylene

- This is the only gaseous bioregulator.
- They induce ripening and abscission.
- They induce female flowers in cucurbits.

Mode of Action

- They increase protein contents and tissue permeability accompanying climacteric.
- They stimulate cellulose production in the abscission zone which hydrolyze the cellulose, disrupt the cell wall and separate the cell i.e., abscission .

Abscissic Acid

- It is a growth inhibiting substance.
- It acts as a stress hormone.
- It induces abscission and senescence.
- It causes dormancy hence also called as dormins.

Mode of Action

- It suppresses the synthesis of germination enzymes there by causing dormancy.
- It inhibits the K^+/H^+ exchange in guard cells resulting in leakage of malic acid and the guard cells become flaccid.This in turn close the stomata pores thereby acting as a stress hormone especially in water stress condition.

Synthetic growth retardants

- They retard the physiological process but do not inhibit completely

Mode of action

- They act at specific site in the path way of auxin or gibberellins thus retarding their effect i.e., anti auxins or anti gibberellins

Methods of application of Bioregulators

Various methods are adopted based on the effects to be caused by the bioregulators.

1. **Lanolin Paste**

   Lanolin is a soft pat induced from wool and is a good solvent of auxin. This method is commonly used in laboratory experiments andf recommended for parthenocarpy and fruit set.

2. **Immersion in dilute or concentrated solution**

   Organic solvents like methanol (or) ethanol are used for dissolving regulators. This method is used for rooting of stem cuttings. Dilute solutions need long time soaking whereas concentrated solutions are used for rapid action

3. Spraying technique

This is widely used method and is used for the induction of fruit set, parthenocarpy and to regulate flowering

4. Dust method

This is the simplest method for application and is used for rooting, pre harvest fruit drop and selective weed killing.

5. Soil application

This is used to prevent fruit drop and to increase fruit set.

Besides these methods aerosol and vapour forms are used in green house conditions.

Use of Bioregulators in vegetables

Bio-regulators are used in vegetables at various physiological stages starting from seed germination to storage.

1. Seed germination

GA has been widely used in inducing seed germination in various vegetables.

GA (50 ppm) has been reported to increase the germination of radish seeds up to 93% (Singhvi & Chaturvedi, 1990 and Banerjee *et al.*,1999). Singh *et al.*, (1998) reported an increase in germination of 23.61 percent over control in okra by the application of GA (15 ppm).

For inducing seed germination the bioregulators are applied by seed soaking.

2. Breaking dormancy

Dormancy is a main problem in potato where freshly harvested tubers fail to sprout before the termination of rest period. Bioregulators have been reported to break the rest period. GA, thiourea and ethylene chlorohydrins have been reported to break the dormancy period.

El-Asdoudi and ouf (1994) reported that GA(10 ppm) decreased the days taken for sprouting in potato. Miedema & Kamminga (1994) reported that BA (25 ppm) break dormancy in onion. GA(25-50 ppm) along with thiourea and KNO_3 has been reported to break dormancy in spine gourd (Panda *et.al.*, 1997)

Bio-regulators are applied as tuber or bulb treatment

3.Sex expression

Bio-regulators are widely used for changing the sex ratio in cucurbits. GAs have both inhibitory and promoting effect on female flower induction. It was foud to promote femaleness in watermelon, cucumber and squash melon whereas inhibited femaleness in muskmelon, summer squash.

Ethrel (300 ppm) reduced the number of male flowers in summers quash (Gad *et. al.*, 1993). GA (35 ppm) in Bitter gourd induced the earliest female flower whereas NAA (50ppm) induced the earliest male flower (Gedam *et.al.*, 1998) Basu *et.al.*, (1999) reported that GA3 (40 ppm) increase female flowers up to thirty percent over control in pointed gourd which is a dioceous cucurbit. Nagaich *et.al.*, (1999) reported that GA (25 ppm) induced the earliest female flower in pumpkin. Sulochanamma (2001) reported that ethrel (20 ppm) delayed the male flower production up to nineteenth node in muskmelon.

For sex expression the bioregulators should be sprayed at 2-3 true leaf stage.

4.Morphological features

Application of bioregulators has been found effective in improving seedling characters like number of branches, shoot length, root length, etc.

Singhvi and Chaturvedi (1990) reported that GA (25 ppm) as seed treatment in radish induced radicle and hypocotyl elongation. Sharma *et.al.*, (1992) reported that GA(300 ppm) and NAA(50 ppm) as spray improved morphological features like plant height, number of branches etc. Mulge *et.al.*, 1998) reported that seed treatment of onion with GA (200 ppm) recorded maximum shoot length. Bhore *et al.*, (1997) reported that seed treatment of tomato with GA (30 ppm) induced root elongation. GA (0.1ppm) as shoot tip dip enhanced leaf and stem growth (Grunzweig *et al.*, 2000).

5.Flowering and fruit set

Induction of flowering in plants which otherwise fail to flower has also been reported with the use of various bioregulators. Moreover, poor fruit set is a main problem in tomato, brinjal and chillies, which is frequently caused by adverse weather conditions during flowering. Bioregulators have been found to enhance fruit set under both material and adverse weather conditions.

In tomato PCPA (50 ppm) along with Molybdenum (25 ppm) has been found to increase fruit set (Arora *et al*, 1990). Patel and Singh (1991) reported increased podset in okra by spraying CCC (1000 ppm). Das and Maurya (1992) reported that Ethrel (150 ppm) increased the number of fruits per plant in pumpkin. Barai and Sarkar (1999) reported improved flowering and fruit set and reduced flower and fruit drop in chilli by the application of NAA (10ppm) and GA (45ppm). Resmi (2001) reported increased fruit set in yard long bean by the application NAA (30ppm).

FRUITSET IN TOMATO

CONTROL AUXIN SPRAY

FRUITSET IN CHILLI

CONTROL VIPUL SPRAY

FRUITYIELD IN OKRA

FRUITYIELD IN YARD LONG BEAN

6.Fruit yield

Fruit yield has been found to be enhanced by the application of bioregulators.

Deore and Bharud (1991) observed increased yield of onion by the application of GA (60 ppm) as root and root dip and spray. Mozarkar *et al* (1991) reported an increased yield of 12 percent over control by seed treatment with NAA (30 ppm) in tomato. Gasti *et al* (1997 & 1998) reported an increased yield of 29 percent, 44 percent, 63 percent and 65 percent of potato, okra, onion and garlic respectively by the spray of CCC (150-175 ppm). Singh *et al* (1995) reported an increased yield of 30 percent over control in okra by seed treatment with GA (45 ppm).

7.Fruit quality

Bio-regulators have been found to improve quality parameters of vegetable crops like TSS, Ascorbic acid content, etc.

Samdyan *et al* (1994) reported increase in ascorbic acid,TSS and flesh thickness of bitter gourd by spraying CCC (200 ppm). GA (40 ppm) as spray in pointed gourd increased carbohydrate and ascorbic acid (Basu *et al*, 1999). Ethrel (500 ppm) increased TSS and ascorbic acid content in cucumber. (Das and Rabha, 1999) McGiffen *et al* (1999) reported that ethephon (500 ppm) increased root carotene content in carrot.

8.Biotic and Abiotic stress

Bioregulators have been found to increase the tolerance of vegetable crops to various biotic and abiotic stresses.

Arora *et al* (1990) reported that CCC (500 ppm) as seed soaking and spray reduced YVM incidence in okra. Prasadji and Sitramaiah (1992) reported that spraying 2,4 –Dichloropropane reduced root knot nematode incidence in tomato.

Kalloo (1995) reported that CCC (100ppm) as seedling dip increased the tolerance of onion to salt stress. Santos *et al* (2000) reported that GA (40 ppm) as spray reduced the incidence of Alternaria blight in carrot. Singh *et al,* (2001) reported that CCC (500 ppm) and NAA (50 ppm) as spray increased the tolerance of tomato plants to water stress.

9.Storage

Bioregulators have been found to be effective in increasing the storage life of vegetables.

Ray *et al* (1991) reported that MH (2000 ppm) increased the storage life of potato. Similar result was obtained by Kumar *et al,* (2000) in onion.

10.Seed production

Bioregulators have been found to increase the seed yield in various vegetable crops. NAA and GA have been widely used.

They are used as selective gametocides in hybrid seed production. A male Gametocide is a chemical which retards the pollen formation thereby causing male sterility. MH @ 100-500 ppm has been found to be very effective.

Limitations of Bioregulators

- Concentration must be very specific. Super optimal dose results in vegetative and reproductive malformations.
- They are seasonal specific.
- The application should be at correct physiological stage.
- It lacks popularity.
- It lacks repeatability.

Bioregulators and their effects in vegetables

Bioregulators	Crops	Attributes affected
Cycocel (CCC)	Cucurbits	Flowering, sex-expression
	Okra	Resistance to salt, fruiting and yield
	Tomato	Resistance to virus, fruiting and yield
Ethephon	Cucurbits, Okra, tomato	sex-expression ripening
GA	Potato Watermelon Tomato	Breaking dormancy Sex-expression, fruiting yield
IAA	Okra, tomato brinjal cowpea, onion	Seed germination, fruit set yield
MH	Onion, garlic	Reduce storage loss
NAA	Chillies, tomato	Flower drop, fruitset and yield
TIBA	Cucurbits	Flowering, sex-expression yield
Ethylene	Potato	Breaking dormancy

CONCLUSION

In the present day situation as the land area cannot be increased for increasing the productivity it became imperative to adopt new methodologies. Now five emerging biotechnologies have been suggested for increasing the productivity of which bioregulators form a part.

Bioregulators have witnessed a substantial upsurge in synthesis and utilization in the last decade and have emerged as magic chemicals, which could be profitably exploited to overcome physiological constraints leading to enhanced production. The performance of these chemicals is unprecedented and are shown to remove many of the barriers which otherwise are imposed by environment or genetics. There is no doubt that bioregulator technology can be used for sound environmental management processes and increasing productivity of several crops.

DISCUSSION

1.How will you prepare 50 ppm solution?

1 mg of regulator in 1 litre of water gives 1 ppm. So,to prepare 50 ppm solution take 50 mg of the regulator ,dissolve it in ethanol or methanol and make up to 1 litre with water.

2. Whether bioregulator can be sprayed at any time during the day?

No. Since bioregulator exhibits photodenaturation ,bright sunshine hours should be avoided.

3. What is the difference between Growth regulator and Plant hormone?

Plant hormones are naturally occurring whereas growth regulators are referred to synthetically produced analogues.

4. Can bioregulators be applied through irrigation water?

If we can maintain the concentration at the specific level, we can go for application of bioregulator through irrigation water.

5. By the production of seedless fruits whether nutrient content of the fruit is lost?

No. The shape of the fruit only is changed as the seeds are very important for the fruit shape.

6. Whether the bioregulators cause any residual effect?

It is said that it causes residual effect but there are no confirming reports.

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ADVANCES IN HERBICIDE APPLICATION

SEMINAR REPORT

by

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ABSTRACT

Herbicides are available as solid and liquid formulations. Methods of application of these formulations decide the bio-efficacy of herbicides. There are different types of nozzles, which play an important role in deciding the efficiency of spraying.

Improvised methods of herbicide application like Controlled Droplet Application and Direct Contact Application use specialized equipments for spraying. Herbigation, Herbicide – fertilizer mixtures, Herbicide coated seeds and Controlled release herbicides are modifications of normal application practices. Electrodynamic spraying and Electronic reflector sensor spraying are the latest innovations yet to be commercialized. Methods for monitoring the efficiency of spraying include Droplet test square method, Droplet analysis, Flourimetery, Plant photography etc.

With modernization of agriculture and increasing interest in precision farming, advanced techniques of herbicide applications are gaining importance. The suitability and efficiency of many of these methods in our country, where majority of the farmers are small and marginal, are yet to be studied.

INTRODUCTION

The awareness of the use of herbicides has brought to light the necessity of choosing appropriate application method suited for different farming systems, wide range of crops and weed problems.

When vast areas are to be treated with herbicide, there are several factors like time of application, method of application, type of equipment used, type of crops, type of weed problems etc., which can influence the efficiency of herbicide application. Weather can restrict the number of days available for herbicide application. Under these conditions a greater precision in the method of applying the right dosage at the appropriate time is a necessity (Gupta, 1984 and Rao, 2000). This is achieved by using specific and improvised equipments for herbicide application precisely on specific targets at accurate dosage.

Generally herbicides are applied as spray solutions or as solid formulations. Types of herbicide formulations which can be used for preparing spray solutions include wettable powders, soluble powders, EC and soluble concentrates. Solid formulations like granules, encapsulated materials, controlled release herbicides or herbicide-coated seeds can be applied by hand or by using granular applications (Rao, 2000).

Classification of liquid formulations

A spray is defined as a liquid discharged into particles and scattered as dispersed droplets. Herbicides are mixed with a suitable carrier to facilitate distribution and even coverage over the area applied. Water in the most common carrier of herbicide spraying.

In a spray solution herbicide is dissolved, emulsified or suspended in water. Herbicide application is directed to the soil in case of preplanting and pre-emergence herbicides and to foliage in case of post-emergence herbicides. Based on the droplet size the methods by which liquid formulations are applied can be divided into the following groups:

1) Fogging: In this method the size of the liquid particles applied is between 0.005 mm and 0.01 mm diameter i.e., 5 μ to 10 μ.
2) Atomizing: In this case the size of liquid particles applied is between 0.01 mm and 0.2 mm diameter i.e., 10 μ to 200 μ.

3) Spraying: Here the particles sprayed are of diameter 0.2 to 0.4 mm i.e., 200 μ to 400 μ.

In the first 2 cases foggers and atomizers are the special types of equipments used for application. Dust and liquid forms can be fogged and atomized. These 2 methods are not generally employed in herbicide application - but used in fungicide and insecticide applications. Since the particle size is very less spray drift problems are higher in both cases.

Spraying done using different types of sprayers is the best method for herbicide application. Here the ideal particle size which can avoid spray drift and have maximum retention on plant surfaces is about 250 μ diameter.

Another classification of application of liquid formulations of pesticides is based on spray volume. The quantity of water used as carrier determines the spray volume. Based on this the classes of sprays are:

1. Ultra-Ultra Low Volume (UULV)	<0.5 lit/ha
2. Ultra Low Volume (ULV)	0.5-5 lit/ha
3. Low Volume(LV)	5-50 lit/ha
4. Medium Volume(MV)	50-150 lit/ha
5. High Volume(HV)	>150 lit/ha

In UULV and ULV spraying, emulsion oil or emulsifiers are used as carriers instead of water. High Volume (HV) sprays are the type used in herbicide application. The volume of spray is to be 200 litres/ha.

Types of nozzles

The effectiveness of spraying depends on the uniformity of distribution of spray on plant surfaces. This is influenced by spray droplet size which is determined by type of nozzle used. Nozzle breaks the pressurized spray liquid into droplets on application to target (Bouse *et al.*, 1976). There are different types of spray nozzles, which include -

1) Hollow cone

2) Solid cone

3) Flood jet fan/Flat fan

4) Flood jet deflector

Hollow cone nozzle produces the heaviest droplet distribution on the edge of spray pattern.

Solid cone nozzle produces a solid jet of spray and coarser droplets are produced at the periphery of the cone.

Flood jet fan nozzle gives a more even distribution of spray and uniform coverage. Spray comes out as a band.

Flood jet deflector type is also called anvil or impact nozzle. Here the droplets are coarser under pressure and so spray drift minimized. There is no clogging of the nozzle and spray pattern is fan type.

Hollow and solid cone nozzles are usually used for spraying insecticides and fungicides, and also they can be used for spot spraying on specific tree weeds or shrubs.

Another advance in nozzle types is the use of polyjet nozzles. These are recommended for precision spraying. Different colours are given for different nozzles based on spray swath at 50 cm above ground level, spray angle to. This helps the farmers for easy identification of the type. There are nozzles suited for spot treatment, banded spraying in narrow spaced and wide spaced crops and for blanket treatment.

The important factors affecting the bioefficacy of herbicides are droplet size, spray volume and droplet density.

Improvised methods of application

So far we have discussed about the different factors affecting the weed control efficiency of different herbicides. Now we will consider some of the improvised or advanced methods of applying these herbicides based on the crop type, method of cultivation, type of weed problem etc. These methods are popular in countries like USA, Canada, France, UK, Australia, Germany, Netherlands, Russia etc., (McWhorter and Gebhardt, 1990). They include:

1) Controlled Droplet Application (CDA)
2) Direct Contact Application (DCA)
3) Herbigation
4) Herbicide + Fertilizers
5) Sand mixed application
6) Herbicide coating of seeds
7) Controlled Release Herbicides
8) Electrodynamic spraying
9) Electronic Reflector Sensor Spraying

10) Aerial spraying

(1) CONTROLLED DROPLET APPLICATION (CDA)

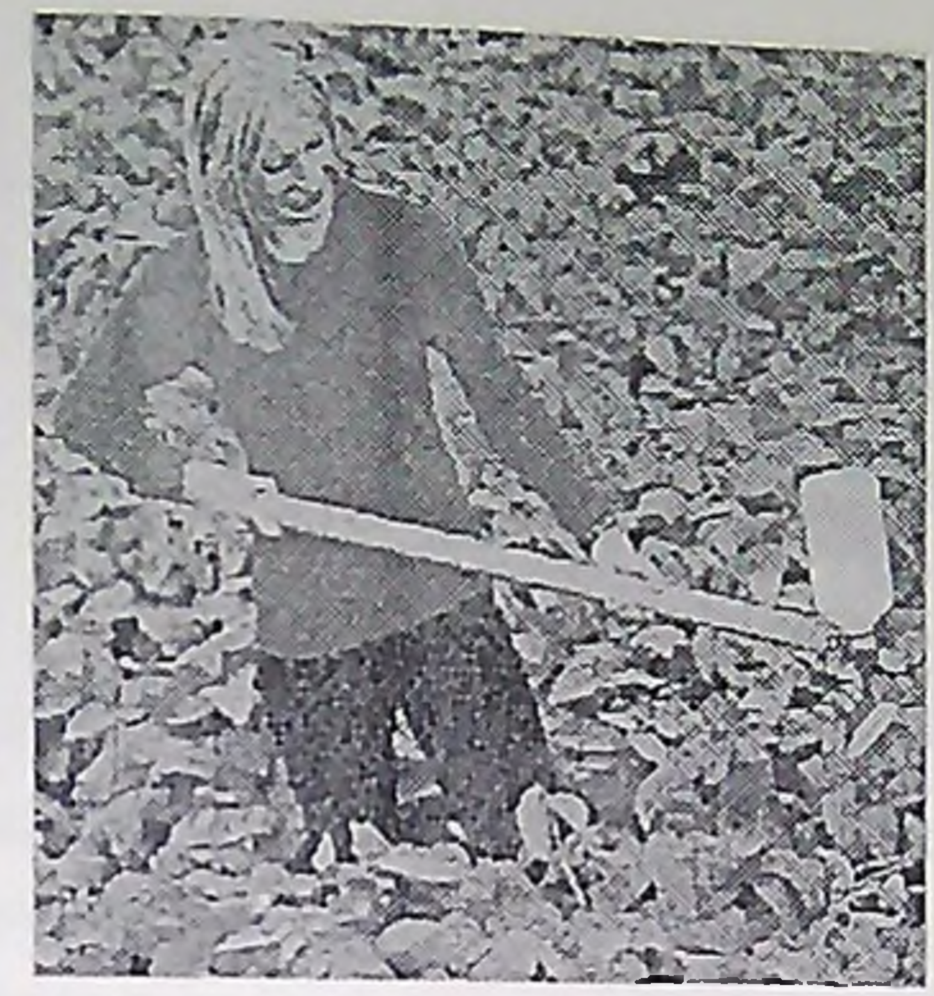
It is a new method of applying herbicides in which the technology produces spray droplets that are relatively uniform in size and permits the applicator to control the droplet size. On the other hand, conventional spray nozzles produce droplets that vary widely form small droplets that may drift or evaporate before reaching the target, to large drop lets that can concentrate too much of the pesticide in one spot (Bals, 1975 and Leibrandt, 1996).

Rotary spray nozzle is the key to CDA technology. It creates a consistent droplet size and uniform pattern width.

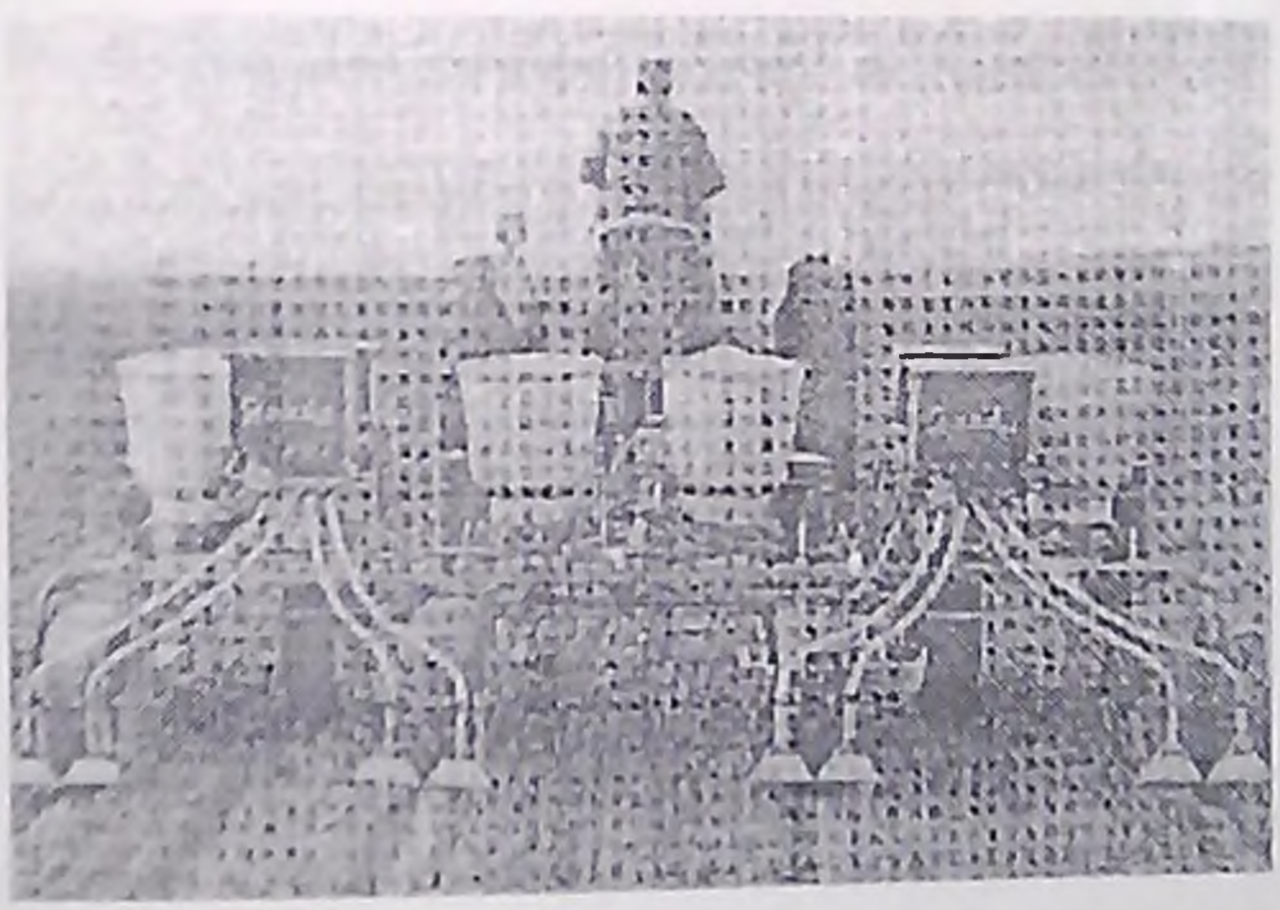
Spray solution accumulates at the bottom of a spinning cup and spray droplets are produced due to the centrifugal force created due to rotation of the cup (Mathews and Garnett, 1983).

CDA nozzles can produce droplets of size ranging from 75 microns to 250 microns at 2 speeds of rotation. 250 μ droplets are considered best for herbicide application. The increased efficiency of CDA is due to the increased percentage of retention of herbicide by the CDA than conventional knapsack sprayer. This can be seen from table below.

Controlled droplet applicator



Granular applicator



The total retention of herbicide (μg/plant) with 2 spraying methods @ 1 kg a.i/ha

Crop	CDA	Conventional spray
Wild oats	31.3	21.5
Redish	362	339

(Merrit, 1980)

Advantages

1) Less carrier/water required per unit area for application (1/10 to 1/20 of the volume needed conventionally).
2) Reduced spray drift since droplet size comes to 75μ-250μ.
3) Efficient use of herbicide since lesser quantity is used over longer area (Farmcey, 1998).

(2) DIRECT CONTACT APPLICATION (DCA)

In these methods the herbicide is placed, wiped, rubbed or smeared on to the plant surface by direct contact (McWhorter and Gebbardt, 1990).

Benefits of DCA

1) Greater speed and ease of operation compared to hand weeding.
2) Ability to treat areas inaccessible for other herbicide application equipments.
3) Ability to control weeds which are impossible to hand weed due to spines, bristles etc.
4) Reduced volume/quantity of herbicide required.
5) Freedom from walking speed.
6) Faster than hand weeding.

Different types of DCA are

1) Recirculating sprayer
2) Rope wick applicator
3) Roller applicator
4) Herbicide glove

(1) Recirculating sprayer

The spray is directed horizontally only to weeds growing above the crop so that minimum amount of herbicide contact the crop plants. The herbicide spray that is not deposited on the weeds is collected in the spray trap of the recirculating sprayer and reapplied. The amount of interception ranges from 40%-50%. The main difference of recirculating sprayer from conventional sprayer is that the former directs the spray horizontally rather than vertically. The recirculating sprayer has solid jet nozzles instead of fan or cone nozzles normally used in conventional sprayers. The spray trap can be box type or foam/sponge or rubberized fibre (McWhorter, 1977).

Advantages

Total spray solution requirement can be reduced to 60% of conventional spray.

Disadvantage is that there are chances for the spray droplets to splash and cause crop injury.

(2) Rope wick applicator

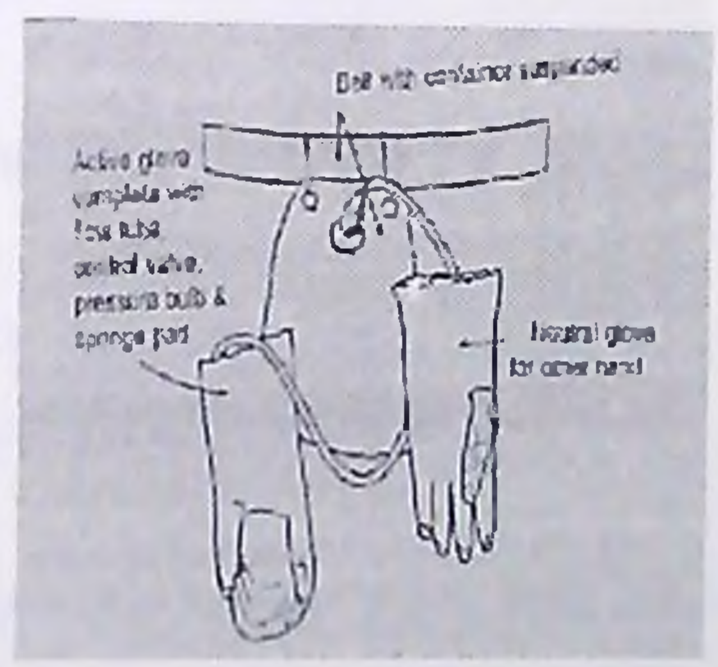
The rope wick applicator first devised by USDA in 1980 has improved from its crude from (prototype) to tractor mounted advanced equipment with multiple wicks. This method uses the capillary action and gravitational flow to move the chemical out

DIRECT CONTACT APPLICATION METHODS

Recirculating sprayer

Rope wick applicator

Surface roller applicator



Herbicide glove

of a reservoir to nylon rope wicks. The chemical is rubbed from the soaked rope on the tall weeds by direct touches (Dale, 1978).

This method has the advantages:

1) No spray drift and splattering

2) Very little chemical needed

3) Nonselective foliar herbicides can be used safely

4) Residue problem reduced

(3) Roller applicator

This is used for control of weeds in turf grass and pastures. In this type the roller is covered with carpet, which is always kept soaked with the herbicide formulation, when the roller is rolled over the surface of land. It can also be raised and height adjusted using levers of tractor-mounted sprayer, according to the height of weeds present. When the herbicide soaked carpet rotates at the fixed height it touches the weeds by direct contact and herbicide is smeared over them (Wilker and Peterson, 1989).

Advantages

1) No spray drift

2) Minimum quantity of herbicide used

3) Easy to control taller weeds

4) Chances of weed escape is less (Irons and Burnside, 1978)

Disadvantages

1) The soaked carpet may pickup prickly weeds and transport it.

2) The herbicide may drip from excessively wet carpet roller.

(4) Herbicide glove

It is designed to allow safe application of specifically effective strong herbicide to long to control weeds, which are thorny, too woody or with prickles (Rao, 2000)

1) It consists of a plastic belt from which the container is suspended.

2) An active glove for one hand with flow tube, control valve, pressure bulb and sponge pad.

3) A neutral glove for the other hand

All parts are made of tough plastic. Below the protective palm and foam pad rests a rubber bulb which is deflated with each grip or squeeze of the glove.

While walking along the crop row, the stem just below the panicle of each weed is squeezed to deposit the spray on the plant.

Each squeeze of the gloved had releases about 1 ml of the herbicide in the palm pad. During squeezing grip should not be hard on the plant so as to break it.

The optimum time of herbicide application through herbicide glove is panicle emergence. The container holds 2 litres, which is sufficient for 2500 panicles.

Advantages

1) Selective and effective control possible

2) Optimum time of application is panicle emergence

3) Spot control of weeds

Disadvantage

Method is very slow

3) HERBIGATION

Application of any chemical in irrigation water is called chemigation. Application of herbicide in irrigation water, called herbigation is a relatively new practice. Herbicides can be applied through surface irrigation, drip or trickle irrigation and sprinkler system.

Surface irrigation, furrow or flooding is not effective for herbicide application, because it is a gravity flow system. There is no guarantee uniformity of water application and so there is no control over quantity of herbicide reaching each plot. Perfect land leveling is a problem.

In drip and sprinkler system the quantity of herbicide required to be applied per head is added to the irrigation water at the point of entry to the field. The herbigation method is more effective in drip and sprinkler system than surface method (Ogg, 1980).

The length of irrigation period frequency of irrigation, rate of water application, concentration of herbicide etc. can affect the efficiency of herbicide application. The other important factors affecting the efficiency of soil applied herbicides are soil properties like structure, texture, porosity, WHC etc. Weed control is possible in the immediate vicinity of drip irrigated plants. In drip irrigation excessive growth of vegetation in the wet zone is a great problem. This can be overcome by herbigation.

In sprinkler irrigation system application of pre-emergence herbicides as a blanket application on the soil surface is possible and is found very effective in weed control.

4) HERBICIDES WITH FERTILIZERS

Soil applied herbicides can be applied along with fertilizers. Triazines, substituted ureas, thiocarbamates etc. can be applied using fertilizers as carriers of the herbicides.

A combination of nitrogen solution and triazine herbicide is the first mixture to gain acceptance among farmers.

This method (1) save time, labour, energy and cost of application, (2) enhance the efficient use of plant nutrients by effective weed control in root zone area, (3) weed control is affected at germination itself avoiding initial competition.

Two types of mixtures are usually used - fluid mixtures and dry mixtures.

(a) Fluid mixtures

Liquid herbicides and fertilizers are combined in this type.

Mixtures which are physically compatible need not be chemically compatible. So compatibility tests are required before a new herbicide-fertilizer mixture is recommended or attempted.

Physical incompatibility of a mixture is shown by

(1) Separation of material into layers

(2) Excessive thickening

(3) Formation of precipitates etc. in the mixture

Gelling of the suspensions and physical characters that prevent the fertilizer salts from settling are desirable. Clay material and organic agents can be used as thickening agents, which help to maintain homogeneity of herbicide fertilizer mixture.

Generally all nitrogen fertilizers are compatible with most herbicides. Compound and complex fertilizers are not compatible with herbicides. Specific nozzles, which produce larger drops i.e., orifices of 4 mm or larger diameter needed.

(b) Dry mixtures:

A liquid herbicide formulation is impregnated or coated on a dry granular fertilizer. The correct amount of herbicide is sprayed on to the bed of fertilizer as it is rotated in the blender and gets mixed.

After herbicide impregnation dry mixtures are applied by using tractor mounted centrifugal spreaders.

(c) Sand mixed application

For application on a small area broadcasting of the sand-herbicide mixture may be done manually. Uniform application is achieved by using the impregnated mixture in dry sand. Some works have been conducted in Kerala in this regard.

In a trial conducted by John and Sadanandan (1989) at RRS, Moncompu, application of Fernoxone 1.00 kg/ha litre sprayed separately or mixed with urea and Weedone @ 5.6 kg/ha mixed with urea 20 DAS were equally effective in reducing the population as well as dry weight of weeds in low land direct sown rice. This could also reduce the cost of production to a considerable extent. Jayasree (1987) has also reported that sand mix application is as efficient as spray application of thiobencarb in dry sown rice weed control.

Bindu (1995) has reported that in a work conducted at ARS, Mannuthy granular preparation of butachlor and anilofos alone or in combinations with fertilizer recorded higher weed control efficiency than their sprays. Butachlor granular preparation (sand mix) + fertilizers 3 DAT gave Weed Control efficiency of 90.74% in transplanted rice. The Weed Control efficiency of hand weeding 3 DAT was 95.87% only. In anilophos and oxyfluorfen also sand mix preparation were found to be as effective as spray solutions.

(5) HERBICIDE COATING OF SEEDS

Crop seeds are coated with fungicides, insecticides, nematicides and crop safeners to protect seeds and emerging seedlings from pathogens and pests. Seeds are also pelletted or coated with minerals, nitrogen fixing bacteria inoculums, carbon protectants etc.,

Thus coating of crop seeds also with herbicides is found to be a convenient method of herbicide application to control weeds in the immediate vicinity of germinating seeds and emerging seedlings.

However, this is not at all a safe method as the margin of herbicide tolerance and susceptibility between crop plants and weeds is so thin that an overdose may adversely affect the crop.

This is found most suited for legume seeds like afalfa, snap beans, field beans etc. First the seeds are coated with a commercial porous material called 'Rhizokote' (which is used as carrier of Rhizobium inoculum) or Goldkote, containing lime and gypsum. These materials are added @ 50% of weight of uncoated seed (i.e., ½ kg for 1 kg seed) generally. The required proportion by weight of coated seeds + technical grade of the material + acetone sufficient to give a uniform mixture is mixed and the seeds added and shaken gently and acetone allowed to evaporate. The saturated seed coating will contain the herbicide, uniformly dispersed in the porous material.

When herbicide coated seed in planted, the rate of herbicide applied depend on quantity of herbicide per seed and seeing rate. Eg. Alfalfa seeds coated with EPTC could give 95 to 100% control of *Lolium perenne* (Perennial rye grass).

The success of this method depend on the

1) Tolerance level of crop to the herbicide
2) Rate of dispersion of herbicide in the soil after coated seeds are planted.(Yates *et al.*, 1981)

In African countries where maize is cultivated on large scale witch weed, *Striga* is a major problem. This can be controlled by a low-dose (as low as 30 gm/ha) of imazapyr seed coating applied to imazapyr resistant (IR) maize seed.

The effectiveness of imazapyr seed dressing on maize for control of striga can be understood from the following data.

Effect of imazapyr coated IR maize seed on striga control and grain yield

Imazapyr gms/ha	Striga plants/m² 12 WAP	Grain yield tons/ha
0	23.2	0.55
30	4.0	2.50
45	1.4	2.72

(CIMMYT, 2002)

(7) CONTROLLED RELEASE HERBICIDES

These formulations provided a staggered release of herbicides over an extended period of time. These are mainly 2 types (1) micro encapsulation and (2) herbicide tablets.

(1) Micro encapsulation

This method is mainly useful in having a prolonged availability of the soil applied herbicides like alachlor , metolachlor, atrazine etc. in soil by a timed release by starch encapsulation of the herbicide molecules. Encapsulation encloses the herbicide in porous polymer particles that release the active ingredients slowly. The particle size is 2 to 15 μ diameter. They offer timed and prolonged release over a longer period of crop season. Herbicides are released from microcapsules by swelling, bursting, drying and cracking. It is in dependent on the encapsulating material, microcapsule environment and herbicide properties. Starch matrix widely used for encapsulation of herbicides (Owen, 1999).

Procedure of encapsulation

1) Dispersion of starch in water
2) Gelatinization of starch with heat
3) Addition of herbicide
4) Cross linkage of starch with herbicide molecules
5) Encapsulated material dried, ground and sieved to produce various size particles of 2 to 15 μ (dia)

Metribuzin, Metolachlor, Acetolachlor, Alachlor etc. are the soil applied herbicides available as encapsulated (Peterson and Shea, 1989).

(b) Herbicide tablets

These have 1 mm to 15 mm diameter. Lignin cellulose acetate cloth, organic mulches, plaster of paris etc. are used. Dicalcium phosphate is very effective for preparation of herbicide tablets. The technical grade of herbicide is mixed with the above materials and dry pressed in a single punch tablet machine. These herbicides are soil-applied herbicides and the availability is prolonged over a long period. The radius of release and period of release depend on size of tablet. There are several advantages like reduced risk of leaching, reduced off target deposition of herbicide, reduced environmental pollution etc. Alachlor - Dicalcium phosphate herbicide tablets are popular in western countries (Gorski *et al.*, 1989).

(8) ELECTRODYNAMIC SPRAYING

This is also called electrostatic spraying. This type of sprayer needs a special type of nozzle. In this nozzle the herbicide is constrained through a thin slit - high voltage nozzle. The liquid becomes subjected to intense electric field upon emergence to the atmosphere. A nearby-earthed electrode ensures field strength at the nozzle. The droplets are deflected away from the nozzle due to the repulsion and these particles are propelled to the target surface with force. These particles will thus stick to the target surface (Coffee, 1981).

A uniform droplet size of 100 μm is found to give best results in electrodynamic spraying (Givelet, 1981).

This method is tested in the field. But large-scale adoption has not yet materialised.

(9) ELECTRONIC REFLECTOR SENSOR SPOT SPRAYING

This electronic equipment has sensors of red and infrared photodetectors. These are used to measure the Vegetative Index (VI) of the field by sensing the reflectance from the plants. Using these values Normalised Difference Index (NDI) is calculated. There are specific NDI values for each type of vegetation and different plant densities. When the NDI value calculated from the VI exceed a threshold level, the plant density is found to be in excess. Then the electronic valve is activated and the spray nozzle opens automatically letting out the spray (Merrit *et al.*, 1996).

This is also called Patch spraying in the sense that only patches of weed growth were weed density is higher than critical is sprayed and controlled.

(10) AERIAL APPLICATION

The aerial application of insecticides is very popular even in our country, even though practiced only to a small extent. Percentage of cropped area treated with plant protection agents by air in different countries is as follows.

Germany - 30%

Russia - 14%

USA - 10%

Canada - 3%

India - <1%

The worldwide use of agricultural aviation is as follows:

Fertilizers - 50%

Plant protection chemicals	- 35%
Seedling	- 10%
Other practices	- 5%

The use of aviation for herbicidal application need great precision and care. Only very large and contiguous areas of same crop can be aerially sprayed with herbicide. The maize and wheat fields of North America are sprayed with 2,4-D for the control of lambsquarter, *Chenopodium album*. Selective herbicides are also applied by air for wild oats control in wheat. Spray drift is the major problem is aerial spraying (Owen, 1999). Research is being conducted for making necessary changes in nozzles for reducing this problem.

METHODS OF MONITORING HERBICIDE APPLICATION TECHNIQUES

Practical methods of checking application techniques of plant protectants were developed in 1970's, and have been improved very much now. These methods give greater accuracy in spraying application (Allan, 1980). They have contributed greatly to further refinement of application technology, enabling plant protection agents to be applied with even better efficiency and with less risk to our environment (Godbole and Coates, 1994).

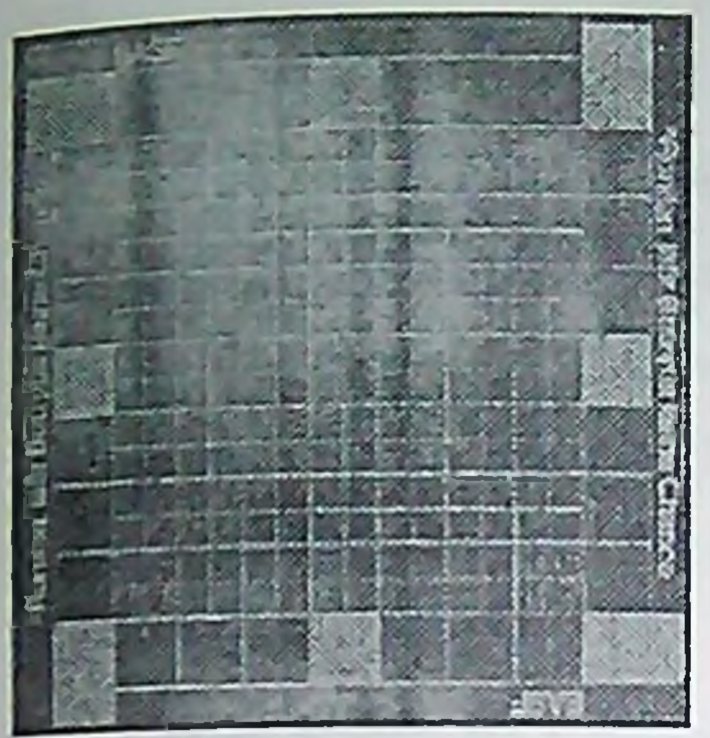
The 4 important methods are (1) Droplet test square, (2) Droplet analysis, (3) Fluorimetry, (4) Plant photography.

1) Droplet test squares

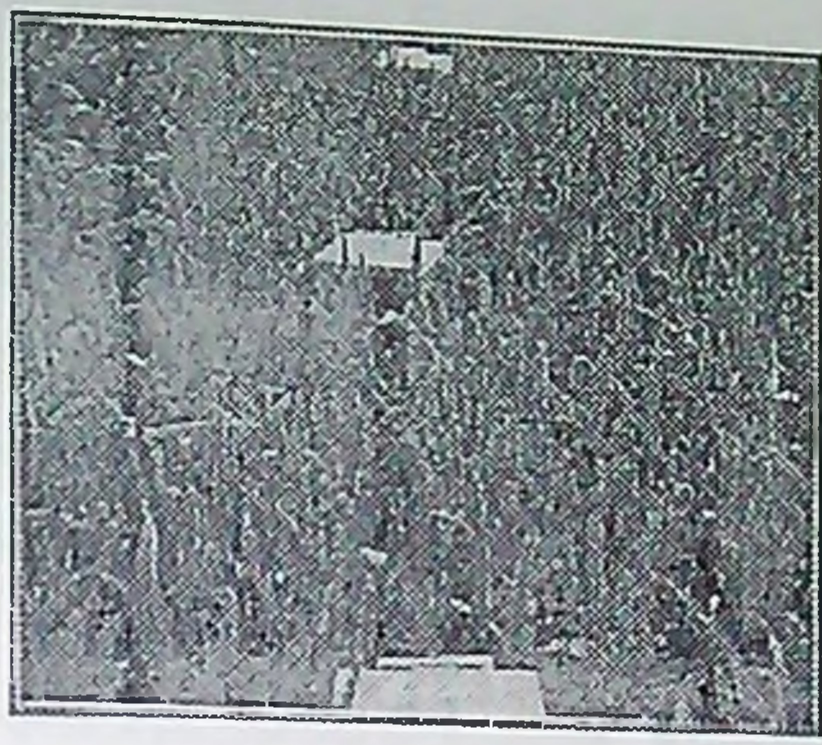
The method of using droplet test square was developed primarily for the farmer/applicator. It is not able to deliver highly accurate measurements. But it provides the user a practical method for assessing more reliably the quantity and quality of a spraying coating.

The test square is black in colour, 10cm X 10cm size. It is divided into squares of 1 cm x 1 cm and to 1 mm x 1 mm. The test sheets may be useful in field crops as well as tree crops. A dye is added to the spray to make the coating visible. The front and back sides of the square are identical and so both sides can be evaluated in the case of tree crops.

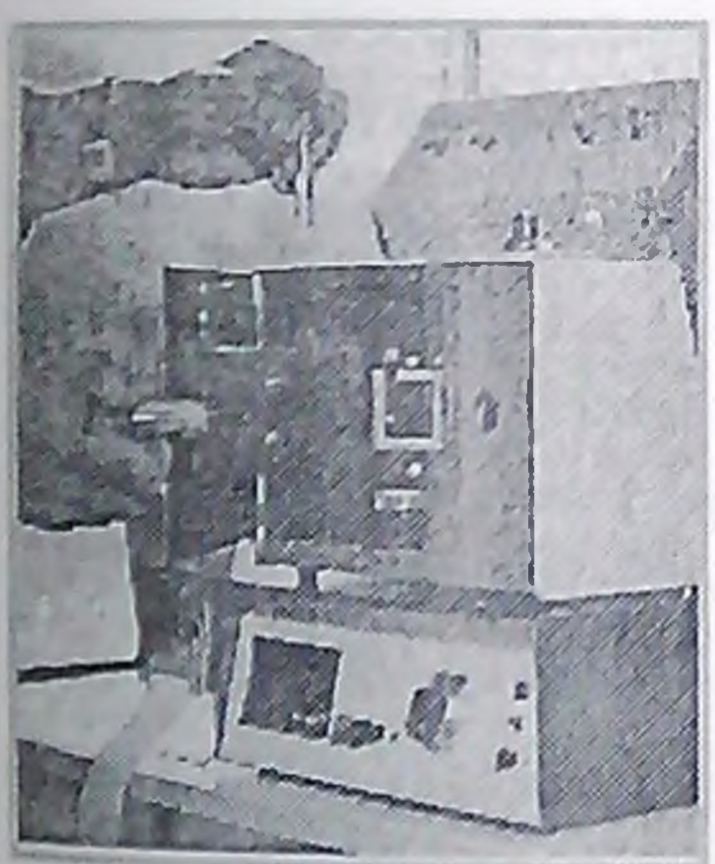
MONITORING HERBICIDE APPLICATION



Droplet test squares



Receptacle for droplets



Fluorimetry

Plant photography

(2) Droplet analysis:

This method is preferred for scientific evaluation of spray. It records with considerable precision the number of droplets their size and the area covered by the total droplets.

Receptacles filled with silicone soil are placed in the crop being treated. The droplets collected in the plastic cups during the spray application are recorded on fills by contre-jour (against the light) photography. To ensure adequate contrast between the droplets and oil a dye is added to the spray. The black and white photographs are evaluated using a scanner connected to a calculator.

3) Fluorimetry

It is used for quantitative evaluation of spray coatings. A fluorescent dye is added to the spray. This makes possible to measure the amount of spray on the target surfaces. This method is quite labour intensive since a large number of plants (at least 100 per plot) must be sampled from treated crop. The dye is washed off with distilled water and the colour intensity of the washed liquid is measured in a fluorimeter. Different application methods can be compared by this method.

It also has advantage that not only horizontal target surfaces, but also surfaces of all inclinations up to vertical are included.

4) Plant photography:

This renders the spray coating visible, which permits an optical control of the plants. Only qualitative analysis is possible by comparing photos. The plants are removed from the plot and photographed under ultraviolet light. Prerequisite for this method is again the use of a fluorescent dye added to the spray.

CONCLUSION

With increasing cost of energy, chemical, labour and machinery, the farmers will continue to seek for new and novel herbicide application techniques. The changes in the relative importance of weed species will lead to use of new herbicide formulations and new effective application methods. Further development of techniques and easy monitoring methods will be needed to provide more selective and cost effective means of integrating herbicide usage with weed management programmes. At present the high cost of these equipments and higher level of technical expertise needed limits the use of these equipments.

DISCUSSION

1) Are any of the above methods discussed by you useful/applicable under our conditions?

Among the different methods discussed, herbigation, herbicide + fertilizer application, sand mixed application, herbicide coating of seeds controlled release herbicides etc. can be effectively used under our agricultural conditions. But most of these methods are yet to be standardised for our situations.

2) What is difference between chemigation of herbigation?

Chemigation is the application of chemicals - insecticides, fungicides etc. along with irrigation water. Herbigation is specifically the application of herbicides with irrigation water.

3) Are surface flow irrigation methods useful for herbigation?

The surface flow irrigation methods are not efficient for herbigation in the sense that uniform distribution of herbicide in the soil is not possible. A very perfect land levelling and precise checking of the volume of irrigation water applied is necessary which is rather difficult.

4) Are the different equipments/machines described by you useful for our fragmented lands?

The use of tractor mounted herbicide applicators require high initial investment and are suited for large contiguous areas. They can be economical if only redesigned the suit our agricultural situations. Besides continuous uniformly cropped areas with similar weed problems are required for their efficient use. Fragmentation of land is a disadvantage in using these methods.

5) Are the use of herbicides possible for aquatic weed control?

The use of herbicides is not generally recommended for aquatic weed control because of the easy translocation of herbicides to water and affecting fishes and other aquatic organisms. Only under very controlled conditions and under strict supervision herbicides are to be used.

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PROCESSING AND QUALITY ASPECTS OF SUGARCANE

By

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Seminar Report

Submitted in partial fulfillment for the Course
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ABSTRACT

India is the largest producer of sugarcane in the world with a share of 35 per cent of world production (Shahi, 2002). Sugarcane provides useful raw material to many industries to produce sugar, Jaggery and a range of agro industrial co-products such as alcohol, paper, newsprint, a variety of chemicals, cattle feed and electricity. Therefore, for industrial security, sustainable production of quality sugarcane becomes inevitable.

In the country method, Jaggery and Khandasari are made from sugarcane. Where as, sugar is manufactured at an industrial level. Molasses is one of the important byproduct in sugar manufacturing process. From Molasses, rum, carbon dioxide etc. are made through anaerobic fermentation process employing yeast (*Saccharomyces cerevisiae*).

The yield and quality of sugarcane are affected by both biotic and abiotic factors such as climate, planting season, nutrients, irrigation, optimum ease of harvest, effect of ripeners, sucrose loss due to microbial infection, method of harvest and transport etc. Among all microorganisms, *Leuconostoc sp.* caused heavy damage (Solomon, 2000). Hence, an understanding on the effect of theses factors on quality of sugarcane becomes essential

PROCESSING AND QUALITY ASPECTS OF SUGARCANE

Introduction

In our country, agriculture is not an agribusiness, but a way of living and sugarcane, an agro industrial crop, is an important integral component of agriculture. It assumes an important position in the economy by contributing nearly 1.9% of National GDP (Rao, 1988). Sugarcane is cultivated in over 4 million hectares spread over a wide range of agro-ecological situations, both in tropical and subtropical regions. The crop sustains the 2nd largest organized agro-industry - the sugar industry. This has enabled us to be the largest producer of sugar and second largest producer of sugarcane on world. At present, the total production of sugarcane in the country is around 300 million tonnes and we are producing over 18 million tonnes of sugar (Shahi, 1999). In addition, sugarcane supports a large number of open pan sugar (Khandsari) and jaggery (Gur) units in the unorganized sector with a production of over 10 million tonnes of jaggery (Gur).

The world sugar industry is facing a crisis because of a steep decline in price on international market. The price has come down from 5396.65 tonne in 1995 to $ 326.60 mainly because of excessive production in relation to the demand (Shahi, 2002). It is difficult to sell this quantity even at cost price. Because, three major issues before the industry are the high cost of sugar production, high price of cane paid to farmers and low recovery achieved in mills. In world, India is the highest sugar producer and 2nd largest producer of sugarcane followed by Brazil. But sugar recovery is highest on Australia of about 14%.

In India, North Indian cane belt consisting of Punjab, Haryana, UP, MP, Bihar etc. gives 68% of the total care production and occupies 76% of total acreage under the crop. The South Indian cane belt (A.P., TN, Gujarath, Maharashtra, Karnataka) occupy nearly 1/3 of the area under North Indian belt and production is also less than ½ as that of under North Indian cane belt. UP alone counts nearly 50% of area and highest producer of sugarcane in the country. Tamilnadu ranks first with respect to productivity is concerned and Gujarath ranks first in sugar recovery of about 11%.

With respect to host land-kerala, there is no much appreciable area in kerala but parts of Palakkada district and Chittur farmers are taking sugarcane cultivation. According to latest figures, sugarcane crop occupies of 7000 ha with an average yield of 60 tonnes/ha. The yield ranges from 30-40 tonnes in some flood-prones areas to well over 100 tonnes/ha in well managed farms (The tonnage of sugarcane is low due to unfavourable climatic conditions.

Table 1. World area, production and productivity of sugarcane.

Country	Area ('000 ha)	Production of cane ('000 t)	Cane yield (t / ha)	% of world cane	Sugar yield (t/ ha)
India	4414	301256	75.8	35.12	7.59
Brazil	1220	75000	61.5	10.57	6.48
Cuba	1400	70000	50.0	9.86	5.57
Australia	350	26950	77.0	3.80	10.54
Pakistan	540	25000	46.3	3.52	4.19
World	11572	709758	61.3	100	6.27

Source : Survey of Indian Agriculture, 1996

Normally sugarcane cultivation starts from December - January to February - March i.e. Eksali. Crop faces dry spell during germination and tillering from February - May. An overcast sky with less than 6 hrs of bright sunshine during grand growth phase from June - September and flowers in September - October which arrests further vegetative growth. This is totally lack of interaction between plant and climate. Crop has tested on Kuttanad regions also, but research result found that there is very low sugar recovery. The crop has not become popular on Kerala mainly due to labour scarcity, high cost of labour, low remunerative price, out break of red-rot, unfavourable climatic condition etc.

Crop - Its Importance:

Sugarcane is a multiple product commodity crop. It produces, *Inter alia,* about 10 Metric Tonnes (MT) sugar, 4 MT molasses, 3 MT fiber cake, 9.3 MT furnace ash, 120 MT fine gases (at 180°C), 30 MT bagasse and 150 KWh electricity for the every 100 MT of sugarcane crushed in a sugar factory. It serves as a food, feed, fiber, fuel, fodder, foreign exchange earner and organic manuring crop. It provides useful raw materials to over 25 types of industries which utilize its different components to produce Sugar, Jaggery, *Khandsari* and a range of agro-industrial co-products, like alcohol and its derivatives, fuel, chemicals, paper boards, news print, antibiotics and electricity. Sugarcane, therefore, has a unique agro-industrial potential which is not found in any other crop.

The sugar industry occupies a prime place in Indian economy, being one of the five largest industries comprising of about 400 units spread all over the country. These sugar industries have attained so far a maximum annual production of 16.45 million tonnes and have been working as nuclei for the development of rural areas of the country by mobilizing the natural resources, generating sizeable employment directly and through ancillary industries, transport and communication facilities, etc. Nearly 35-40 million sugarcane growers and 3.5 lakh skilled and unskilled workers are engaged in sugar industries. It is one of the largest contributors to the Central and State exchequers. It contributes annually Rs.8000-8500 million towards excise duty to the central exchequer, Rs.4000 contributes annually Rs.8000 million towards purchase taxes, 8500 million towards excise duty to the central exchequer, Rs. 4000 million towards purchase tax, cane cess, commission on sugarcane purchase to sugarcane co-operative societies etc. and State Government and over Rs.50 thousand million as cane price to the sugarcane growers.

It is one of the most efficient cultivated plant in the process of absorption and utilization of Co_2 from air, when Co_2 concentration of 300 ppm limits the photo synthesis process in pulses, oilseeds and cereals like rice. But sugarcane continues the process till the concentration of air is exhausted to 5 ppm or < 5 ppm. So, this leads to high water and fertiliser use efficiency.

By-products of sugarcane

Sugar industry is the largest industry of India. Traditionally sugarcane is cultivated to produce jaggery, for chewing and extraction of juice for beverage purposes. Even after sugar production from sugarcane was started, the traditional uses continues on large scale in our country. About 40% of the cane produced is utilized for Gur and Khandsari production.

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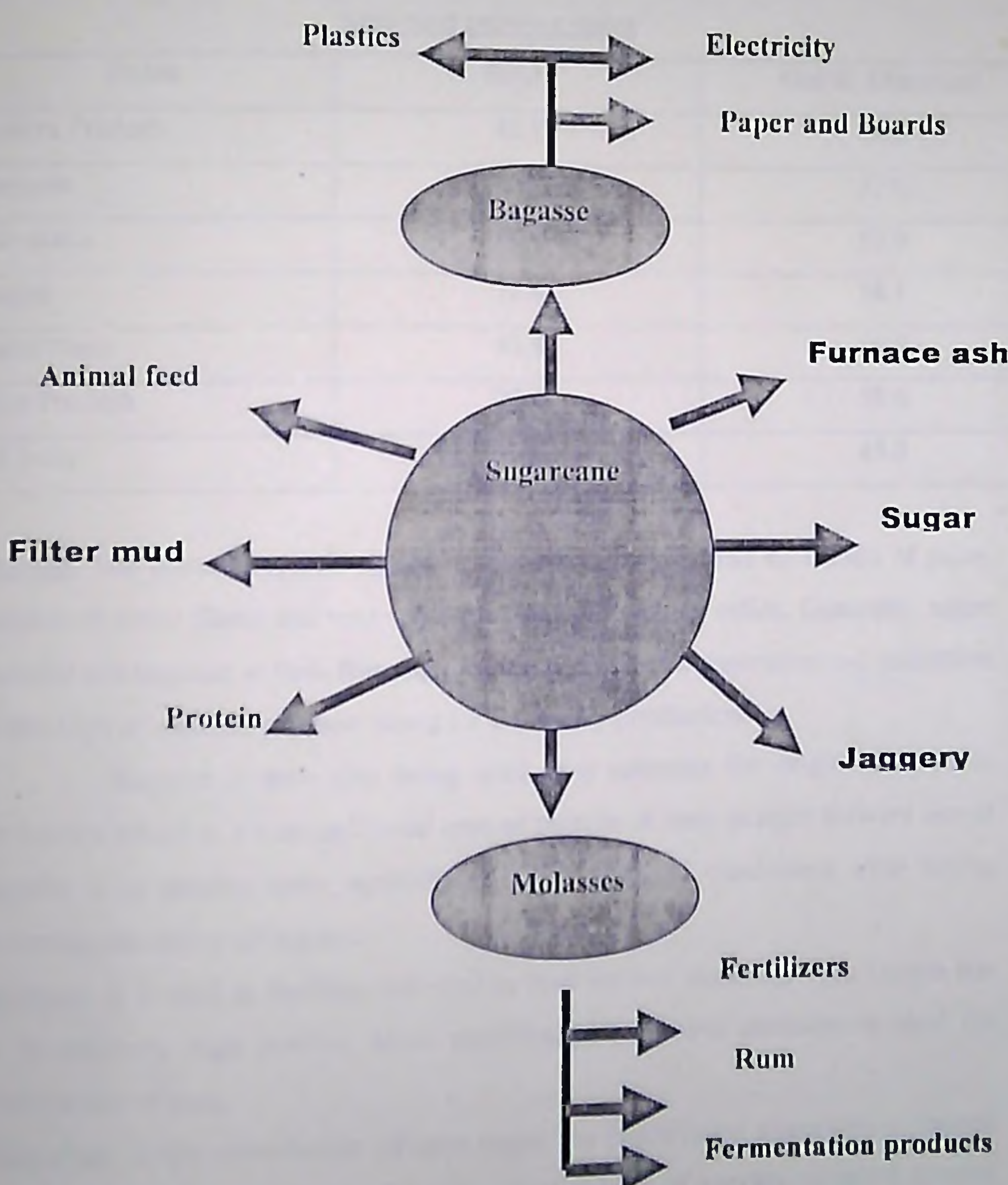
Gur is in great demand through the country, particularly in rural India. Many of the traditional sweets are made using jaggery. It is used for preparing liquor. This syrup of jaggery is known as 'Kakvi' is every popular is Karnataka, where it is consumed along with chapathi. Jaggery is also used in preparing cattle feed and to fed to honey bees to prepare 'honey' also.

Fig I: By-products of sugarcane



Khandsari and Gur are very popular in subtropics, about 59% of the cane produce in UP is used for Gur and Khandsari (Sreenivasan *et al.*, 1995).

In U.S.A. insulation board and poultry litter were the more important end uses, while elsewhere the utilization of bagasse for paper is slowly building up. A more recent market for particle board is showing great promise.

Cane wax is the general term used to designate the lipids contained in the sugarcane, such lipids being divided into waxy lipids and fatty lipids. Care wax being a valuable product, methods have been derived for its extraction from fitter cake.

Table 2. Per cent utilization of sugarcane for different purposes in some sugarcane growing states

States	Sugar	Gur & Khandsari
Andhra Pradesh	48.7	44.0
Haryana	50.0	37.0
Karnataka	38.0	52.9
Punjab	71.4	16.1
Tamil Nadu	43.9	46.0
Uttar Pradesh	27.6	58.6
All India	43.2	45.0

Bagasse: The fibrous residue of cane stalks after crushing and extraction of juice, consists of water fibres and very small quantities of soluble solids. Generally, sugar factories use bagasse as fuel. Burning of bagasse for steam generation and utilization of this high or medium pressure steam for electricity production.

Bagasse is now also being used as a substrate for single cell protein production which is a non-traditional type of protein. A very straight forward use of bagasse is as poultry litter, agricultural mulch and soil conditional after drying screening and baling of bagasse.

Molasses: It is used as fertiliser and used as feed for live stock has been known due to its relatively high content. More specifically, sugarcane molasses is used for manufacture of rum.

Filter mud: In the manufacture of cane sugar, the precipitated impurities contained in cane juice, after removal by filteration from a cake of varying moisture content called filter mud. It contains about 1% N and 1% phosphorus. So, it can be used as fertiliser. Filter mud with bagasse cane tops and molasses is used as animal feed.

Bagasse ash: Composition of bagasse ash closely resembles with that of the mixture of sand and alkalies, commonly used for glass making.

Protein from cane juice - contains very little protein (0.1%), but in view of large tonnage processed by any factory during crushing campaign, amount of protein that could be recovered annually is important.

Sugarcane, using the C-4 pathway, fixes about 4 times as much solar energy as most of the temperate crops and can produce about 50 tonnes of dry matter per hectare per annum. Hence increasing importance of the by-products derived from sugar cane and the economic attraction of their efficient utilization (Nigam and Pandey, 1986).

Composition of sugarcane

There is saying that 'sugar is made in field but not in the sugar will' which sounds true because the sugar cane quality is affected by many external and internal factors besides their genetic characters. From the term 'quality' it indicates the relative proportion of sucrose and other soluble solid in cane juice. A thick cane with long internodes would have more pure juice, less rind juice and least fibre. Thus, it would be regarded as best quality. A higher percentage of starch in cane and juice and shorter internodes with a higher percentage of fibre in cane impairs the quality and creates problems in juice extraction. Fibre strength of the cane also affects the juice extraction from the cane. A cane with a high fibre strength is hard which resists roller pressure and reduces extraction percentage of juice from canes.

Cane juice composition

Water	->70-75%	Ca - 10 mg/100 g
Sucrose	->12-21%	P - 10 mg/100 g
Reducing sugar	->0.3-3%	Fe - 1.1 mg/100 g
Other organic substances	->0.5-1%	
Inorganic compounds	->0.2-0.6%	
Fibre	>14-17%	
Total solids of juice	>17-22%	

Thus, in brief the best quality sugar cane would be the one which has few nodes, longer inter nodes, low proportion of rind tissues to total tissue matters, soft, lower starch content, lower fibre content (13.5%) higher sugar content (18-21.5%)

and low molassegenic substances, low colouring matter and low colloidal substances in juice.

Sugarcane quality parameters:

Important sugarcane quality parameters are the juice brix, pol or sucrose and purity.

Juice Brix- refers to the total solids content present in the juice expressed in percentage. Brix includes sugars as well as non-sugars. The Brix is measured using a Brix hydrometer and then necessary corrections with reference to temperature are made and true Brix is obtained. Brix can be measured in the field itself in the standing cane using a Hand Refractometer.

Juice sucrose per cent - Juice sucrose per cent is the actual cane sugar present in the juice. Juice sucrose per cent is determined by using a Polarimeter. This is why sucrose per cent is also referred to as Pol per cent. For all practical purposes Pol per cent and sucrose per cent are synonymous. Now a days this can be measured by 'sucrolyser' also.

Purity coefficient - Purity coefficient or simply purity refers to the percentage of sucrose in the total solids in the juice

$$\text{Purity} = \frac{\text{Sucrose (Pol)}}{\text{Brix}} \times 100$$

A cane crop is considered fit for harvest of it has attained a minimum of 16 per cent sucrose with 85 per cent purity.

Reducing sugars - This reducing sugar refers to the per cent of other sugars (fructose, glucose) in the juice. A lower RS values indicates that much of the sugars have been converted into sucrose (Iyer, 1986).

CCS % (Commercial cane sugar)

The CCS % refers to the total recoverable sugar per cent in the cane. This could be calculated by using formula:

$$\text{CCS\%} = 1.022S - 0.292\,B$$

S -> sucrose % in juice

B -> Brix in juice

General description of sugar manufacture:

The juice in the cells of the cane stalk is extracted by pressure. This juice is a solution of sucrose and accompanying impurities. The greater part of these impurities is removal by heating the juice, and by the addition of lime and sulpher dioxide, and subsequent settling and decantation. The purified juice is boiled to a thick syrup. This syrup is further concentrated under reduced pressure until crystals of sugar form in it. The sugar crystals are separated from the accompanying molasses in centrifugal machines. The above is a very brief summary of the whole process.

Once the cane comes to the sugar factory. Gross weight of sugar cane and Net weight of sugarcane are computed and price for cane are calculated in computer.

Extraction of juice: in a mill house is not a simple operation. Residue may contain still some sucrose. Water is spread to the fibre and again crushed (Maceration). This juice pumped to boiling house, weighed and processed. The bagasse transferred to boiler furnace where it provides heat due to combustion to operation.

Clarification: Mixed juice coming from milling house to boiling house is a opaque, dark green, brown in colour and acidic. This is heated above boiling point (105-115°C) and lime milk added before and after heating. This clarificants are added mainly to prevent in version of juice in acidic condition, and to clarify the impurities substances i.e. to make the juice clear. So, organic substances like chlorophyll, Anthocyanin, wax, gum, albumin and calcium phosphate - released as mud i.e. filter cake, which contains $< 3\%$ sucrose.

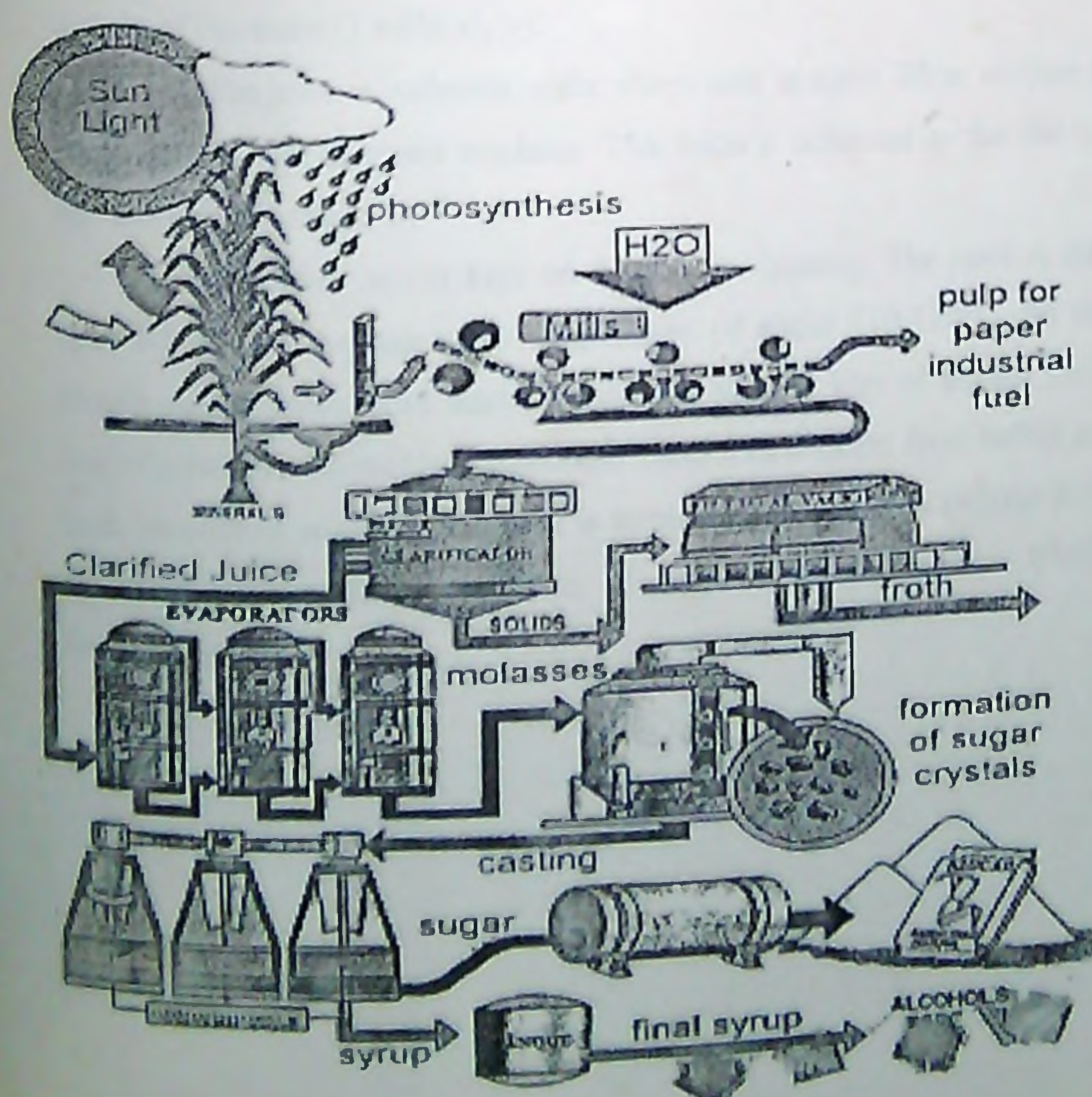
Evaporation: This evaporation station consist of 3, 4 or 5 connected vessels known as triple effect evaporators. Each vessel contains a cylindrical body with calendria tube. Through this tube only, all juice is flowed, heated and driven off. The clear juice is next evaporated to a sticky consistency known as 'syrup'. This is done by heating of with steam under a vacuum in a series of vessels so arranged that the vapour given often one vessel is used to evaporate the juice in the next vessel, thus economizing steam. The set of vessels is known as a 'Triple effect'. The advantage of evaporating under vacuum is that liquids under vacuum boil at lower temperature than the normal atmospheric boiling point, so that risk of darkening the juice by over heating is avoided.

Crystallisation: When this point is reached the mixture of molasses and crystals, which is known as massecuite (French = cooked mass of molasses and crystal sugar) is dropped into long cylindrical vessels in which it is stirred. While it cools. During cooling further sugar forms on the crystals, which is why these vessels are known as 'crystalliser'.

Centrifugal process: The massecuite is then taken to small cylindrical vessels in which it is rotated at high speed. The centrifugal machines have perforated sides which are lined with sheets of metal gauge. The centrifugal force throws out the molasses through this lining and sugar crystals are left behind. The sugar in the centrifugals may be washed and steamed, if required, after which it is removed and weighed into bags.

The molasses at this stage still contains a fair amout of recoverable sucrose, so it is sent balk to the pans and boiled again and another crop of crystals is formed and removed as before. The resultant molasses may be sent back again for a further similar treatment. The 'final' molasses is used as raw material for distilling.

Fig. 2. From sugarcane to sugar.



Recently, U.S. has gone over to highly economical process known as 'ABC Process' for producing sugar with a purity of 99.98% (Shahi, 1997). This process has three components like continuous screening, ultra clarification and adsorption.

This is supposed to be a full process that may be more economical than our current system as claimed by the chemical industry. The ABC process has generated lot of enthusiasm among entrepreneurs. Therefore, India's sugar processing technology must be tailored accordingly.

Manufacture of Jaggery

'Gur is the product obtained in concentration of sweet juice of sugar cane with or without prior purification of juice, into a semi solid or solid state'. The important steps are:

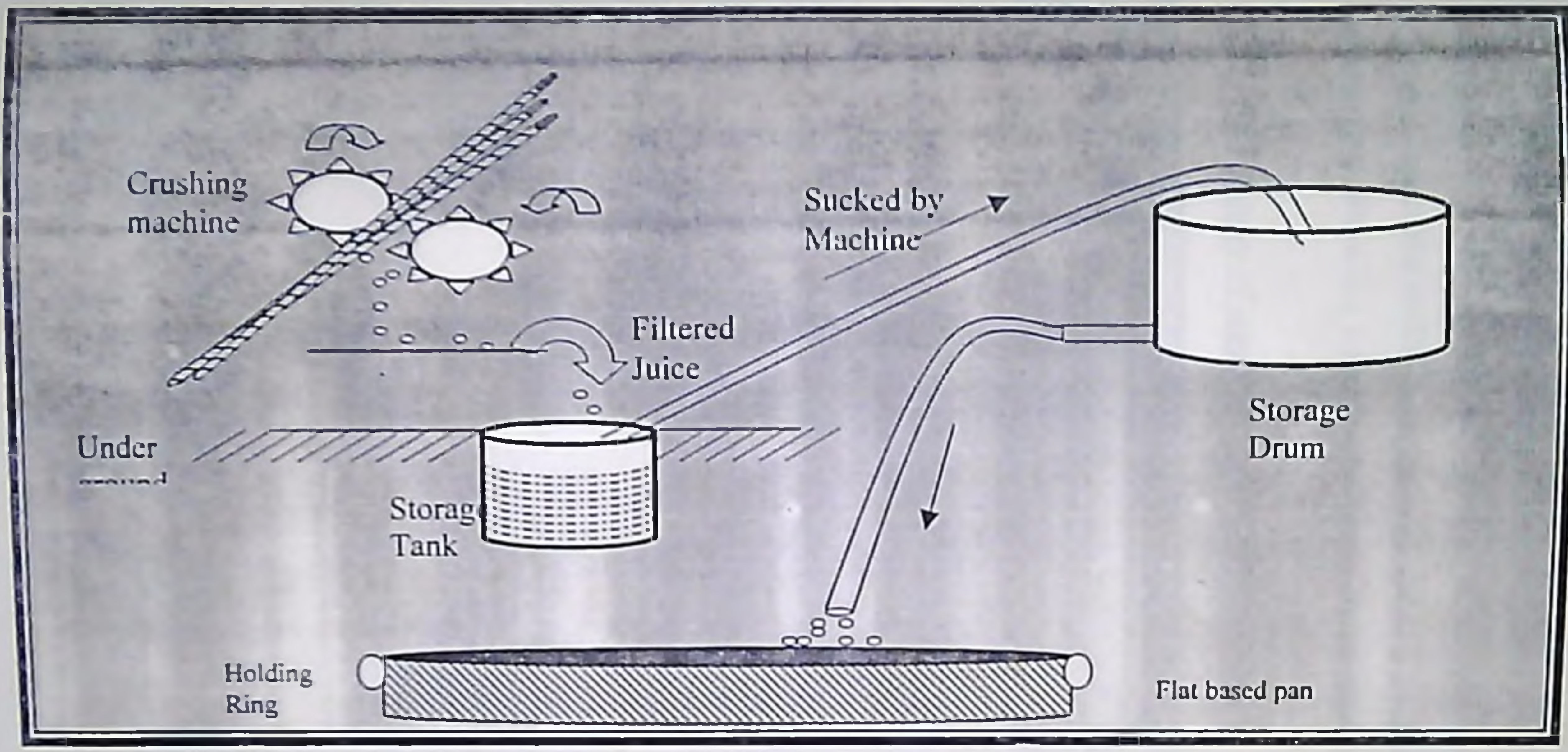
- Extraction of juice
- Clarification of juice
- Concentration of juice

Sugarcane is crushed by a machine. The juice is collected at the bottom of machine, where a storage tank is fixed. Machine can be washed before extraction by help of Formalin (1 ml/lit H_2O).

The juice is collected at the storge tank is again lift to another drum with the help of power operated machine. This juice is collected in the flat based open pan and lime is added.

The open pan is kept on furnace for heating. The juice is start heating upto 4-5 hrs by maintaining a temperature of about 110-120°C. So that after a certain period, when juice starts boiling add about 1 litre of bhendi for every 100 litre of juice. The bhendi is crushed and make it in solution form before adding. The main purpose of adding clarificants is to prevent he inversion process and bring the pH of juice to neutrals, so colour of jaggery becomes good - which is price determining factor.

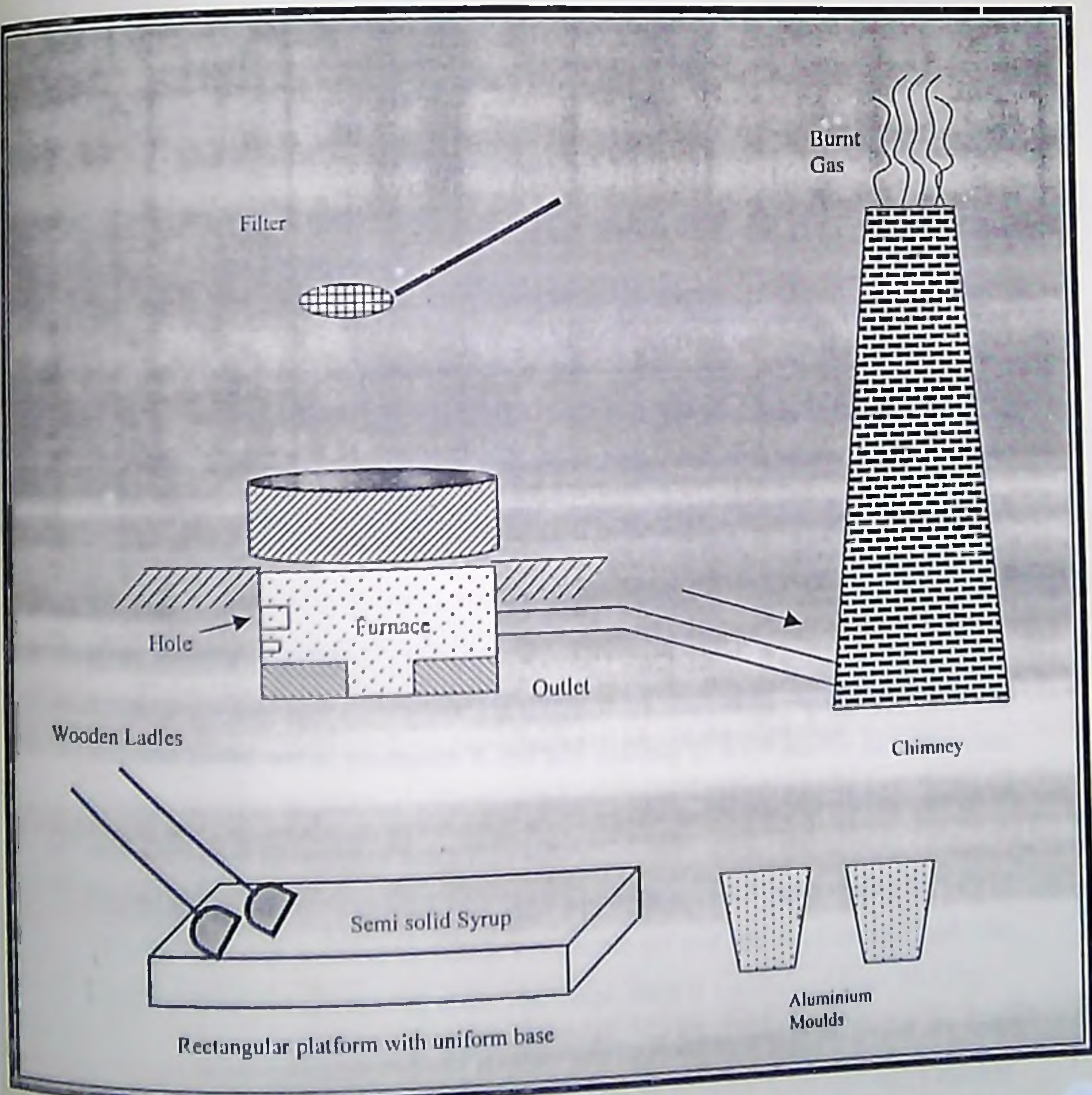
Fig3. Manufacture of jaggery - extraction of juice



One person sitting near big hole of furnace whose duty is to add bagasse and fresh for uniform heating of pan. The remaining burnt gas is connected to chimney through gas will released to atmosphere. The importing are removed by filter while boiling juice.

The heated juice, once it reaching semi solid stages - which is tested by Technician. He will decide the whether it is right stage or not. After reaching semisolid stages the boiled thick mass of syrup is transferred to Rectangular shaped uniform base. Here it is subjected to stirring by wooden ladles.

Fig. 4 Manufacture of jaggery- Concentration of juice



So that it will get uniform cooling and allow to solidify. Before reaching solidify, transfer it to all mould of required shape, size and quantity. Then allowed to store in godowns.

Research conducted by Mungare *et al.* (2000) shows that use of botanical clarificant is safe compare to chemical clarificant. Because, chemical clarificant may contain sulpher dioxide, which is dangerous to human health.

Effect of clarificants in jaggery production

- Chemical clarifcants
  - Lime water
  - Sodium carbonate
  - Alum
- Botanical clarificants
  - Wild okra (*Abelmoschus ficulneus*)
  - Okra (*A. esculentus*)
  - Shuklai (*Kydia sp.*)

Mungare et.al.(2001)

Among botanical clarificant, wild okra shows better result - because of it's higher decolourisation power. Use of wild okra during greeny, fresh vegetative shows good results compared to after drying. After drying, it will loose it's clarificant quality.

Manufacture of RUM

Molasses preparation: Molasses is taken from the tanks and did not it by decontaminated water, pasteurize it and add nutrient to it (N source as ammonium sulphate or urea) to develop yeast population '*Sacharomyces cerevisiae*'. Different strains are used for different alcohol products.

Fermentation: Molasses diluted with H_2O on the ratio of 1:6 just to bring 86°brix to 17°brix. The wash is added by H_2SO_4 to maintain pH and add -1 of urea or feed. The wash is passed through cooling coils. The temperature is maintained from 30-33°C.

In pre-fermentation stage, population of yeast is due to feeing. In later stages, this will undergo in unaerobic condition to produce CO_2 and ethyl alcohol from sugar present in molasses. This is most important step - that is quality and yield are determined.

Distillation

Distillation consist of 5 column modern method steam is fed to bottom of column and causes beer on the lowest plate to boil. Vapours comes to 2nd plate, on when some are condensed and some pass to 3rd plate and so on vapours form at top of column is liquefied, drawn and place in barrels.

Fig. 5: Manufacture of rum- Fermentation and distillation

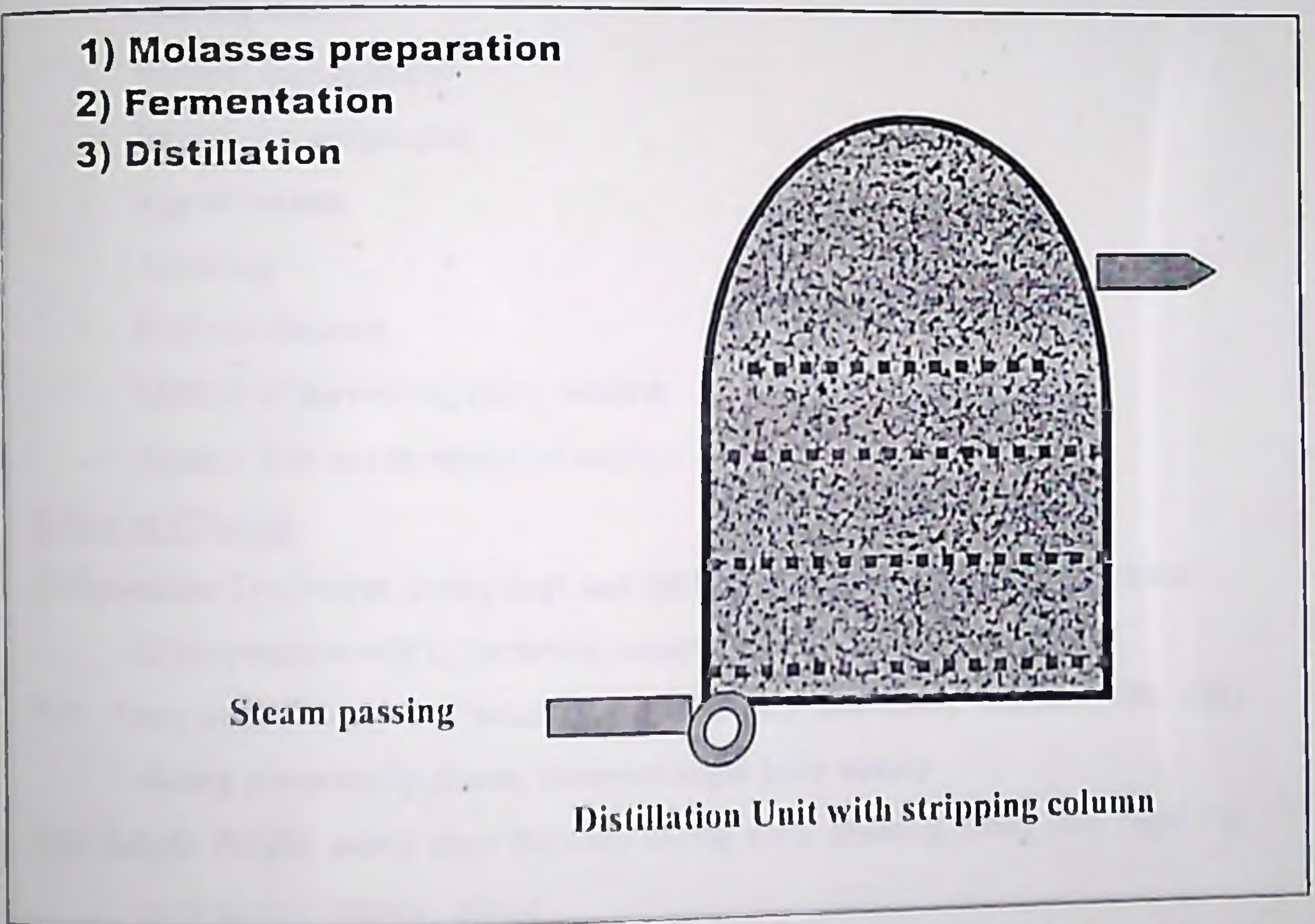


Fig 6 : White oak barrel

Co-operage and Ageing

The distilled alcohol is transformed to barrel made of white oak with capacity of 185 litre. The barrel are kept in big ware house with thermal insulation in order lower the alcohol evaporation during ageing. The wood is porous in nature to allow entry of air. So, free organic acids and alcohols reach to form esters.

This will add aroma and flavour to it.

Blending

Blending is an art rather than science. It is transferred to big stainless steel tanks diluted with demineralised water to attain a required strength, i.e. to lower the alcohol content.

Bottling

Insoluble substances are allowed to settle, and after several days the rum is drawn off, filtered and bottled.

Factors affecting cane yield and quality:

- Climate
- Planting season
- Nutrient management
- Irrigation management
- Age of harvest
- Arrowing
- Pest and diseases
- Method of harvesting, transportation
- Sucrose loss due to microbial action

Effect of Climate

Temperature: Dry, warm, sunny days and cool clear nights during maturity - ideal

If temperature >40°C, Inversion occurs

RH: Temperature fairly hot weather (about 30°C) and moist climate (70% RH) during pre-maturity phase, increases sugar juice quality

Day length: Bright, sunny days required during early planting. Long cool night - is ideal during maturity phase

Rainfall: The rainfall during maturity period, leads to watery shoots. This leads to utilization of sucrose to development of watery shoots

Climatic influence

An ideal climate for sugar cane should have two distinct weather conditions viz. 1) growing season which is long and warm with adequate rainfall or irrigation, long hours of bright sunshine and higher relative humidities which permit rapid growth to build up adequate yield. 2) Ripening season of around 2-3 months duration having warm days, clear skies, cool nights and relatively a dry weather without any rainfall for build up of sugar. However, such ideal conditions are not found in all the sugarcane growing regions.

Temperature: Optimum cane growth is achieved on temperature between 24 and 30°C. A temperature less than 5°C is harmful even to resistant varieties. Temperatures above 38°C reduces the rate of photosynthesis and increase respiration. At temperatures above 35°C cane appears wilted irrespective of water supply. A mean day temperature of 12-14°C would be highly desirable for proper ripening. At high temperatures reversion of sucrose into fructose and glucose may occur, thus leading to less accumulation of sugars.

Rainfall: Sugarcane is grown under varying rainfall situations, from nil in certain parts of peru (where it depends fully on irrigation) to over 350 cm per year in some parts of Hawaii. Even in India, it is grown in areas ranging on rainfall of about 600 mm to 3000 mm. The crop can survive normal variation around a mean of 1200 mm. For obtaining high yields, a rainfall of 2000-2500 mm per annum, evenly distributed is considered ideal.

During the active growth period rainfall encourages rapid cane growth, cane elongation and inter node formation. But during the ripening phase, it is not desirable as it leads to poor juice quality, encourages vegetative growth, formation of 'watery shoots' and increases the tissue moisture.

Relative humidity: Moderate values of 45-65% coupled with limited water supply is favourable during the ripening phase. However, high humidities coupled with warm weather favour good vegetative growth.

Sunshine: Sugarcane is a sun loving plant. Therefore greater solar radiation (sun shine) favours higher sugarcane and sugar yields. The effect of sunshine is modified by temperature which is altered by latitudinal position. About 7-9 hours of bright sunshine is highly useful both for active growth and ripening.

Frost: In some parts of the north western India, the problem of extreme cold weather conditions are confronted. Severe cold weather inhibits bud sprouting in rations and arrest cane growth. At temperature $^{-1}$C - 2°C, the cane leaves the meristem tissues are killed.

Wind: High velocity winds exceeding 60 km/hr are harmful to grown up cares leading to lodging and cane breakage. Also, leaves are damaged even at early stages. Winds enhance moisture loss from the plants and thus aggravate. The ill effects of moisture stress.

Effect of planting season:

The planting season are found to affect the quality of juice because the age of cane at harvest is governed by planting season. Choosing appropriate season for growing sugar cane is an essential steep to raise a successful crop. The 'Adsali' and 'Eksali' planted canes are harvested after one year and because of a higher atmospheric temperature through the growing period, the canes are found poor in sucrose content and high in glucose content.

The experiment by Yadav *et al.* (1986) on effect of planting season, based on various multi location trials involving over a season has been found that October to March planting ideal for higher CCS% in North India, July to October and January to February is suitable for central India and for south India, except hot summer; planting can be done in all months

Table 3 :Effect of planting season to maximise sugar recovery

Regions	Suitable Planting Month
South India	All months except hot summer
Central India	July, October, Jan - Feb
North India	December to February

Yadav (1993)

Effect of time of application of Nitrogen:

Nitrogen is the key nutrient element influencing sugarcane yield and quality. It is required for vegetative growth i.e., tillering, foliage formation, stalk formation, stalk growth, and root growth.

Time of nitrogen application seems to have its great impact on the quality of juice. Late top dressing with nitrogenous fertilizers result in more glucose and molasses content in the juice which impairs the quality.

Research conducted by Srinivasan *et al.* (1998) shows that by delaying the nitrogen application beyond 120 days, considerable loss in cane yield occur. This is mainly due to higher mortality of tillers caused by lack of adequate nutrients at the cane formation stage.

Table 4: Effect of time of application of N on yield and juice quality

Time of application of N	Yield of cane (t/ha)	Sugar Recovery (%)
45 and 90 days	98.98	11.48
45 and 120 days	99.60	11.00
45 and 150 days	92.17	10.51
45 and 180 days	87.02	9.79

Srinivasan *et al.* (1998)

Effect of Biofertilizers:

Biofertilizers or bacterial cultures are essentially a supplemental source of organic nitrogen to inorganic fertilizers. There are at least 96 species of free living bacteria of which one belonging to the group of Azoto bacter has been recognized as efficient biofertilizer in agriculture.

Table 5: Effect of bio-fertilizers on cane yield and quality

Treatments	Cane yield (t/ha)	Sucrose (%)
Well drained soil		
75 % N +Azospirillum	148.50	16.50
75 % N + Azotobacter	112.00	14.95
100 % N + Control	131.00	14.60
Sandy loam soil		
75 % N +Azospirillum	103.30	17.93
75 % N + Azotobacter	105.20	18.50
100 % N + Control	99.00	16.92

Srinivasan *et.al.* (1995)

A soil bacteria, Azospirillium possessing many advantages over Azotobacter is also used in sugarcane. It is considered to be an 'Associative symbiotic' nitrogen fixing bacteria and has a very high nitrogen fixing potential by living in the root tissues.

Research conducted by Srinivasan *et al.* (1995) shows that 'In well drained clay soil, where moisture is not a limiting factor, Azospirillium is better. In candy soils, Azotobacter is better source.

Effect of potassium:

Though the potassium uptake by a sugarcane crop is high, it is not necessary to apply a fertilizer dose equal to that of crop removal. Every soil is capable of supplying the crop requirement of K to some extents. Therefore it is sufficient if part of the crop removal is applied to soil as fertilizer. Potassium maintains the turgidity of plant cells, low availability of K decreases moisture content in plants. Therefore, K application is very necessary.

Experiment conducted by Tiwari and co-workers (1996) show that application of 50 kg/ha potassium is optimum for getting higher cane yield.

Table 6 : Effect of Potassium on yield and quality

Dose (kg/ha)	Cane yield (t/ha)	Sucrose %	Potassium uptake(kg/ha)
50	78.0	18.88	184.30
100	79.00	18.99	200.70
Control	64.5	18.61	162.90
CD (p=0.05)	3.7	0.05	17.90

Tiwari *et.al.* (2000)

Effect of time of application of 'K'

Absorption of K by sugarcane is most active after 4 months age during grand growth period. During this period, about 85% of K_2O is absorbed. Therefore, potassium fertilizer will be have to be applied in such a way that its availability is maximum during the grand growth stage of the crop.

Research conducted by same author in different combination of potassium treatments - results shown that split application of potassium at ½ at basal and ½ at onset of monsoon will better yield.

Table 7: Time of application of [illegible] on yield and quality

Application time	Cane yield (t/ha)	Sucrose %	Potassium uptake(kg/ha)
Full basel	74.30	18.80	177.80
Two split	76.30	18.82	185.00
CD (p=0. 05)	0.3	0.08	2.80

Tiwari *et al.* (2000)

Role of Micronutrients:

Iron, Manganese, Zinc, Boron, copper, molybdenum, aluminium and silicon are some of the micronutrients found to play a major role in sugarcane production influencing the cane yield and quality. These elements through not essentially constitute the plant parts, assume catalytic role in plant metabolism through enzyme mediated process. Therefore, micronutrients play a major role in sucrose accumulation, fibre content and efficacy of nitrogen, phosphorus, and potassium fertilization on cane yield and quality, either alone or in combination (Ramanujam, 1995).

Iron chlorosis is one of the major micronutrient problems observed, particularly time induced chlorosis in calcarious soils. This could be connected by spray application of ferrous sulphate at 0.5% - 1% concentration.

Another problem of Zn deficiency can be corrected by 0.5% $ZnSO_4$ spray on crop.

Effect of Irrigation:

Sugarcane being a long duration crop producing huge amount of biomass, requires large quantity of water. It is mostly grown as irrigated crop.

There are 4 distinct growth phases of sugarcane like germination, tillering, grand growth stage and ripening stage. Water requirement and thus irrigation scheduling vary distinctly during these phase of sugarcane. Approximate water requirement of a 12 month sugarcane at each growth phase is indicated below (Singh, 1988).

Germination (0-45 days) => 300 mm

Tillering (45-120 days) => 550 mm

Grand growth phase (120-270 days) => 1000 mm

Ripening phase (270-360 days) => 650 mm

Table 8: Effect of irrigation on cane quality.

Varieties	Irrigated	Semi-irrigated	Rainfed
	CCS %	CCS %	CCS %
CO 740	8.51	8.43	7.30
CO 740	9.65	8.70	7.60
CO 8021	8.51	8.21	6.28
CO 8021	9.56	8.52	7.74
Co 7805	8.92	8.85	6.38
Average	9.03	8.52	7.06

Rajkumar &Kuntia (1997)

In most instances, the crop plants require an optimal moisture regime. Any deviation from this optimum results in adverse transpiration rate leading to poor growth and yield reported by Yadav and Verma (1986). Research conducted by Rajkumar and Kuntia (1997) shows that increase in yield and CCS% in irrigated condition compare to semi irrigated and rainfed.

Effect of age of harvest V/S CCS%:

Mother plants and primary tillers have more sucrose content than the secondary and tertiary tillers which is primarily because of the age. Thus the quality of individual tillers is not always uniform.

Yates (1996) reported that delaying the harvesting mature cane losses about 1/3rd of a unit of rendement per one month.

The growers have to retain the crop beyond 12 months for various reasons. Under such situation, the sugar which had already accumulated undergoes inversion and ultimately reflects on quality decline. Hence a study has been undertaken to quantify the loss of quality under delayed harvest.

The research conducted by Vijayaraghavan (1998) shows that 12th month old sugarcane plant is optimum for harvest of cane to get higher yield and higher CCS%.

Table 9: Effect of age of harvest on cane quality.

Varieties	Commercial cane sugar % at months				
	10th	11th	12th	13th	14th
CoSi 86071	12.31	12.40	13.57	13.19	10.42
Si.81610	12.76	12.78	12.95	12.59	10.52
Si. 86098	11.68	11.95	13.58	12.07	11.35
Grand mean	12.50	12.71	13.44	13.14	10.99
CD (p=0.05)	0.77	0.83	0.40	1.19	0.69

Vijayaraghavan (1998)

Effect of ethrel on cane yield and sucrose%:

Uniform maturity or ripening of sugarcane is of paramount importance in achieving higher recovery throughout the crushing season. Ripening is not only an accumulation of sucrose in cane but a complex phenomenon and outcome of number of processes.

Table 10: Effect of Ethrel on cane flowering, yield and sucrose %

Dose (kg /ha)	Flowering %	Cane yield (t/ha)	Sucrose %
0.25	0.7	113.4	19.40
0.50	0.0	85.8	19.06
Control	49.6	98.6	18.18

Rao (1995)

2,4-D, polaris, ethrel and cycocel are some of the important ripeners. Ethrel is another important cane ripener. Under Lucknow condition, ethrel was effective in improving juice quality in cane at lower concentration and at shorter interval after application.

Study conducted by Rao (1995) at Sugarcane Breeding Institute shows that application of ethrel 0.25 kg @/ha at 8 weeks before harvesting increases sucrose 19.4% and also cane yield 113.4 t/ha.

Effect due to close harvest to ground:

Cane harvest must be done very close to the ground side since the lower cane portions are rich in sugar. Close harvest besides giving higher tonnage to the farmer would also give better recovery. One assessment made by Sundara (1998) at Sugercane Breeding Institute Coimbatore indicated that on many occasions about 100 g per stalk of cane is left in the field while harvesting. This means a loss of about 10 tonnes of cane/ha (= 1 tonne sugar) if there is 1 lakh cane population. This method is more advantage particularly where stubble shaving practice is not followed.

Method of harvest and transport:

In developed countries like - Australia, Cuba, Brazil etc. They will crush the cane immediately after harvest of cane. So there will not be any loss of sucrose %. But in India due to gap between cutting and milling loss of sucrose is more. The heavy post-harvest loss is mainly due to inconvenient transport facilities, gap between cutting and crushing of cane, cane stalking microbial infection etc.

Research conducted by Solomon (2000) shows that In India, cane is harvested manually and 70 per cent transport done by cart bullock - which leads to post harvest loss.

Table 11: Effect of method harvest & transport on post harvest loss.

Country	Mode of harvesting	Mode of transport (%)			Post harvest losses
		Tractor	Train	Bullock cart	
Australia	M	10	90	-	Low
Cuba	H or M	10	90	-	Moderate
Brazil	M	30	70	-	Moderate or High
India	H	30	-	70	High
USA	M	100	-	-	low

Solomon (2000)

The same work was supported by another scientist Rao (1995) reported that 2 per cent decline in recovery after every delay in crushing of 72 hrs.

Sucrose loss due to microbial infection:

Studies conducted by Solomon (2000) to assess the microflora on cane revealed the presence of approximately 50 different micro-organisms. Among all, Leuconostoc sp. is

more important. This bacteria enters the cut end of cane and infects juice quality. Infection is found heavier if the cane harvested in the early morning. Massive infection is found upto 6 inches from the cut end after about one and half hours storage.

These organisms form nodular colonies after multiplication, under favourable conditions by converting sucrose into polysaccharides such as 'Dextran'. One report says that every 0.1% dextran produced represents sucrose loss of 0.04%.

Recently, IISR, Lucknow released a new chemical 'Sucroguard' - which reduces 70% microbial infection and increases 0.9% sugar recovery (Solomon, 2000).

Effect due to pest and diseases:

Loss of sugarcane crop due to the different type of borers was more in weight of cane than in the quality of cane.

Attack of scale, mealy bug, pyrilla and whitfly are responsible for reducing sugar content, germination of cane, both tonnage and sucrose per cent and sugar content respectively (David, 1995).

Shoot borer, top borer and inter node borer etc. are causing low juice quality. Pyrilla is most destructive foliage sucking pest.

Effect due to cultural operations:

Some of the operations like detrushing, wrapping, removal of late shoots, defoliation etc. are some of the operations that have their indirect effect on quality of juice (Singh, 1988). Leaf pruning results in poor recovery and the extent of deterioration has been found proportional to the degree of pruning. Earthing and an increase in depth of planting in furrows have been found to increase the sucrose per cent in the cane juice. Burning of canes in the freed delays the natural process of inversion due to the temperature effect on the enzymes and thus it improves the juice quality in sugarcane (Kakde, 1985).

Conclusion:

So for presented starting from planting to processing - The factors which are affecting on sugar cane quality and yield.

Also presented the manufacturing processes of sugar, jaggery and rum.

Hope that a better understanding of both external and internal factors which are affecting quality of cane, would be of great useful to everyone.

Those who have engaged in sugarcane production, those who have engaged in sugarcane processing, one should adopt that "First cut cane should crush first" - This is the only massage to world sugarcane growers.

Discussion:

1) *Why North-Indian canes having higher recovery?*

Sugarcane requires extremely cold conditions for maturity, and only then higher sugar content on cane juice can be obtained. Usually, planting of cane starts from October-November to January-February in North India. So, when crop reaches harvesting stage in next December-January, during this stage climatic conditions are very favourable - with low temperature, cooler nights, greater sunshine hours and fairly wide diurnal variation in temperature etc. These conditions favour higher sugar accumulation (Singh *et al.*, 2000).

2) *Among Botanical and Chemical clarificant, which are more safer?*

Chemical clarificants may contain sulpher dioxide or any chemicals compounds which are dangerous to human health. But use of botanical clarificant have no problem. For example, wild okra shows better result because of its higher decolourisation power care should be taken that, we should use this one during greeny, fresh vegetative stage.

3) *Among bold and fine sized crystals, which one will get higher price?*

Bold sized sugar crystals will get higher price compare to fine sized crystals.

4) *What are important diseases of sugarcane?*

1. Red rot caused by fungi *Colletotrichum falcatum*
2. Smut caused by fungi *Ustilago scitaminea*
3. Wilt caused by fungi *Fusarium moniliformae*
4. Bacterial Ratoon disease - *Clavibacter xyli*

5) *Other than alcohol preparation, what are uses of molasses?*

Molasses can be used as fertiliser and as animal feed. It is used as a media for microbial growth. It is used for production of Acetic acid, Citric acid, Lactic acid, Glycerol and yeast. And also in production of high protein food yeast '*Torulopsis utilis*' (Blackburn, 1984).

6) *What is 'Sucroguard'?*

Recently, Indian Institute of sugarcane Research has developed a new chemical formulation 'Sucroguard' - which reduces 70% microbial infection and increases 0.9% sugar recovery.

Since many scientists reported that, sugar recovery is low in India due to delayed crushing and also due to microbial infection after harvest of cane. One bacteria *Leuconostoc* enters the cut end of cane after harvest and infects the juice quality. To avoid this infection; sucroguard has developed (Sundara, S. 2000).

7) *How Indian farmers getting higher economic return by increasing juice quality?*

In developed countries, price is given based on their sugar recovery per cent. If the recovery is high, farmer will get higher price and vice-versa. But in India, actually system itself is wrong. Here farmers are getting money based on the cane weight but net on recovery basis. i.e. quality of cane is not considered. Even if the farmer's cane having higher recovery, he will get low price compare to developed countries. So, Indian farmers are losers.

8) *Is there any recent improvement in sugar manufacturing process?*

Yes. U.S. has developed one method i.e. 'ABC process' for producing sugar with a purity of 99.96%. This method involved 3 steps like - continuous screening, Ultra clarification and adsorption.

This method is more economic than our current system which having purity of only 96-98 per cent. This 'ABC process' has developed lot of interest among entrepreneurs.

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MECHANISATION IN RICE PRODUCTION PROBLEMS AND PROSPECTS

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SEMINAR REPORT

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THRISSUR

ABSTRACT

The area and production of rice in Kerala is at a declining trend in the past few decades. Paddy land is being converted for several purposes in our state as the traditional methods of cultivation is not profitable. The percentage of agricultural labourers to the total labour work force in Kerala is also sharply declining. Partial or complete mechanization is a solution to the problems associated with it.

Ahamed and Sivaswami (1994) has suggested a technically feasible and economically viable farm mechanization package for rice farms in Kerala. Different machines for different cultural operations in paddy cultivation are available in the state. But the twin constraints like poor investing capacity of the farmers and lesser holding size of paddy field always limits rice mechanization. There is a lack of awareness among the farmers about rice machinery with respect to its technical operation, available and use. After sale service centres are also not available. The suitability of machinery with respect to land also hinders introduction of more machines.

Rice mechanization has several advantages like time saving, reduction in drudgery, improvement in productive efficiency of resources and increase in the profitability (Veerabadran *et al.*, 1999).

All the cultural operations in rice cultivation can be completely mechanized. Hundred per cent mechanization has been achieved in land preparation. Several machines, though not ideally suited for Kerala conditions, have been introduced for rice cultivation. Varying agro-ecological situations and size of holdings of rice fields necessitates modifications of machinery to make them suitable to our conditions. Establishment of customary service centres and entrepreneurship development programmes for unemployed youth to start these centres are a few frontier areas where sufficient research and development activities are urgently needed.

INTRODUCTION

Rice is the staple food of more than 60 percent of the world population. It is also the most important crop in India, cultivated in almost all the states. About 90 percent of the rice grown in the world is produced and consumed in the Asian region. Area and production of rice in Kerala is showing a declining trend (Table 1)

Table 1. Area and production of Rice in Kerala

	90-91	91-92	92-93	93-94	94-95	95-96	96-97	98-99
Area (Lakh ha)	5.59	5.41	5.37	4.57	5.03	4.71	4.30	3.70
Production (Lakh t)	10.86	10.60	10.84	10.03	9.75	9.53	8.71	7.71

(The Hindu, Survey of Indian Agriculture, 1999)

Millions of farmers in India still rely on traditional tools and methods of production. In Punjab and Haryana, where modern technologies are used, the soil and climatic conditions have been fully exploited and a yield level of 12t ha^{-1} has been achieved. By 2025 A.D., the production has to be increased by 65 percent from the existing area with the same amount of water and inputs so as to meet the demands of the growing population.

Skillful utilization of resources and mechanisation should be employed to achieve this objective, which will boost up the rice production, productivity levels and the employment potential. Mechanisation includes application of engineering and technological developments to do a job better, more precisely and to improve productivity. Effective mechanisation contributes to increase in production in two major ways: firstly the timeliness of operation and secondly the good quality of work.

The aim of mechanisation should consider all the factors to meet the short term and long term objectives. The attitude of farmers towards mechanisation, in areas where other developments are taking place are more positive than the farmers in less developed regions. It mostly depends on the availability of credit, cash flow and the social status attached to the machinery. So the machines should be introduced taking into consideration the perception of the farmers.

Rice production system globally has undergone changes in terms of the application of inputs to achieve higher level of productivities. Mechanisation in rice production has advanced considerably even in India. The level of mechanization in states like Punjab, has gone far ahead than the national average.

Level of mechanisation

The initial research was aimed at the improvement of bullock drawn equipments. A major operation, harvesting is mechanised to 0.71 percent and threshing to 11.06 percent. The sowing was done with seed drills on 68 per cent of the area. Interculture was done by weeders covering only 4.7 per cent (Srivastava and Srivastava, 1993) (Table 2).

Table 2. Comparative level of mechanisation of farm operations in India

Operation/Machinery	Population ('000)	Total area covered in ha	Percentage of total cultivated area covered (142 mha)
Tillage			26.84
Tractor	1140	17.10	12.04
Iron plough	7005	21.01	14.80
Sowing			
Tractor drawn seed-cum-fertiliser drill	619	9.28	26.53
Plant protection			
Sprayers & dusters	2850	34.20	24.08
Harvesting			
Reaper	24	0.37	0.29
Combine	5.25	0.53	0.42
Threshing			
Paddy thresher	270	1.62	2.70

(Srivastava and Srivastava, 1993)

Land preparation

Tractors and power tillers are available, which is recognised as, an important factor to achieve higher production per unit area. Tractor population in Indian farms is also showing an increasing trend for the past few decades (Table 3).

Table 3. Tractor population on Indian farms ('000)

Year	1978	1980	1982	1984	1986	1991	1994	1997
No.	369.9	452.3	595.1	752.5	850.5	1000	1300	2000

(Gajendra Singh, 1998)

Tractor is a self- propelled machine, used either for pushing loads or for stationary belt works. As farmers were demanding a cheaper alternative, Kerala Agricultural University has developed a low cost 5 Hp garden tractor with a rotary tiller using locally available components, which costs half the cost of a commercial power tiller. It can be operated up to a depth of 15 cm with an effective width of 32cm. The field, capacity of the machine was 0.054 ha hr^{-1}. The unit could be used for dry land ploughing (Jose, 1990).

Power tillers

Power tiller is a multipurpose hand tractor designed primarily for rotary tilling and allied farm operations. It is also known as garden tractor, hand tractor or a 2- wheel tractor. In recent years, the sale of power tillers has grown from around 3,000 units till recently to 20,000 units during the 9^{th} five year plan. The growth of power tiller industry has been sidelined because of the popularity of tractors.

In India, about more than 50 percent of the power tiller marketing is concentrated in Kerala Agro Machineries Corporation Ltd. (KAMCO). Mainly 2 types of tillers are manufactured by KAMCO. One model is for tillage purpose and the other is for transportation of materials. To the first model, rotavator is attached. This tiller can also be used for leveling, constructing bunds etc. For these purposes, accessory materials are attached. These accessory materials include, two different types of steel wheels for different soil types, a tailskid for operation in flooded paddy field, leveller for levelling the ground, ridger for construction of bunds and trailor which can be attached to this tiller. The average turn over of a power tiller with cage wheel and rotary tyne attachment is 0.1 ha hr^{-1} for two round ploughing.

Puddlers

Puddling is defined as the process in which the soil loses its granular structure and become deflocculated. Puddling reduces leaching of water, kills weeds by decomposing and facilitates the transplanting of paddy seedlings by making the soil softer. Puddling is done in a standing water of 5 to 10cm depth in the field, which has already received one ploughing with the mould board plough. The field should be ploughed and levelled by a planker or leveler before transplanting. An indigenous plough is used in the absence of a puddler. Puddlers are classified as

1. Hand operated 2. Animal drawn and 3. Tractor drawn puddlers.

Rotating blade type puddlers are the most effective type available in the country. In South India, the open blade type implement is commonly used. The latest designs of puddler reported are cono puddler of IRRI, APAU puddler of Andhra Pradesh, float disc harrow of CRRI (Datt *et al.*, 1986) and disc harrow - cum puddler of PAU. These puddlers were able to reduce the operational time to 20 hours per hectare compared to 75-100 hours required in case of puddling operation with country plough.

Drum Seeder

The manually drawn drum seeder is light in weight and has a simple mechanism. It consists of four sheet metal drums with holes to meter the seeds, two floating skids and a centrally mounted ground wheel that drives the drums. The seed rate requirement for drum seeder was 80 kg ha^{-1} as against 100kg ha^{-1} for broadcasting (Ventkatachalapathy, 1997). Studies on the use of drum seeder have brought out many advantages. Cost reduction, faster growth and establishment, easiness in interculture, lesser seed rate and higher yield compared to broadcasting.

Wet and dry seeder

Wet seeding is the common practice in the state, especially in irrigated rice farming, where dry seeding is not possible. Sprouted seeds can be dropped from hold drums of the wet seeder at the required spacing. For dry seeding, the land suitability should be considered. Drum seeding results in additional grain yield.

Dibbler

Dibbling means placing 2 or more seeds in holes made to definite depth and covered with soil. Compared to drilling, the seed requirement per unit area is reduced.

A power operated dibbler for dry sowing of paddy was developed and tested by Jayarajan (1996). Emphasis was to develop a power operated dibbling mechanism for paddy sowing at the desired spacing and depth. Dibbler consisted of 2 seed boxes, metering mechanisms, opening mechanisms, dibbler wheels, seed tubes with plungers, transport wheels and a frame with suitable arrangement to be pulled by a power tiller (Table 4 and 5)

Table 4. Spacing between hills (cm) with power operated dibbler

	I	II	III	IV	V	VI	VII	VIII	IX	X
	20.5	21.0	21.5	20.0	20.5	20.0	21.5	20.5	20.0	21.5
	20.0	21.5	21.0	20.0	20.0	21.0	21.0	20.0	20.0	21.0
	21.0	21.5	21.0	20.5	20.0	20.5	21.0	20.0	20.5	21.0
	20.5	21.0	21.5	20.5	20.5	20.0	20.5	20.0	20.5	21.5
	20.0	21.0	21.0	20.0	21.0	21.0	21.0	20.5	20.0	21.5
Mean	20.4	21.2	20.2	20.2	20.4	20.5	21.2	20.2	20.2	21.3
S.D.	0.37	0.24	0.25	0.24	0.37	0.44	0.25	0.25	0.25	0.25

(Jayarajan, 1996)

Table 5. Germination percentage with power operated dibbler

	No. of seeds dropped	No. of seeds germinated	Germination percentage
Plot I	54	48	88.89
Plot II	46	41	84.13
Plot III	49	42	85.71
Plot IV	55	48	87.27
Plot V	46	39	84.78
Average	50	43.60	87.16
S.D.	3.85	3.72	1.71

(Jayarajan, 1996)

The spacing between hills varied from 20-21.5 cm. The dibbled seeds had an average germination percentage of 87.16. The maximum depth of sowing was 4.6 cm.

A manually operated 3 row paddy dibbler for dry sowing was developed and tested by Bini (1992). The machine consists of seed box, roller with metering mechanism, seed tube with furrow opener, frame and a handle. The percentage losses of seeds after germination was 9.52. 3 seed boxes with a total capacity of 4kg paddy seeds were fabricated and assembled on a main frame with other components. There was no covering device in this unit. When the dibbler was taken out from the soil, the seeds would be automatically covered with surrounding soil.

The observed spacing between the hills varied from 10 to 13.5 cm. Manual dibbling is done in a bending position which is arduous to the farmer. But in the present design of dibbler, a suitable handle is provided which ensure easy and comfortable operation in a straight posture. The cost of sowing one hectare of land was Rs. 717/- while for manual dibbling the cost was Rs. 919/ha.

Seed drill

Drilling is the dropping of seeds in the furrow through seed tubes. Metering of seeds may be done either manually or mechanically. The development of seed drills was reported as early as 1968. For sowing rice, single, two and three row seed drills of manually pull type and 3-row seed-cum fertiliser drill or 5-row seed drill of bullock drawn type and a tractor drawn seed drill have been developed, at CRRI. These can sow seed in lines and cover more areas in unit time.

According to the power employed, they may be called animal drawn, tractor drawn or self propelled ones. A seed-cum-fertiliser drill performs the mechanical functions like,

1. It opens the furrow to a uniform depth
2. It meters the seeds and drops uniformly at a desired depth without injury.
3. It meters the fertilisers and drops at a desired depth and
4. It covers the seeds and compacts the soil around.

The nine tyne cultivator cum seed drill costs nearly Rs. 27,000/-

Transplanters

Seedlings are transplanted in a puddled field, 1 to 3 days after ploughing, puddling and leveling of the paddy field. Tractor mounted transplanter was developed and evaluated by PAU, Ludhiana. The results indicated that transplanting could not be achieved properly, as the wavy motion is created by tractor wheels on the surface of water resulting in floating of seedlings. They have also developed a self propelled transplanter.

Six row paddy transplanters which use mat-type seedlings were fabricated at PAU. Transplanting by this machine saved 45 percent cost and 60 percent labour as compared to manual transplanting. The average grain yield was 250 kg ha^{-1}, higher than for manually transplanted fields at almost all locations (Garg *et al.*, 1997)

At a time, 8 rows can be transplanted by 8- row Yanchi shakthi rice transplanter. A seed rate between 0.4 and 0.6 kg m^{-2} was sufficient to produce a mat having seedlings at the rate of 3-4 plants per hill while transplanting. Mechanical transplanting required only Rs. 530/ha against the manual cost of Rs. 2300/ha (Beena and Jaikumaran, 1999).

The disadvantages or difficulties associated with this are that missing hills are seen, which is due to more depth of cake or breakage of fingers, while in operation. Floating of seedlings may also occur. Cakes of 50 cm x 21 cm containing rice seedlings are cut from the nursery bed and about 400 cakes are required for transplanting one hectare. A feasibility study conducted at IRRI indicated that it may be too costly for small rice farmers to use power transplanter.

Apart from seedlings raised in mat nursery, conventional seedlings can also be transplanted by a power tiller operated paddy transplanter (Prakash, 1993) A reduction of 296 man hr ha^{-1}, which is 92.5 percent was achieved for transplanting alone, compared to manual transplanting. The net labour saving was about 145 man hrs ha^{-1} (Table 6).

Table 6. Average no. of seedlings hill^{-1}, percentage of missing and damaged hills

Sl No.	No. of seedlings per hill	Missing hills (Percentage)	Damaged hills (percentage)
1	3	6.20	3.62
2	2	7.45	2.52
3	4	8.31	3.82
4	3	4.12	3.92
5	4	5.84	4.35
6	2	8.52	3.63
7	4	5.36	4.82
8	3	7.94	3.35
Average	3.11	6.72	3.76

(Prakash, 1993)

In the trial conducted by Bainu (1990), with a six row rice transplanter for conventional seedlings, the average number of seedlings per hill was 1.91 and the percentage of missing hills was 9.32.

The percentage of missing and damaged hills were 6.72 and 3.76 respectively by this method of transplanting. (Table 7).

Table 7. Percentage of missing hills and average number of seedlings hill^{-1}

No.	Seedlings hill^{-1}	Missing hills
1	1.89	10.0
2	1.99	7.77
3	1.85	10.37
Average	1.91	9.38

(Bainu, 1990)

Kukje mechanical transplanter

This is a walking type light weight transplanter which requires mat nursery for its operation. It is having a hydraulic suspension system and the machine costs about Rs. 1.5 lakhs.

Yanmar mechanical transplanter

This is a riding type machanical transplanter with 4 row, 6 row or 8 row option depending upon the model. Mat nursery is essentially needed for transplanting. The machine costs about Rs. 7 lakhs.

Weeders

Weeders are of two types

1. Japanese Rotary Hoe
2. IRRI type conoweeder

Japanese Rotary hoe

Japanese rotary hoe had root stirring action during the operation which was beneficial for plant growth. When the implement is pushed between rows, the spikes bury the weeds under the soil. It is easy to operate by simply pushing and pulling the unit . It has a wooden handle for convenience in handling and is widely used in many Asian countries. The weeder is lightweight and can easily be carried by a single person. It is cheaper and made of locally available material. After the operation of weeder, the weeds will be incorporated into the soil. It has got a capacity of 0.012 ha hr^{-1}.

2) IRRI type conoweeder

There are two types –single row or double row. The wheels are truncated cone shaped over which teeth are provided. The pair of wheels are rotatably fitted on a long handle. When this is run over the interspaces of paddy, the soil is stirred, uprooting small weeds and puddling the soil. TNAU has modified this cone weeder.

Field trials were conducted by Gajendra Singh (1998) at Ghaghraghat, Uttar Pradesh, to evaluate the weed control equipment in rice. Paddy weeder was introduced 15 days after transplanting. Weed dry weight was reduced to 1.00-1.79 by the treatments compared to 2.68 in the unweeded control.

Sprayers

The common sprayers are,

i) Knapsack sprayer/duster

ii) Plunger pump sprayers

iii) Power operated sprayer cum duster

i) Knapsack sprayer/duster.

These are manually operated sprayers/dusters having tank capacity varying from 9 to 16 litres.

ii) Plunger pump sprayers

Foot sprayers and rocker sprayers with plunger pump attachment is available. Here two persons are required field capacity is 1 ha $8hr^{-1}$. Spray solution is prepared in a separate tank and is sucked through the foot valve of the pump immersed in it.

iii) Power operated sprayer cum duster

The tank made of industrial plastic, generally has the capacity of 10 litres. Unlike the others, this is a low volume sprayer (200l ha^{-1}) and has a capacity of 1 to 1.5 ha $8hr^{-1}$.

Ramachandran (1988) has designed and developed an insecticide applicator for the control of Brown plant hopper. Spraying was carried out at a height of 15-20 cm from the field surface. From the field tests, it was observed that around 450 litres of fluid was sprayed in 8 hours covering 1 hectare. Total cost of the applicator is Rs. 1650/-

Harvesters

Harvesting in paddy is the operation of cutting the straw along with the earhead in order to recover the grain and straw. Manual harvesting with sickle is practiced in most of the rice growing regions. Harvesting by sickles and threshing by manual labour and animal require 40 labourers, out of which 25 are required for cutting and laying the crop. A light weight engine operated paddy harvester with a petrol start kerosene run engine has since been developed. Tractor drawn, power tiller operated or self-propelled reaper harvesters have been developed and proved to be efficient for rice (Srivastava, 1990) Shiny (1997) reported that when the forward speed of power tiller operated paddy reaper crossed 1.2 m s^{-1}, a total grain loss of 9 per cent occurred (Table 8).

Table 8. Average values of total yield, pre-harvest loss sickle loss uncut loss, shattering loss and cutter-bar loss for 1 m^2 area for 5 plots

	I	II	III	IV	V	Average
Total yield (g)	300	300	300	300	298	300
Pre-harvest loss (g)	0.03	0.00	0.02	0.02	0.00	0.02
Sickle loss (g)	2.64	2.64	2.64	2.58	2.58	2.62
Uncut loss (g)	0.24	0.24	0.24	0.48	0.00	0.24
Shattering loss (g)	5.70	6.24	7.68	5.64	7.68	6.59
Cutter-bar loss (g)	5.94	6.48	7.92	6.12	7.68	6.9\82

(Sujatha, 1993)

Based on the study regarding the various losses, it is noted that shattering losses was the maximum (Sujatha, 1993).

Combine harvester

Along with harvesting, threshing and winnowing is also done and the grain is stored in an inbuilt tank. The chaff in the grain is blown out to the harvested field itself and also the straw, which is cut into bits of 30-60 cm.

A study was carried out to investigate the problems associated with the working of a locally made rice combine harvester used by farmers in Thailand. The results infer that the farmers were satisfied with the performance of the machine. The field efficiency of this combine harvester varied from 28 to 92 percent, with an average of 66 per cent (Kalsirisilp *et al.*, 1999).

Threshers

Threshing is the process of loosening the grain from straw. Threshing by manual labour is done by rubbing between two palms or between two legs or beating by sticks or striking against a hard object. Threshing of paddy is carried out manually and to a small extent by treading under tractor tyres. Threshing capacity, loss, efficiency and cost are considered as the most important factors of threshing methods in evaluating their performances. Pedal threshers saved 18-24 per cent cost over hand beating.

A hold on type power operated thresher has the capacity of 45-50 kg grain hr^{-1}, if two labourers are holding the sheaves for threshing. The pedal rice thresher was most efficient when the plants were harvested with seed moisture content below 20.2 percent. Best machine performance was obtained when plants were cut with short straw (Silva *et al.*, 1999).

The pedal operated and the Japanese power threshers were introduced for threshing in India around 1956-57. Later the power operated, spike drum type (Japanese design) and European designs were developed. The hold on type paddy threshers are more popular.

Thresher –cum-winnower

Power operated thresher cum winnower is available now. Axial flow spike tooth or flow through raspbar type threshers can both thresh and winnow and the grain can be directly bagged. Studies conducted at KCAET Tavanur show that 8HP axial flow spike tooth type and 10 HP flow through raspbar type threshers have average output of 50 and 107 kg grains hp^{-1} hr^{-1} for the respective machines.

An axial flow spike tooth type thresher cum winnower, known as "Kumarakom model" is also available in the market. But in this, only short statured crops or earheads with 30-40 cm length can be threshed. Long or medium straw gets entangled inside the drum and obstructs the machine.

Maximum threshing efficiency of 94 percent and maximum output of 340kg ha^{-1} was achieved with double directional spiral cylinder, when the moisture content was 35 percent. The proto type thresher was found to decrease the cost of threshing to 81 per cent and reduction in labour to 85.16 per cent compared to manual threshing (Hamza, 1993).

TRACTOR

POWER TILLER

PUDDLER

PADDY WET SEEDER

TRACTOR DRAWN
SEED DRILL

SELF PROPELLED
TRANSPLANTER

KUKJE RICE TRANSPLANTER

YANMAR RICE TRANSPLANTER

JAPANESE WEEDER

TRIPLE PISTON
HIGH PRESSURE SPRAYER

PADDY HARVESTER

COMBINE HARVESTER

PADDY THRESHER

PADDY WINNOWER

Winnowers

Winnowing is the operation of separating grain from a mixture of grain and chaff in an air stream, created artificially or naturally. Winnower is the most efficient, quick, easy and effective machine that has been designed. It consists of frame, sieves, blower, set of gears, handle, hopper and oscillating mechanism. A winnower run with a 1.5 HP electric motor has the capacity of 100 to 200 kg grain hr^{-1}. The output varies with speed of feeding and size of the winnower. Grain can be passed through the hoppers against an air current caused by a blower. Filled grains and half filled grains are collected separately and chaff is blown off.

Constraints in rice mechanisation

Very often, farm mechanisation is equated with just tractorisation or automation of farm operations. In the Indian context, mechanisation to fully substitute human labour may meet with social dissension. (Veerabadran and Pandian, 1999). Mechanisation has to be done at various levels. But many people are of the opinion that Indian agriculture cannot be fully mechanised due to the common myths prevailing like,

1. There is a surplus of agricultural labour
2. There are enough draft animals available.
3. It is not possible to increase the yield by mechanisation.
4. Mechanisation will not lower the cost of production.
5. It is impossible to mechanise all farm operations.
6. A large labour force will be displaced from agriculture.

One of the major handicaps in mechanisation is the low investing capacity of farmers to buy machines. This can be solved by giving long term loans to the farmers to buy tractors and related farm machines.

From a study on gender concerns in rice farming, Singh *et al* (1991) quote that women who constitute a majority of agricultural labour force, perceive drudgery of work as a major constraint for productive efficiency of labour. They have emphasised the need for light tools and implements for planting and weeding and light machinery for threshing. There is a general assumption that the efficiency of female labour in our farms is lower than the male labour. The agricultural operations in which female labour is mainly found are sowing, inter culture and harvest, which require less muscular exertion.

Farmers are having some other misconcepts also, which present hindrance to effective mechanisation. They believe machines are less efficient as compared to manual labour in operations like weeding, machine operations require skill for its adjustment and repairs and they can break down at times of need etc. A move from conventional to mechanical techniques would lead to the displacement of bullock and human labour in all operations, but to different degrees in different operations.

Available mechanisation technology from the industrialised countries have limited scope of introduction in the developing world. (Ojha and Michael, 1996) Mechanisation will mainly affect the hired labourers, as they will have to face unemployment. It will not create any immediate impact on permanent labourers. However, thinning out of work load of family labour can be considered as a positive aspect

A detailed survey of mechanisation on a 104 ha rice farm was carried out. Timing of the operations is critical to achieve good rice quality. When harvesters broke down, harvesting time increased, rice quality dropped and farm income was therefore reduced. It is recommended that the land suitability aspect should be taken into consideration before the introduction of machines. Machinery should also be readied and maintained well for the harvest. (Je Cheou Chae *et al.*, 1996). According to Tado (2000), the developments in rice mechanisation must consider social and economic backgrounds as well as environmental protection.

Prospects

Crop intensification in rice farming has become a reality with the advent of short duration rice varieties and efficient soil fertility management technologies. For promoting the use of machinery in rice farming, many requirements have to be met. These include, creation of awareness among the farmers, demonstration and training, infrastructure for manufacture, sales and service and easy credit supply. More importantly the mental block that these machines will completely substitute human labour has to be removed (Veerbadran and Pandian, 1999) (Table 9).

Table 9. Cost of cultivation and savings in cost & man hrs ha^{-1} by the introduction of appropriate machinery for paddy cultivation

Sl. No.	Operation	Conventional		Mechanised		Savings	
		Man-hr	Cost	Man-hr	Cost	Man-hr	Cost
1	Transplanting	320	1600	24	800	296 (92.5%)	800 (50%)
2	Harvesting	200	1625	14	348	186 (93%)	1277 (78.6%)
3	Threshing	370	1700	20	800	350 (94.6%)	900 (52.9%)
	Total	890	4925	58	1948	832 (93.56%)	2977 (60.4%)

(Selvan, 1995)

It can be seen that, by the introduction of appropriate machinery for paddy cultivation for transplanting, harvesting and threshing, man-hour saving of 93.56 percent and cost saving of 60.4 per cent was achieved. The greatest saving of cost of 78.6 percent was seen in harvesting (Selvan, 1995).

An operation wise analysis of the effect of selective mechanisation on the economics of production in transplanted, wet seeded and dry seeded was conducted by James *et al.* (1994). The total input cost (Rs./ha) under non mechanised system for transplanted, wet seeded and dry seeded cultivation was 22341, 20941 and 20053 with the B : C ratios of 1.17, 1.25 and 1.31 respectively.

A computer programme was developed, which can select machines to minimise the management and maintenance cost by analysing available working days in different areas, machinery to purchase, farm size, total farm size in a village and the number of machines required for rice production (Lee *et al.*, 1996) (Table 10).

Table 10. Labour requirement in rice cultivation

Operation	Percentage
Land preparation	11.3
Planting	21.0
Crop care	24.2
Harvest	18.1
Threshing	25.4

Veerabadran and Pandian (1999)

Among the operations, planting accounts for 21 percent of total human labour requirement. Harvesting and threshing require 43.4 percent of total labour. Weeding is another operation where human input is high.

IRRI's role in rice mechanisation

The initial efforts were directed to develop a low cost, power operated rice thresher. The 5 row manual rice transplanter using mat type seeds were developed. Rice harvester of self propelled type was also developed and evaluated. Central Government has introduced an integrated programme for rice development, in which subsidies for animal drawn implements and rice transplanter was made 50 per cent.

Situation in Kerala

Paddy cultivation in Kerala needs appropriate mechanisation to cope with the increased cost of cultivation due to high wages and scarcity of labour. Ploughing, puddling and spraying are done almost completely using machinery. Both manual and self-propelled transplanters as well as tractor front mounted reapers and flow through rasp bar threshers are suitable for Kerala conditions (Muhammad *et al.*, 1999).

Table 11. Percentage of agricultural labour to the total labour

	1981	1991	2001
Total persons	28.23	25.66	16.10
Male	23.32	22.61	14.20
Female	43.55	35.76	22.00

(Census report)

The labour available for agriculture is declining as the development of market economy and rural industries have caused migration to the industrial sector (Table 11). This trend will continue in future and full or partial mechanisation has thus become a necessity in rice cultivation, where manual labour input is very high from planting to harvest. Nearly 4500 ha paddy lands are utilised for other purposes annually, mainly because of the non availability of labourers (Jaikumaran *et al.*, 1999). Mechanisation is an important step to attract these labourers.

Ahamed and Sivaswamy (1994) conducted experiments in farmers fields with the objective of suggesting technically feasible packages for rice farms of Kerala. The trial comprised three mechanisation packages namely low (LMP), medium (MMP) and high (HMP) levels. HMP and MMP required lesser labourers resulting in higher net returns than the conventional package. The labour input (Man days) for medium and high level mechanisation packages was 127.22 and 107.88 compared to 136.44 for low level package respectively. In Kerala, as the holding size is very small, costlier machines cannot be introduced.

Labour /Human component

Mechanisation can be used as an effective tool to solve the labour peak problem. Mechanisation of power intensive operations has had minimal negative effects on the labouring class even in labour surplus economies of Asia. On the other hand, the switch over from manual labour to mechanical or chemical technologies for weeding has indeed had adverse effects on employment for low wage countries (Pingali *et al.*, 1998).

Future Thrust

Varying agro-ecological situations and size of holdings of rice fields require suitable modifications of machinery and research should be concentrated in this direction. The working efficiency of transplanters under different systems, mat nursery techniques, main field requirement, modification of sprayers for wider area coverage, workability of combines, workability of reapers under wet situations and lodged paddy are some of the areas which require immediate attention. Group farming system and establishment of after sales service centres by trained unemployed youth will also encourage effective mechanisation.

CONCLUSION

For sustainable growth in agriculture, it is very important to pay special attention to farm mechanisation and in a crop like paddy, there is ample scope for mechanisation. There is a widespread belief that machines will completely wash off the labourers. However, the fact is that machines like tractors and transplanters will provide employment to a set of people who are specialised in their operation. Complete mechanisation in rice cultivation should be achieved with the co-operation and support of the labourers and thereby the productivity should be raised to reach the targeted level.

DISCUSSION

1. How many man days are required for 1 hectare rice cultivation?

   It is estimated that nearly 145 man days are required per hectare of rice.

2. What is the average holding size of an Indian farmer ?

   Around 35 per cent of the farmers have a holding size of less than 0.2 ha.

3. Which are the agencies involved in the manufacture of machines in Kerala?

   The Regional Agro Industrial Development Co-operative of Kerala Ltd. (RAIDCO), Kerala Agro Industries Corporation Ltd. (KAICO) and Kerala Agro Machinery Corporation Ltd. (KAMCO) etc. are the major agencies engaged in the manufacture and distribution of machines. Apart from this, several private institutions are also there.

4. Is there any step taken by the state Government to encourage mechanisation?

   Under the Integrated Cereal Development Programme, 50 percent subsidy is provided to group farming units for purchase of tractors, power tillers, plant protection equipments etc.

5. How can the problem of incompatibility of machines from developed countries solved?

   Suitable field testing and evaluation should be carried out before introducing the machines. Apart from this manufacture of indigenous machines, should also be tried.

6. What is the problem with the operation of the harvester?

   Harvester cannot be efficiently operated when the field is flooded or when the crop has lodged.

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