THREE DECADES OF

RESEARCH ON WATER MANAGEMENT IN KERALA AGRICULTURAL UNIVERSITY

KERALA AGRICULTURAL UNIVERSITY
2005

AGRONOMIC RESEARCH STATION
Chalakudy, Thrissur – 680 307

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FOREWARD

Irrigated agriculture accounts for 38 per cent of the total cultivable area in India. Since the possibility of expansion of irrigated area and irrigation water is limited, growth in future food grain production can be achieved by enhancing performance of existing irrigation system and efficiency of applied water. Judicious conservation and application of this scarce input is important for sustaining the available water resources on long term basis. Hence research on Water management assumes greater significance.

The Agronomic Research Station, Chalakudy was mandated for conducting water management research right from the beginning of its inception in 1962 by the Department of Agriculture. The station was taken over by the Kerala Agricultural University in 1973 for implementing the All India Co-ordinated Research Project (AICRP) on Water Management. The achievements of the station include standardising optimum irrigation schedule for rice, pulses, oil seeds, vegetables and tuber crops. The on farm water management studies in rice conducted by the station were taken as the basis of group farming technology implemented by the Department of Agriculture.

The biennial scientists' meet of the AICRP on Water Management is being hosted by the Kerala Agricultural University for the first time in 30 years. It is appropriate to bring out a compilation of the water management research carried out in Kerala Agricultural University at this juncture.

I am sure that this manuscript will be of benefit to the scientists and personnels involved in irrgation management. I congratulate the scientists involved in this compilation and hope that this will also help in streamlining research in new and efficient ways of utilizing and conserving this precious gift of nature.

Prof. (Dr.) K. V. Peter

Vice Chancellor

Kerala Agricultural University

Vellanikkara

May 14, 2005

PREFACE

Research on water management has gained considerable attention with the recurrence of drought in recent years. Studies on water management and irrigation was started in Kerala since 1962 with the inception of Agronomic Research Station, Chalakudy. Since 1974, the All India Co-ordinated Research Project (AICRP) on Water Management is functioning at this station under the Kerala Agricultural University. In connection with the AICRP Biennial Scientists Meet and National Workshop 2005 we are bringing out this publication compiling the results of water management researches carried out in Kerala Agricultural University. These information were collected from research papers and annual research reports of the University and theses submitted at various colleges.

We hope this will be useful to the scientists and development personals involved in water management and irrigation. Your suggestions to improve the publication, such as omissions to be incorporated, corrections and modifications are welcome.

We place on record with gratitude all the fomer scientists of this station and their hard work while brining out this publication. The authors acknowledge the Kerala Agricultural University, Rubber Board, Kottayam and Indian Council of Agricultural Research for the support rendered to bring out this publication.

Chalakudy,

16-5-2005

Authors

CONTENTS

THREE DECADES OF RESEARCH ON WATER MANAGEMENT IN KAU

1. INTRODUCTION

The production and productivity of an area is determined to a large extent on the availability of water. Stability in production against weather based parameters is achieved by modifying the soil moisture regime by irrigation. Present water management practices cannot be considered sustainable due to the luxurious use of water. About 3000 tonnes and 1000 tonnes of water are used to produce one tonne of husked rice and wheat respectively. Faulty irrigation practices have resulted in problems like pollution of surface water resources, water logging and salinization. Over exploitation of ground water has led to receding ground water table in many areas.

India owns the largest irrigated area in the world. The current irrigated area of 80 million hectares comprises of 38 per cent of the total cultivated area. Most of the future food grain production has to be met from irrigated agriculture only by enhancing the performance of existing irrigation systems and increasing the efficiency of applied water.

The small state of Kerala, is considered to be blessed with a large abundance of water. The narrow strip of land in the southwestern side of India is criss- crossed with 44 rivers, lakes and lagoons. The Arabian Sea running along the western side and the vast stretch of lowlands almost in continuation add to the delusion of bountiful water. Furthermore, the annual rainfall in Kerala is 3000mm, much higher than the national average. But the actual facts present a scenario towards the darker side. The South-West and North-East Monsoon, contributing the lion share in rainfall is effective for six months only. The undulating topography and the anti environmental activities of the overcrowded population act as barriers in reaping the full benefits of this gift of nature.

Farming in Kerala for ages had been a gamble with the vagaries of monsoon. But with the commissioning of Irrigation projects rainfed cropping slowly gave way to irrigated agriculture at least in the command areas. New crops demanding more water were introduced. Though technologies for scientific water management were developed for different crops, they were not being adopted due the fragmented holdings and the ignorance about the diminishing water resources and availability. The gross irrigated area in Kerala is 4.32 lakh hectares, which is only 14.4 percent of the gross cropped area.

As water is becoming scarce, it is becoming increasingly important to conserve the available water. The three major uses are domestic water supply, industry including power supply and agriculture. About two third of water which is drawn worldwide from rivers and ground water is used for irrigated agriculture. Changes in water policy and institutional arrangements and increasing demand from other two sectors will restrict the use of water for agricultural purposes. Because water cannot be stretched further for agriculture, it is faced with the challenges to use water more beneficially and efficiently. A number of on-farm and off-farm measures need to be imposed to use water more efficiently.

The All India Co-ordinated Research Project on Water Management was initiated in Kerala Agricultural University in 1974 at the Agronomic Research Station, Chalakudy. The Station is situated in the command area of Chalakudy Irrigation Project, which is a River Diversion Scheme. The research works in the earlier years mainly centered on basic studies and water management in rice, pulses and oil seeds. Simultaneously, research works were being done on similar lines in other research stations of KAU. This manuscript is an attempt to bring together all the water management research under KAU so as to project the key findings and identify the gaps.

2. BASIC STUDIES

Soils vary widely in the capacity to store water in the plant available form. Meaningful information on this can be had only when the water content is related to soil moisture tension. Much of the soil- to- soil differences in moisture content- tension relations is often accountable as due to differences in texture and organic matter content. Data on texture and organic matter content are more easily gathered than Field Capacity (FC) and Permanent Wilting Point (PWP) and hence it may be worthwhile deriving the latter from information on texture and organic matter content.

i) Soil moisture characteristics of different soils

Soil moisture characteristics curves were developed for major soil types of Kerala namely, laterite (Thulasidharan, 1983), alluvial (Prameela,1984) and red (Mathew, 1985) soils. Soil samples were collected from five depths from 15 soil profiles for each soil type. Moisture retention studies of 2 mm sieved soil were made at 0.3, 1.0, 3.0, 5.0, 10 and 15 bar pressures using pressure plate apparatus. Prediction equations were developed to predict moisture percentage at 0.3 and 15 bars from organic matter content and textural constituents of the sieved soil.

1. Laterite soil

The moisture contents at FC and PWP were 25.2 and 19.4 percent respectively.

Moisture percentage at 0.3 bars

$$Y_1 = -80.988 + 0.7647X_1 + 1.1465X_2 + 1.2407X3 + 0.8974X_4 + 0.9429X_5 \quad (R^2 = 0.38)$$

Moisture percentage at 15 bars

$$Y_2 = -12.9880 - 0.3575X_1 + 0.4033X_2 + 0.5214X_3 + 0.1344X_4 - 0.2714X_5 \quad (R^2 = 0.31)$$

2. Alluvial soil

The overall mean of FC was 25.8 per cent and PWP 13.9 per cent

Moisture percentage at 0.3 bars

$Y_1 = 10.3387 + 0.3405X_1 + 0..3616X_2 + 0.0030X_3 - 0.1170X_4 + 0.0176X_5$ ($R^2 = 0.87$)

Moisture percentage at 15 bars

$Y_2 = 14.11 + 0.4309X_1 + 0.4198X_2 + 0.1575X_3 + 0.1547X_4 - 1.66514X_5$ ($R^2 = 0.31$)

3. Red soil

The overall mean of FC was 10.45 per cent and PWP 7.75 per cent

Moisture percentage at 0.3 bars

$Y_1 = 1.9228 + 0.2920X_1 + 0.3171X_2 + 0.002X3 + 0.0186X_4 + 1.393X_5$ ($R^2 = 0.87$)

Moisture percentage at 15 bars

$Y_2 = 19.8026 + 0.0552X_1 + 0.0352X_2 - 0.1938X_3 - 0.2064X_4 + 0.01635X_5$ ($R^2 = 0.90$)

X_1 . organic carbon content (%)

X_2 – Clay content (%)

X_3 - Silt (%)

X_4 – Fine sand (%)

X_5 - Coarse sand (%)

A similar study on the moisture retention and release characteristics of command areas of Chalakudy irrigation project was under taken from 1982- 83 to 1985-86. Soil moisture retention characteristics of soils from seven depths ranging from 0-15 to 120-150 cm of the major sixteen soil series were evaluated using pressure plate apparatus at various tension values ranging from 0.3 to 15 bars(AICRP 1984-1996).

The study indicated that garden land soils and wetland soils contain appreciable amounts of gravel (6.8 per cent to 45.3 per cent). The main garden crops raised are coconut, arecanut, cocoa, banana, mango, jack, tuber crops etc. The soil textural classes include clay loam, silty clay, silty clay loam, silty loam and sandy clay. The wetlands where paddy was raised belong to clayey soil.

The organic carbon content varied from 0.37 to 1.62 per cent, available moisture ranged from 4.7 to 17.1 per cent, bulk density from 1.1 to 1.36 g cm^{-3} and infiltration rate varied from 0.8 to 21.6 cm h^{-1}. The moisture content was higher in the lower layers than the surface ones in most of the series. The moisture retention decreased steeply from 0.3 to 1.0 bar and gradually up to 5 bars. Wide variation in available moisture content could also be noticed in these soils.

ii) Conveyance loss

Conveyance loss of water is considered to be the major impediment in achieving irrigation efficiency. Lining the irrigation channels with impervious materials could decrease the seepage loss. Hence different lining materials like brick pointed in cement sand, polythene sheet and cow dung mixed with clay were evaluated for their durability, effectiveness and economics. The seepage loss in unlined channel was estimated to be 1.19 litre min^{-1} m^{-2}, which corresponded to 88.5 per cent. The polythene sheet recorded the minimum loss. But its durability was very less compared to brick lined channel. Clay-cow dung mixture was also not durable. Hence the brick lined channel was found to be more economical with regards to durability and maintenance cost (AICRP 1984-1996).

Seasonal fluctuations in water table consequent to irrigation were studied at seven locations representing wet, upland and garden land. Water samples were collected from piezometers, canals and open wells at periodic intervals for chemical analysis of water quality. Soil samples drawn from each location once in a year were analysed for physico-chemical characters. The results of the study indicated that the quality of water with respect to pH, conductivity, bicarbonate and chloride were satisfactory. Carbonate, sulphate and nitrate were absent in all samples. The ground water depth at different locations fluctuated from 1.70 cm to 200 cm in lowland and between 11.5 cm to 200 cm in the upland (AICRP 1984-1996).

Studies were conducted at Chalakudy to find out the possibility of channeling percolation water through subsurface drain for irrigating low lying tail end plots and to estimate the yield of water and area commanded. The results indicated that the drainage water collected through tile drains was sufficient for irrigating 3.646 ha of rice during rabi season and 1.776 ha pulses and oilseeds during summer season (AICRP 1984-1996).

iii) KAU Micro-sprinkler

The research works carried out in the Agronomic Research Station, Chalakudy, Kerala Agricultural University for the development of an affordable, dependable, simple and farmer friendly technology, resulted in a low cost micro sprinkler head, originally named as Bubbler head. Water is delivered through a network of main pipes, sub mains and laterals and falls as a circular spray through these sprinkler heads. It is very simple in design and clog free system, ensuring complete wetting of the basin area of the crop. It can be considered as a unit in between the drip and the mini-sprinkler systems, the discharge rate being 35-45 lph (Sreekumaran et al, 1998).

The rotating sprinkler head is made of a 6cm long piece of 12mm/8mm diameter good quality Low Density Poly Ethylene (LDPE) pipe, plugged at both ends by end caps. Nozzles of 1mm diameter are drilled on opposite sides of the pipe, 5mm away from both ends, with the help of punching tool. A hole of 4.4mm diameter is drilled at the center of the pipe to insert the micro tube pin connector.

The essential components of the system are water source, pumping unit or overhead tank, main pipe, sub main pipe, lateral pipe, micro tube, and sprinkler head as emitter. The maximum allowable length of laterals is 30m, with 15 to 20 sprinkler head units. An area of 1 ha could be irrigated by a 0.5 hp electric motor pumping unit in two stretches. This system of irrigation can be used in coconut, banana, vegetables, medicinal plants, lawns and ornamentals. Fertilizers can also be applied through the emitters.

The area of coverage (wetting area) varies from $3m^2$ to $5m^2$. This can be increased or decreased by adjusting the height of riser pipe, according to the stage of crop growth. The duration of irrigation is fixed as per the water requirement of crops.

Since these units are very light in weight, the energy required to rotate the unit along with water is considerably small and the pressure required for the operation of these units is only 0.3 – 1.0 kg cm^{-2}, which is easily available even from a domestic overhead tank.

Advantages of the system

- No sophisticated components
- Lesser operating pressure than in sprinkler irrigation
- Lesser clogging susceptibility
- Area of coverage is in between drip and sprinkler methods
- More uniform distribution of water in the crop root zone
- Complete wetting of the basin area and providing a cool environment for plant
- No losses due to deep percolation and runoff
- Facilitates application of fertilizers, herbicides and cooling of green houses, poultry houses, cow sheds etc
- Minimum initial investment, running and maintenance costs.

iv) Wetting pattern of surface and subsurface drip.

The flow phenomenon under surface and subsurface drip irrigation was studied by Visalakshi *et al* (2004) by observing the wetting pattern of the soil surface and soil profile under the system. The wetting pattern of emitter flow were studied with emitters of 2, 4, 6 and 8 lph discharge rates applied at the surface and 30cm below the surface of soil. Profiles were exposed by cutting the soil vertically across the center of point of application of the drip, 24 hours after irrigation. The dimensions of the wetted profile in horizontal and vertical directions were measured and recorded. Soil samples at 15cm x 15cm grid points were collected and analysed for moisture contents and distribution pattern.

Generally an inverse relationship was observed between discharge rates and area wetted. The lower the discharge rates, the wider was the area wetted and vice versa. The subsurface application resulted in an increase in soil moisture retention of 3 – 4% at the point of application, compared to that of surface application. The pattern of moisture distribution was almost the same under both the locations of drip emitters. Mathematical models were also developed relating the horizontal and vertical waterfront advance and the rates of discharge.

The models developed were as follows:

Surface application:

$$X = 0.2083q^2 - 2.8475q + 38.225 \ (R^2 = 0.8885)$$
$$Y = -0.0812q^2 - 0.6025q + 29.775 \ (R^2 = 0.9712)$$

Subsurface application:

$$X = q^2 - 14.15q + 79.5 \ (R^2 = 0.998)$$
$$Y = -0.6875q^2 + 4.925q + 34.75 \ (R^2 = 0.9958)$$ Where,

X = horizontal distance from the point of application (cm)

Y = vertical distance from the point of application (cm) and

q = rate of discharge (lph)

iv) *Impact of Irrigation in homesteads*

The results of a field study on the impact of irrigation in small household plots of Thrissur district indicated a higher cropping intensity in irrigated areas. Farmers adopting irrigation were also found to use modern technologies to a comparatively higher extent. The productivity of crops, benefit-cost ratio and labour utilization was higher in irrigated gardens. Some of the constraints identified in irrigation are lack of assured irrigation water supplies, erratic supply of electricity and voltage problem, low water table and financial difficulties (Indiradevi & Geethakutty, 1996)

3. WATER MANAGEMENT OF CROPS

i) Rice

Rice is the staple food of over three million people of Kerala. It is cultivated in 2.25 lakh ha which comes about 96 per cent of the area under food crops. In Kerala, extensive cultivation of rice is concentrated in three pockets – Kuttanad, Kole and Palghat area.

Traditionally rice is grown in low lands where other garden crops cannot be raised. Rice is considered to be the crop having the maximum requirement of water and adapted to submerged conditions. Continuous submergence is the prevailing water management practice in rice. This provides added advantages like weed control, nutrient availability, regulation of soil temperature and alleviation of toxic effects. However, optimum yield potential in rice can be realised under saturated conditions. Water being a scarce commodity with increasing diversified uses, availability of water for irrigation is limited now a days. Experiments conducted in Kerala Agricultural University to find out the optimum water management practice for rice are discussed below.

The optimum water requirement of transplanted rice variety Jyothi from transplanting to milk stage was estimated to be 1700 mm. The work was done at RARS, Pattambi using Drum Culture Technique. The percolation rate amounted to 12.04 $mmday^{-1}$ and Evapo-transpiration (ET) 10.40 $mmday^{-1}$. In another experiment, during the virippu season, the percolation rate was estimated to be 3.9 $mmday^{-1}$ and ET 4.8$mmday^{-1}$. However, during the mundakan season, the percolation rate and ET increased to 7.99$mmday^{-1}$ and 7.32 $mmday^{-1}$ respectively (KAU, 2001).

Experiments were conducted at Chalakudy to find out the water requirement of rice during virippu (*kharif*), mundakan *(rabi)* and punja (summer) season and the results are presented below.

Table 1. Water requirement (WR) of rice (mm)*

	Virippu (97 days)	Mundakan (86 days)	Mundakan (94days)	Punja (80days)
Water used	473	629	557	830
Percolation loss	379	686	1805	893
Total WR	852	1316	2362	1723
WR/day	8.8	15.3	21.5	

* Water required for land preparation not included.

In Kole lands of Thrissur District, Chirayath (1988) estimated the water requirement of variety Triveni during punja season. The average percolation loss was 17.15 mm day^{-1} and average ET was 7.42 mm day^{-1}. The total water requirement was estimated to be 2134.22mm.

The optimum irrigation scheduling for both short and medium duration rice during summer season at Pattambi was found out to be intermittant irrigation giving 5 cm irrigation two days after disappearance of ponded water (DADPW) (once in 6 days), thereby saving 214 mm water which could be used for irrigating an additional area of 0.57 ha (KAU, 1978-2001).

Table 2. Influence of water management practices on yield and WUE in rice

Treatment	No. of irrigation	Qty. of water (mm)	WUE (Kg ha mm^{-1})	Grain yield (kg ha^{-1})	Straw yield ((kg ha^{-1})
T_1 - 5 cm continuous submergence throughout the crop period	57	1352.1	3.30	4370	3711
T_2 - Irrigating to 5 cm submergence 2 DADPW*	19.5	1138.2	3.72	4159	3916
T_3 – T_2 + protective irrigation at critical stages	33.0	1590.2	3.13	4452	4281
T_4 – Maintaining 5 cm irrigation till MT stage and thereafter irrigating the crop to 5 cm submergence 2 DADPW	26.0	1113.4	3.59	3957	3829
T_5 – Irrigating to 5 cm submergence 3 DADPW	15.8	960.6	3.75	3552	3829
CD (0.05)	2.2	100.0	NS	554	365

* Days after disappearance of ponded water.

Under shallow water table conditions and moderate rainfall during the mundakan season, irrigating the crop at 3 DADPW was found to be statistically on par with continuous submergence. The results also indicated that with slight reduction in yield, the treatment of 5 cm irrigation 5 DADPW could be adopted in areas of scarcity of irrigation water with considerable saving of water.

In a study conducted in the iron toxic lateritic rice soils during the second crop season, intermittant irrigation of 5 cm at 3 DADPW was found to be statistically on par with continuous submergence. This was in conjunction with NPK at 90-45-120 kg ha^{-1} and silica 250 kg ha^{-1} This technology could produce 20 to 70 per cent increase in yield over farmer's practice and existing KAU recommendation of 90-45-45 kg NPK ha^{-1} (Bridgit and Potty, 2001).

Water management practices were developed for summer rice under limited water resources. Phasic stress irrigation can be practised to the advantage of saving substantial quantity of irrigation water without any significant reduction in yield. About 20 – 30 per cent more area can be irrigated with the same water resources by adopting any of the following phasic stress irrigation schedules (KAU, 2002).

Table 3. Category of irrigation schedule for rice.

Schedule	Stage		
	Rooting to Max. tillering	Max. tillering to heading	Heading to maturity
Category I	Continuous submergence	Saturation point*	Saturation point
Category II	Saturation point	Continuous submergence	Continuous submergence
Category III	Continuous submergence	Continuous submergence	Continuous submergence
Category IV	Continuous submergence*	Continuous submergence	Continuous submergence

* Irrigation at 5 cm to be given at the stages marked.

Depending upon the schedule, water saving ranged from 24 to 36 per cent of the requirement for 5 cm continuous submergence throughout the crop growth. Grain yield reduction in the above practice was only 0.1 to 1.6 per cent.

The effect of different levels of submergence at different growth stages was studied in order to assess the damage due to flood during the first crop season. This was done by providing 30 and 45 cm submergence continuously for 12 days at different growth stages between transplanting and harvest. This was compared with the normal practice of 5 cm continuous submergence throughout the crop period in two varieties H4 and IR-8. The results indicated that 45 cm submergence adversely affected the yield of crop when flooding was given at 13 to 24 days after transplanting (DAT) and at 85 to 96 DAT. However, 30 cm submergence at any of the growth stages did not affect the grain yield adversely (AICRP, 1984-1996)

In another experiment with 100 and 75 per cent submergence in rice variety Jaya at different growth stages for different period, 100 per cent submergence for two days and above at tillering stage was found to significantly reduce the yield. At panicle initiation stage, 100 per cent submergence even for a day resulted in significant reduction in grain yield. However, 75 per cent submergence at the above stages did not significantly affect the yield up to 5 days of submergence. Submergence treatment was effected by keeping the pots in tanks where the desired water level was maintained. During the non-submergence periods, pots were kept under identical conditions in the field (AICRP, 1984-1996).

Table 4. Effect of submergence/flooding at different growth stages of rice on Grain and straw yield.

Treatment	Active tillering stage		Panicle initiation stage	
	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
Control	129.4	154.0	103.8	154.0
75% - 1day	139.0	186.0	97.2	164.6
75% - 2days	162.5	178.8	96.8	160.6
75% - 3days	142.0	170.8	92.6	167.4
75% - 5days	130.5	161.4	81.0	124.2
75% - 7days	129.0	159.0	76.2	133.8
100% - 1day	128.2	143.2	88.0	139.4
100% - 2days	99.5	116.6	74.0	129.4
100% - 3days	56.5	81.0	71.4	131.0
100% - 5days	-	-	67.0	132.0
100% - 7days	-	-	64.2	131.8
CD (0.05)	25.54	41.87	13.83	26.4

Water – Nutrient interaction

Among the fertilizer elements, Nitrogen is subjected to different types of losses under submerged conditions. Split application of N is considered as one of the methods for ensuring maximum utilization of applied nutrients. Experiments were conducted in this line to find out the optimum requirement and time of application of N under different water management practices.

The results of a study indicated that under continuous flow submergence, application of N in four splits at planting, active tillering stage, panicle initiation stage and booting stage was found to beneficial for medium duration rice variety Jaya during mundakan season. The quantity of N used was 90 kg ha^{-1}. The application of N can be limited to three splits under continuous stagnant submergence and 5 cm irrigation at 1 DADPW (AICRP, 1984-1996).

In short duration transplanted rice variety Triveni, 70 kg N ha^{-1} was found to be optimum under all water management practices viz., continuous submergence and irrigation at 1, 3 and 5 DADPW (AICRP, 1984-1996).

In another experiment under wet sown condition, short duration variety Triveni responded only up to 50 kg N ha^{-1} applied in three splits. The optimum water management practice was 7 cm irrigation 1 DADPW in sandy loam soils under shallow water table conditions (AICRP, 1984-1996).

The fertiliser and water use efficiency in medium duration transplanted rice variety Jaya was estimated during mundakan season. Two water management practices were tested along with different time of application of N and K. The results indicated that irrigating paddy at saturation point and applying N and K fertilizer at 90:45 kg ha^{-1} in three splits at basal, 15 days and 38 days after transplanting could be optimum for higher yield and WUE. The results also indicated that there is no advantage in applying N and K fertilizers in more than three splits for medium duration rice (AICRP, 1984-1996).

Experiments conducted in farmers' field at Alathur in Palakkad district revealed that the variety IR-20 responded up to 135 kg N ha^{-1} and irrigation could be delayed up to 5 DADPW. Compared to continuous submergence, the yield reduction was negligible in the above irrigation practice and at the same time irrigation water could be saved (AICRP, 1984-1996).

Water management and Weed control

Continuous submergence throughout the crop growth period in rice is considered to be the optimum water management practice for efficient weed management and maximum yield. However, irrigation at 1DADPW was found to be equally effective for weed control in dry sown rice during the virippu season at Chalakudy in sandy loam soils (AICRP, 1984-1996).

Rice based cropping pattern under constraints of irrigation water

The following cropping patterns were suggested for sandy loam soil, on the basis of maximum productivity, water use efficiency and land utilization intensity (KAU, 2002).

Table 5. Rice based cropping pattern for sandy loam soils.

First crop	Second crop	Third crop
Rice (M)	Rice (SM)	Vegetable (water melon/Ash gourd)
Rice (SM)	Rice (M)	Groundnut
Rice (M)	Rice (M)	Sesamum
Rice (S)	Rice (S)	Tapioca

S – short duration SM – semi-medium M – medium

In another experiment involving five crop sequences viz., Rice-Rice-Bhindi, Rice-Rice-groundnut, Rice-Rice- cowpea, Rice-Rice-sesamum and Rice-Rice-Rice, Rice-Rice-Bhindi was found to be most economic when water management practices for second crop rice was scheduled as 5+/- 2 cm irrigation 3DADPW. Depending upon the availability of irrigation water during summer seasons, the following rotations are suggested in the order of decreasing water availability ((AICRP, 1984-1996).

1. Rice-Rice-groundnut
2. Rice-Rice- cowpea
3. Rice-Rice-sesamum

Lysimeter studies were conducted at Chalakudy to assess the ground water contribution in rice production and the results revealed that water level is to be maintained at ground level continuously for higher yield. Increasing the depth of ground water table from the ground level significantly reduced the grain yield (AICRP, 1984-1996).

Sub surface drainage using tile drains was successful in the Kari soils where large accumulation of toxic chemicals in the root zone prevented successful rice production. Baked clay pipes 60cm long, with bell mouth at one end and straight edge at the other, with 110mm inner diameter were used as the basic unit to form a tile drain lateral line. Holes were provided on the 1/3rd periphery of each clay pipe. Pipes were laid in trenches of 40cm width taken to a depth of one meter. The drains were then covered with a 10 cm thick sand layer around the joints and the excavated earth was back filled. The laterals were laid at a spacing of 30m. All the laterals were connected with a common subsurface pipe collector drain, which was connected to a sump well for discharging the leachate collected from each of the laterals. A suitable pumping system was installed in the sump well to pump out the water to a flowing open water body. The subsurface drainage resulted in increased paddy yield of one tonne per ha on a long term basis (Mathew *et al*, 1997).

The results of the experiment conducted to study the comparative efficiency of different puddlers in reducing percolation losses in paddy fields and to compare the impervious layer formation during puddling and subsoil compaction revealed that neither residual effect of subsoil compaction at 30 cm depth and soil dressing with lateritic loam nor puddling with power tiller or country plough could effectively reduce the high percolation loss of irrigation water in sandy loam soils. The study was conducted for five years from 1979-80 during the first and second crop seasons (AICRP, 1984-1996).

ii) COCONUT

Kerala has nearly 9.05 lakh ha under coconut cultivation. It is mainly grown in the homesteads of small farmers of Kerala as a rainfed crop. Irrigated area comes about 17 per cent of the total area. Irrigation during dry months not only increases the yield of coconut by as much as 50-100% but also ensure stability in production.

Response to irrigation

Response of coconut palm to summer irrigation was observed in almost all the experiments conducted, the magnitude of response depending on soil type, depth of water table and moisture conservation practices (Nair, *et al*, 1988). At Nileswar, where the soil type was littoral sand, the yield response to irrigation was assessed on a group of seventy year old palms from 1959 to 1965. 35 palms were irrigated in basins of 2m radius once in 5days with 800 litres of water per irrigation. In the other group, where arecanut nursery was raised in the interspaces, the whole area was flood irrigated with 5 cm of water once in 5 days. Basin irrigated palms recorded a mean yield increase of 22.6 nuts as against the yield increase of 85.4 nuts in the case of flood irrigation.

In another experiment in red sandy loam soils of Nileswar, 60 palms belonging to four yield groups were marked out based on their pre- irrigation production status. The palms yielding less than 20 nuts were grouped as poor, 20-40 nuts as low, 40-60 nuts as medium and 60-80 nuts as high yield groups. The palms were irrigated in basins of 2m radius at the rate of 800 litres per irrigation once in 7 days during summer months (Dec.- May). Manuring was done at the rate of 0.5,0.32 and 1.2 kg N, P, K per palm per year. The study was initiated in the year 1964 and lasted for 11 years. Assessment of the yield over a period of 8 years showed an increase of 9,13,8 and 12 nuts respectively for poor, low medium and high yield groups with a mean increase of 11 nuts for the whole group of palms. The average increase over 11years from the commencement of irrigation was also maximum in the low yield group (38.3 nuts) followed by the medium group (32 nuts). This suggests that the low and medium yielders are better responsive to irrigation.

Table 6. Nut yield of WCT palms of varying yield groups as affected by irrigation

Particulars	Yield groups (nuts $palm^{-1}$ $year^{-1}$)				
	Poor	Low	Medium	High	Mean
Pre- irrigation yield	13.4	30.2	54.3	70.8	42.2
Post-irrigation yield for 8 years	42.2	69.5	85.3	94.8	73.5
Percentage increase over pre-irrigation yield	214.9	130.1	57.4	33.8	74.2
Cost- benefit ratio	1: 2.9	1: 3.5	1: 3.1	1: 2.4	1: 3.1

A study on the effect of irrigation on the growth and yield of coconut cv. WCT was initiated in a 12 year old private plantation at Chalakudy in the year 1982. The soil belonged to the textural group sandy clay loam (0-45cm) to clay (90-120 cm). The field capacity and wilting point ranged from 17.69 to 20.83 percent and 8.65 to 9.20 per cent respectively. The ground water table of the field was always below 2m from ground surface. The bulk density varied from 0.973 to 1.2 $gmcm^{-3}$. The palms were irrigated with 500 litres of water in basins of 1.8 m radius.

Table 7. Nut yield per palm per year as influenced by irrigation

Treatments	Pre-experiment period 1982	Experiment period				
		1983	1984	1985	1986	1987
75mm CPE	63.1	73.9	40.8	104.1	96.1	99.8
50mm CPE	67.1	84.5	39.8	112.8	113.9	110.3
25mm CPE	61.1	69.8	39.9	126.9	119.3	116.7
Once in 3 days	65.1	69.7	41.4	124.7	131.8	122.6
No irrigation	59.2	80.8	31.7	95.9	77.1	97.8
CD (0.05)	NS	NS	NS	12.57	24.14	7.4

Results of the study indicated clearly that coconut responded well to irrigation during dry months from the third year after commencing irrigation. Irrigating the crop with 500 litres of water at 50mm CPE (approximate interval of 12 days) was the most economical.

In the laterite region of southern Kerala, irrigating WCT palms with 600 litres of water once in 7 days was found beneficial.

Significant influence of irrigation on yield was observed in root (wilt) affected coconut palms of Kuttanad area. Application of 50 mm water at IW/CPE ratio of 0.5 (approximate interval of 19 days) recorded the highest yield. The fertilizer X irrigation interaction was not significant.

The quantity of water/irrigation/palm for different types of soils is worked out to be 600, 900, 1300 and 1600 litres for sandy, sandy loam, loam and silty clay soils respectively.

With the objective of finding out the response of hybrids to irrigation and fertilizer application right from the initial stages of planting, studies were initiated in red sandy loam soils at Nileswar from 1981. The treatments included combinations of three levels of irrigation (IW/CPE 0.5,0.75 and 1.0 with 30mm depth of irrigation) and four levels of fertilizer (0.5:0.5:1.5; 0.5:0.5:2.0; 0.5:1.0:2.0 and 1.0:0.5:2.0 kg N, P, K per palm per year). The fertilizers were applied as per Package of

Practices Recommendation of KAU. Irrigation water was applied in basins the radius of which varied from year to year in response to the expansion of effective canopy cover. The results indicated that the combination of both irrigation at IW/CPE 1.0 and a fertilizer dose of 0.5:0.5:1.0 Kg NPK per palm per annum was found to be ideal for the hybrid WCT X Gangabondam.

iii) ARECANUT

Arecanut is an important cash crop of Kerala occupying about 57 per cent of the total area in India. About 27% of the arecanut palms are irrigated The irrigation requirement is determined as 175 litres palm^{-1} through surface irrigation once in 7 to 8 days during Nov. – Dec., once in 6 days during Jan. Feb. and once in 3 to 5 days during March – May (KAU, 2002).

The water requirement of Arecanut was estimated as 1689.4mm in laterite soil. Yield and water use efficiency were higher for drip irrigation at 60 per cent of the water requirement without mulch. Benefit –cost ratio was higher for surface irrigation at 100 per cent of the water requirement with plastic mulch. (PDC, KCAET, Tavanurr, 2003).

iv) SPICES

Pepper

Pepper, the black gold, is very sensitive to climatic parameters especially the pattern of rainfall. It is mainly raised as rainfed crop. The flowering and fruiting synchronise with the rainy season and a dry spell before flowering is advantageous for flushing, flowering and higher yields. Irrigation should be given at IW/CPE 0.25 from November- December till the end of March. The depth of application is 10 mm and is to be given in basins at a radius of 75 cm around the plant (KAU, 2002).

Bush pepper

Drip irrigation at 8 litrres day^{-1} plant^{-1} has found to be more beneficial to three year old bush pepper compared to daily irrigation using 10 litres day^{-1}. The optimum percentage of available depletion of soil moisture was 50 (Thankamani, 2000).

Ginger

Ginger is an important spice crop of Kerala, usually grown as a rainfed crop from April- May to Dec- Jan. There is a practice in several parts of Kerala , where ginger is being raised as an irrigated crop in summer months and harvesting as green ginger at six months maturity. Studies were conducted at ARS, Chalakudy to standardize an irrigation schedule and nitrogen level for irrigated green ginger. The results indicated profound influence of irrigation and nitrogen level on yield. The treatment with most frequent irrigation (IW/CPE 1.5) requiring 8-9 irrigations at an interval of 9-10 days was found to be the best schedule for irrigated ginger. With regard to nitrogen treatments, an increase in yield of fresh ginger was noticed when nitrogen nitrogen was applied upto 75 kg N /ha beyond which the yield declined (Sreekumaran *et al.*, 1998)

Table 14. Pooled mean yield of ginger rhizome (t/ha)

Treatment	Nitrogen levels			Mean
	50 kg N ha^{-1}	75 kg N ha^{-1}	100 kg N ha^{-1}	
I_0-Control	15.39	20.47	20.11	18.65
I_1- Irrgn at IW/CPE 0.5	19.12	23.13	22.75	21.66
I_2- Irrgn at IW/CPE 1.0	22.03	27.84	27.14	25.67
I_3- Irrgn at IW/CPE 1.5	23.42	29.66	29.40	27.49
Mean	19.99	25.27	24.85	

v) FRUIT CROPS

Banana

Experiments were conducted in October planted Banana var. Nendran, at Chalakudy, to study its growth and yield response under different irrigation schedules (5 cm at IW/CPE ratio 1.2,0.9,0.6,0.3 and 10mm irrigation once in two days) with and without mulch (paddy straw). The results indicated that irrigation in alternate days with 10mm water is optimum for higher bunch yield and water use efficiency. Mulching the basin with 3.5 kg paddy straw waste was found to improve the bunch yield. Under acute water scarcity situations 5 cm irrigation in basins at IW/CPE 0.6 was comparable with irrigation at IW/CPE 1.2 (Pillai *et al.*, 1989).

Jessy (1988) reported that, in Banana, moisture stress during the period from flower initiation to shooting affected the bunch yield mostly. Basin irrigation with 20 mm water at IW/CPE 0.9 from December to April resulted in maximum bunch yield for August planted Nendran banana. This was comparable with treatments where it was mulched and irrigation was started from April.

Studies conducted in Banana variety Nendran (upland) at Pilicode during 1987-90 in clay loam soils showed that 20 mm (40litre) irrigation in alternate days gave maximum yield and consumptive use (1240.7 mm). Application of 5 mm water by subsoil injection recorded the minimum consumptive use (300.4 mm) and maximum WUE (62.9 kg ha mm) (KAU, 1978-2001)

The response of Nendran to graded doses of N and K under different water management practices in laterite soils (sandy clay loam) was studied from 1990-91 to 1994-95. Four levels of irrigation (5cm irrigation at 20,40 and 50 mm CPE and farmers practice of irrigating once in 2 days with 2cm water) and 3 levels of N and K in factorial combination constituted the treatments. It was concluded that Banana cv. Nendran required 5cm irrigation at

20mm CPE at an approximate interval of 3-4 days at 5cm depth for getting maximum bunch yield. N and K at the rate of 190 and 300 g/plant respectively was sufficient for Nendran under irrigated conditions (AICRP, 1984-1996).

In a comparative trial between drip and basin methods of irrigation Varghese (1985) reported that in both methods, 15 and 20 litres of water per plant per day was found to be superior and on par. The plants irrigated with drip reached maturity earlier than in conventional method of basin irrigation.

In another trial conducted on the variety Nendran, to find out the amount of nitrogen which can be fed through drip irrigation, it was indicated that application of N at the rate of 150g/plant as urea through drip irrigation was better than application of 200g in soil, resulting in 25% saving in N application. Three doses of N viz., 100,150 and 200 g $plant^{-1}$ were tried by applying 100,75. and 50 percent of each quantity through drip irrigation. P and K were applied in soil @ 115 and 300g $plant^{-1}$ respectively (KAU, 1999-01).

Thomas (1999) studied fertigation in banana. Subsurface drip at 75 per cent pan evaporation compensation (PEC) produced comparable yields with that of surface drip at 100% PEC. Both methods were significantly superior to basin irrigation. Subsurface drip yielded a higher WUE of 440 kg $ha.mm^{-1}$ compared to 390 kg $ha.mm^{-1}$ in surface drip at 100% PEC.

Experiments in Banana var. Nendran conducted at Plasticulture Development Center at Tavanur revealed that water use efficiency and benefit cost ratio were maximum at 80 per cent water requirement through drip irrigation with mulching. Fertigation through drip could save 20 per cent of the recommended fertilizer dose for Banana (PDC, KCAET, Tavanoor, 2003).

August planted banana variety Palayamkodan responded well to irrigation during summer months. 40mm irrigation at 30 mm CPE (at an interval of 6-7 days) along with dry leaf mulch was found to be optimum under shallow water table conditions (AICRP, 1984-1996).

Pineapple

An experiment was conducted at Chalakudy to study the performance of pineapple under different moisture regime with and without mulches. The results indicated the superiority of 0.9 IW/CPE with respect to fruit yield of planted crop and two ratoons. But it was comparable with irrigating the plant and ratoon crops with 50mm water at IW/CPE 0.6 during summer season. Mulching the basin of planted crop with dry leaves @ 6t/ha is recommended for higher fruit yield and WUE (Varghese et al., 1988).

Table 8. Yield (q ha^{-1}) of pineapple (plant crop + 2 ratoon crop) as influenced by irrigation

	No mulch	With mulch	Mean
T_1 - No irrigation	196.43	262.57	229.50
T_2 - Irrigation IW/CPE –0.3	363.76	402.78	383.21
T_3 - " IW/CPE –0.6	415.35	499.34	457.35
T_4 - IW/CPE –0.9	443.79	537.04	490.42
Mean	354.83	425.43	

CD (0.05) Irrigation – 69.83 ; Mulching – NS; Interaction - NS

Trials conducted at Kannara in pineapple variety Kew revealed that pineapple responded well to irrigation. The quality parameters except reducing sugars were not influenced by irrigation treatments. The reducing sugar in fruits recorded the highest value when irrigation was given once in 7days followed by the treatment receiving irrigation once in 10 days.

vi) PULSES

Pulses are mainly raised in summer paddy fallow without any irrigation. The crop comes up well with few summer showers received during the cropping period. Irrigating the crop during summer season is found to be beneficial for getting higher yields and studies towards this line is discussed below.

Cowpea

Studies on the contribution of inputs to the grain yield of summer cowpea indicated irrigation to be the principal input, which contributed to more than 50 per cent of the yield. In the absence of irrigation, other inputs failed to increase the grain yield (Joy *et al.*, 1991).

Cowpea raised in summer rice fallows could be given irrigation with 5 cm water at IW/CPE 0.75 (5 irrigations at an interval of 15 days) along with phosphorus @15 kg ha^{-1} or at critical stages of branching, flowering and pod formation. Irrigation at IW/CPE 0.4 was sufficient for attaining vegetative growth for incorporation as green manure (KAU 98-2001).

Studies by Balakumaran (1981) indicated that cowpea might be irrigated at IW/CPE 0.5. This required 5 irrigations (180mm water) in summer season at an interval of 16 days. The economic dose of P was found as 56.70 kg ha^{-1}.

Sprinkler irrigation was found to be very effective and economic in increasing the yield both in bush and trailing type cowpea grown in summer fallows in light soils. Irrigation was to be given at an interval of 6 to 8 days through sprinkler at an intensity of 0.63 cm hr^{-1} for two hours. This scheduling gave an increase in yield of 36.4 per cent over channel/flood irrigation (KAU, 2002-03).

Table 9. Yield of Cowpea (t ha^{-1})

Irrigation	Variety	P levels				Mean
	YLB	Ptb 1	P_{15}	P_{30}	P_{45}	
Sprinkler	12.36	6.25	9.19	9.06	9.94	9.38
Channel	7.94	5.88	6.75	6.94	7.06	6.88
Mean	10.13	6.06	7.95	7.81	8.50	
P levels						
P_{15}	10.25	5.69	CD (0.05)			
P_{30}	9.63	6.00	I & V – 1.79			
P_{45}	10.56	6.38	I x F – 2.54			

Different levels of P did not have any significant effect on yield. Hence recommended dose of 15 kg ha^{-1} was considered to be sufficient for higher yield.

Blackgram

In black gram an irrigation schedule of 3 cm during first 25 days and thereafter 4 cm at IW/CPE 0.75 (10 days interval) was found to be optimum. It was also observed that both border strip and bed method of irrigation was equally effective for the summer crop of black gram (Varghese, *et al.*, 1986).

vii) OILSEEDS

Sesamum

In Kerala, sesamum is usually grown as a third crop in the wetlands purely as a rainfed crop. Studies conducted at Chalakudy indicated that in sandy loam soils, irrigating sesamum at critical stages of 3-4 leaf stage, branching, flowering and pod formation stage or at IW/CPE 0.75 with 40mm water ensured significantly higher yield as compared to unirrigated crop and 30 kg N ha^{-1} was found to be optimum for higher grain yield in irrigated sesamum (Mathew, *et al.*, 1989).

Regarding germination and maintaining optimum plant density, Mathew (1985) suggested sowing one day after irrigating the field to field capacity. One irrigation each during the vegetative and reproductive phases resulted in higher yield.

The productivity of the crop in sandy tracts of Onattukara region was very low and could be enhanced by providing irrigation along with other management practices. The results of a study conducted at this region revealed that giving three or four irrigations viz., 2 irrigations at vegetative phase and one or two irrigations at reproductive phase was found to be optimum for higher yield and WUE (KAU, 2003-2004).

In sesamum, Sprinkler Irrigation at an intensity of 0.63 cm hr^{-1} for two hours was found to be very effective and economic in increasing the yield in light soils. An increase in yield of 16.5 per cent is realized over flood/channel irrigation through this system (KAU, 2002-03).

Table 10. Yield of sesamum (t ha^{-1})

Irrigation	K levels			S levels		Mean
	K_{30}	K_{45}	K_{60}	S_0	S_{30}	
Sprinkler	230.2	215.7	168.5	211.3	197.9	204.6
Channel	190.2	156.8	180.7	177.9	174.0	175.7
Mean	210.2	186.3	174.6	194.6	186.3	
S levels						
S_0	215.7	182.4	185.7	CD (0.05)	I – 24.46	
S_{30}	205.2	190.2	162.9		K- 30.02	

Among the different nutrients S did not show any significant influence on yield. Increasing levels of K from 30 kg ha^{-1} to higher levels tended to reduce the yield. For sesamum grown in summer fallows K @ 30 kg ha^{-1} was sufficient for higher yield.

Groundnut

Studies conducted to identify the critical stages of irrigation and the effect of irrigation on growth and yield of groundnut revealed that irrigation at IW/CPE 0.5 (once in 15 days) was optimum for groundnut in summer months without any significant reduction in pod yield (AICRP, 1984-96).

Irrigation for groundnut in summer season in sandy loam soils of Chalakudy was to be scheduled at 0.9 IW/CPE (5 cm depth) for increased pod yield. Phosphorus and Potassium at 25 kg ha^{-1} was found to be optimum under this water management practice (Mathew *et al*, 1983).

In summer rice fallows of lateritic region, 50 mm irrigation at IW/CPE 0.75 was found beneficial for higher pod yield. Moisture stress during early growth stages delayed flowering and adversely affected nodulation (Mukta, 1995).

Boopathy (2003) suggested that during second crop season in uplands, 50mm irrigation at IW/CPE 1.0 was sufficient for better utilization of applied nutrients. A fertilizer dose of 10:37.5:75 kg NPK ha^{-1} was found to be optimum for groundnut in uplands.

Oil palm

Irrigation at 90 litres palm^{-1}day^{-1} resulted in increased yield contributing characters and palm oil production in oil palm (Varghese, 1994).

viii) TUBER CROPS

Tapioca

Optimum schedule of irrigation for a nine-month and eleven-month tapioca crop were found to be at IW/CPE values of 1.0 and 0.5 respectively. Supplemental irrigation benefited both crops and it enabled earlier harvest of nine-month crop thereby relieving the land for a short crop of rice. Irrigating the eleven-month crop at IW/CPE 0.5 (19 day interval) provided an additional yield of 5.5 tonnes tubers over the nine- month crop (Sushama *et al*, 1982).

Combinations of five cropping systems (tapioca alone, tapioca + ground nut, tapioca + cowpea, tapioca + green gram and tapioca + black gram) and three levels of irrigations (IW/CPE 0.3, 0.6and 0.9), with depth of irrigation 5cm were tried for arriving at an optimum irrigation schedule for tapioca based intercropping system. No significant difference was observed between treatments. Hence it can be presumed that the lowest level of water management tried (IW/CPE 0.3, ie, once in 36 days) would be enough for optimum yield under all cropping systems. The crops like cowpea, black gram and groundnut can be raised successfully as an inter crop with tapioca without affecting the yield of tapioca (AICRP, 1984-1996).

With the objective to evaluate the efficiency of alternate furrow irrigation in reducing water requirement of tapioca and to assess economics of method of irrigation, studies were conducted at Chalakudy with 12 treatment combinations viz., no irrigation, irrigation at 75mm CPE, 100 mm CPE, all furrow and alternate furrow with varying quantities of water (5 cm or its ¾ or ½ depth). The results revealed that in the case of short duration tapioca grown in summer rice fallows after second crop of rice, for better water economy and tuber yield, irrigate the crop either adopting all furrow irrigation with 25 mm water at 100 mm CPE or alternate furrow irrigation alternatively with 50 mm water at 75 mm CPE (AICRP, 1984-1996)

The studies on surge flow and continuous flow irrigation in tapioca revealed significant influence of treatments on tuber yield per plant. Maximum tuber yield was recorded by irrigating the crop at 50mm CPE by surge flow method and was on par with continuous flow treatment at 50mm CPE. Irrigation water use efficiency was found highest for surge irrigation treatment at 75mm CPE, which was 21 per cent higher than that of continuous flow treatment at the same level of irrigation. A saving of 17 per cent water could be attained in surge flow technique with an increase of 29 per cent yield (Visalakshi et al, 2003).

Table 11. Effect of methods and levels of irrigation on WUE and Yield of tapioca.

Treatments	Total Water applied (m^3)	Yield (t ha^{-1})	Irrigation WUE t $ha.m^{-3}$
C_{50}	14.18	32.52	0.80
S_{50}	12.45	38.43	1.09
C_{75}	8.93	25.74	1.01
S_{75}	7.90	31.08	1.41
C_{100}	6.83	21.97	1.07
S_{100}	5.85	19.85	1.31

C - Continuous flow S - Surge flow

Sweet Potato

The results of the study conducted to identify the optimum combination of fertiliser and irrigation revealed that, sweet potato grown under irrigated condition in summer fallows needed irrigation with 50mm at 1.2 IW/CPE (at an interval of 10 days). Application of N and K @ 50 kg ha^{-1} each was found to be optimum for higher yield. (Varghese *et al.*, 1987).

Oommen (1989) worked out the irrigation schedule for Sweet potato to be IW/CPE 0.75along with a fertilizer dose of 100:75:100 kg /ha^{-1}.

Nair (1994) reported that irrigation at an interval of 4 days during tuber initiation and tuber maturity phases was advantageous.

Colocasia

In colocasia irrigation did not show any significant effect on yield. Application of N @ 40 kg ha^{-1} is sufficient for maximum yield.

Amorphophallus

Amorphophallus was to be irrigated (5cm depth) at 0.9 IW/CPE during summer months for increased corm production. It was also recommended to mulch with dried leaves, paddy waste or coir dust, in the order of preference and according to local availability for better moisture conservation and increased yield (Mathew *et al*, 1988).

ix) VEGETABLES

Bitter gourd

In bitter gourd, farmers' practice of pot watering every day was compared with pitcher irrigation in which one mud pot containing 3.5 litres of water was kept buried in soil such that the neck was at ground level. It was found that pitcher irrigation was superior to all other methods (irrigation at IW/CPE 0.50, 0.70 and 0.90 and daily pot watering with 3.5 litres of water (KAU, 1978-2001).

Trials were conducted at Chalakudy to develop drip irrigation technology in bitter gourd and to assess its advantage over basin method of irrigation and its economic viability. Basin method of irrigation recorded significantly higher yield and the increase was 52.3 per cent over drip method. Basin method of irrigation based on IW/CPE 0.4 which require the least quantity of water can be used for raising bitter gourd successfully in summer fallows (AICRP,1984-96).

In bitter gourd, irrigating the crop at 15 mm CPE (approximate interval of 3-4 days) with 40 mm water and application of N @ 90 kg ha^{-1} was more economic considering the yield and quantity of water when planted in summer fallows (Thampatti *et al*, 1993) .

The optimum irrigation schedule for bitter gourd during summer season in sandy loam soils was found to be 3cm irrigation at IW/CPE 1.2. NPK at 60:30:60 kg ha^{-1} produced the maximum net profit. Soil moisture extraction by bitter gourd was maximum from the top 30cm layer of soil (Thomas, 1984).

In another study with bitter gourd cv. Priya, planted in December, Jacob (1986) reported that the optimum irrigation schedule was at IW/CPW 1.0. Highest soil moisture depletion was from top 0.15 cm soil layer in irrigated treatment while it was from deeper layer of soil in the case of treatment without or less irrigation.

The efficiency of locally designed bubbler irrigation system (KAU microsprinkler) was compared with drip system of irrigation at Chalakudy in bitter gourd with three levels of irrigation (100, 75 and 50 % PE).

Table 12. The effect of systems of irrigation on yield of bittergourd.

Treatment	Yield (kgha^{-1}) (Pooled over three years)	Water used (mm)	% Increase in yield over control	% Saving of water over control
T_1- Bubbler irri. at 100%PE	6043	302	+28.33	59.12
T_2- Bubbler irri. at 75%PE	5482	227	+16.42	69.20
T_3- Bubbler irri. at 50%PE	5137	151	+9.10	79.51
T_4 – Drip irri. at 100% PE	5055	302	+7.35	59.02
T_5 – Drip irri. at 75% PE	4317	227	-8.32	69.20
T_6 – Drip irri. at 50% PE	3797	151	-19.60	79.51
Frmers'practice (10mm daily)	4709	737	-	

CD (0.05) 868

From the results it could be concluded that Bubbler irrigation system was more efficient than drip method in bitter gourd grown under mound system of cultivation for realizing increased yield. This system recorded water saving of 59 per cent and 69 per cent when irrigation was scheduled at 100% and 75% PE respectively over control (farmers practice of 10 mm daily). The superiority of bubbler irrigation system might be attributed to the uniformity of wetting of the effective root zone of the crop where as, in drip irrigation, complete wetting of basin area was not attained as the wetting front advance was limited to the point of emitter (Sreekumaran, et al., 1998).

Snake gourd

In an experiment to standardise the optimum dose of nitrogen (35, 75, 105 and140 kg/ha), ethephon (0, 50, 100 and 200ppm) and drip irrigation (5mm CPE and 10mm CPE), it was observed that the suitable levels of inputs for realizing the maximum fruit yield and net income were 105 kg N ha^{-1}, 200ppm ethephon and drip irrigation at 5mm CPE (Syriac, 1998). The crude fibre content and shelf life decreased by higher levels of nitrogen. Nitrogen improved the crude protein content, total sugar, reducing sugar, ascorbic acid and moisture content in the fruit.

The optimum time of sowing in snake gourd for maximum yield and net return was found to be on November 16^{th} with irrigation at IW/CPE value of 1.0. Consumptive use of water increased with frequency of irrigation. Top 15cm of soil layer accounted for highest soil moisture depletion. The depletion was more from the deeper layer in drier regions (Thankamani, 1987).

Pumpkin

Irrigation can be scheduled at 75 per cent depletion of available soil moisture (Lakshman, 1985) Another approach was to irrigate at cumulative can evaporation values of 60-70 mm during vegetative stage followed by 45-55 mm during flowering and fruiting stages.

Cucumber

Andezhahtu (1989) tested the relative efficiency of a low cost drip irrigation system fabricated with the locally available materials and the conventional basin method in cucumber. The amount of water required for producing the same yield was equal in both methods. But in basin method conveyance loss was estimated to 27.7 per cent over drip method.

Rao (1989) indicated that the best schedule of irrigation in cucumber was to irrigate at 25 mm CPE. A fertiliser dose of 100 kg N and K ha^{-1} was needed for optimum yield, net return and benefit cost ratio under irrigated condition. Soil moisture depletion pattern showed that cucumber extracted as much as 60 per cent of the total water used from the top 30cm soil layer.

Oriental pickling melon

Lakshman (1985) suggested irrigation at 75 per cent depletion of available soil moisture. This comes about 5-7 days interval between two irrigation. In another approach using can evaporimeter, irrigation has to be given at 60-70mm cumulative can evaporation values during vegetative stage followed by 45-55mm during flowering and fruiting stages.

The quantity of water for irrigation could be reduced considerably by adopting drip irrigation using one emitter per plant @ 3litres per day. Nitrogen @ 70 kg ha^{-1} and K @ 50 kg ha^{-1} was found optimum under drip irrigated conditions (Lakshmi, 1997)

Drip irrigation at 125 per cent pan evaporation along with black polythene mulch was found to be beneficial for yield and net profit as compared to basin irrigation. In addition to 27.5 per cent yield increase, the treatment brought about 13 per cent savings in water where 45 litres was applied per plant once in 3 days (Gebremedhin, 2001).

In another study employing subsurface moisture conservation techniques (incorporation of saw dust, paddy waste and coir pith @ 1/3rd pit volume), the fruit yield was found to be maximum at IW/CPE ratio of 1.2 (Veeraputhiran, 1996). Under conditions of scarcity of water, an equally beneficial alternative was incorporation of paddy waste or coir pith and irrigation at IW/CPE ratio of 0.8.

Ash gourd

Drip method of irrigation was not economic in ash gourd since the water saving was not commensurating the cost of installation. Irrigating at IW/CPE of 0.7 along with mulching was found to be optimum for higher yield in ash gourd (Visalakshi, *et al.*, 1988).

Irrigation can be scheduled at 75 per cent depletion of available soil moisture (Lakshman, 1985) Another approach was to irrigate at cumulative Can evaporation values of 60-70 mm during vegetative stage followed by 45-55 mm during flowering and fruiting stages.

The relative efficiency of a low cost drip irrigation system fabricated with the locally available materials and the conventional basin method was tested in ash gourd by Andezhahtu (1989). In drip as well as the basin method, the irrigation schedule was IW/CPE 1.0, 0.7 and 0.4. There is 30 per cent saving of irrigation water by drip method over conventional method of basin irrigation.

While assessing different levels of potassium (0,75,150 and 225 per cent of POP) under different levels of irrigation (IW/CPE 0.75,0.50 and 0.25), it was found that the levels of irrigation and potassium did not have any direct effect on yield of ash gourd. A potassium level of 20 kg/ha was the best dose when the irrigation was scheduled at IW/CPE 0.25 (Menon, 1990)

Water melon

Watermelon can be successfully raised in rice fallows if irrigated and sown in November. The crop when sown in November, had to be irrigated with 30mm at IW/CPE 1.0, which was comparable with daily irrigation with 10litre per plant per day with respect to growth and yield (Neendissery, 1993).

Ajith (2000) revealed that incorporation of moisture conservation materials increased growth and fruit yield in watermelon. The fruit yield increased with increase in frequency of irrigation and was highest at IW/CPE 1.4 and surface application of paddy waste as mulch.

In another study daily irrigation showed highest yield followed by irrigation at IW/CPE of 0.90. Irrigation at IW/CPE 0.5 had maximum cost benefit ratio.

Bhindi

Daily irrigation in alternate furrows recorded the highest yield in area where water is not limited. 40mm irrigation at 30mm CPE could also be economically adopted in command areas where rotational supply of water is being practiced (Jayakrshnakumar, 1986).

Sunilkumar (1998) achieved fruit yield of 24.88 t ha^{-1} when the crop was mulched and furrow irrigated at soil moisture tension of 0.08 Mpa. This accounted for 93.48 per cent increase in yield over the control crop that received irrigation by furrow method at 0.06 Mpa without mulch. When mulching was adopted under drip irrigation or surface irrigation with the irrigation schedules at soil moisture tensions of 0.04, 0.06, or 0.08 Mpa, the cropping became profitable and the B: C ratio varied between 0.91 to 1.58.

In order to study the feasibility of application of fertilizer through KAU Microsprinkler (Bubbler system) trials were conducted at Chalakudy in Bhindi. The results indicated that fruit yield was significantly influenced by irrigation levels, but was not affected by levels of fertilizer and their interaction. Irrigation at 100%PE recorded the maximum fruit yield, which was on par with 80% and 60%PE. The percentage increase in yield over control were 38.7, 26.1 and 31.1 respectively in 100%, 80%, and 60% PE. Moreover 40 per cent of the requirement of water could be saved through this system. Application of fertilizer nitrogen through this Irrigation System (Fertigation) was effective and economic and could save 50 per cent of recommended dose.

Table 13. Levels of irrigation and fertilizer on yield of bhindi (t ha^{-1})

Fert. levels	Irrigation levels				Mean
	(100 %PE)	(80 %PE)	(60 %PE)	10 mm daily	
F_1	14.9	14.4	18.3	11.5	14.8
F_2	16.7	15.7	14.9	10.9	14.0
F_3	16.0	15.8	14.0	12.2	14.5
F_4	18.0	14.8	15.0	11.2	14.8
Mean	16.4	15.2	15.6	11.4	
Increase over I4 (%)	43.8	33.3	36.8		
WUE (kg m^{-3})	5.5	6.33	8.7	3.8	

CD (0.05) Irrigation – 2.33

F_1 – 100% N through sprinkler system (70 kg N ha^{-1}); F2 – 75% N through sprinkler system

F_3 – 50% N through sprinkler system F_1 – 100% N soil incorporation

Vegetable Cowpea

In vegetable cowpea under red loam soils (Vellayani), maintaining a moisture regime of 75 per cent of the field capacity through out the crop growth period resulted in higher yield and yield contributing characters. A fertiliser dose of 30 kg N and 40 kg P ha^{-1} also contributed to the yield (Jyothi, 1995).

The advantage of light irrigation in cowpea cv. Malika was supported by Mini (1997) where highest yield of green pod was obtained by giving 10mm daily irrigation compared to irrigation at 15mm CPE and 20 mm CPE with plant density of 16,667 plants ha^{-1}.

In another experiment to study the response of cowpea Cv. Malika to nitrogen and potassium under varying levels of irrigation (Geetha, 1999) reported that, the maximum yield of green pod was obtained when the crop was irrigated through micro sprinkler at 20mm CPE with a depth of 10mm water. The N and K levels at 20 kg ha^{-1} enhanced the pod yield. Moisture depletion was higher from the top 0-15 soil layer when the crop was irrigated at 10 mm CPE with a depth of 20mm water through micro sprinkler. At 15-30cm and 30-45cm depth, surface method recorded the highest moisture depletion. Higher level of K was found to influence the moisture depletion pattern. The maximum proline content was recorded when the crop was irrigated through micro sprinklers and potassium was applied at the rate of 40 kg ha^{-1}.

Amaranth

In a comparative study of drip (low cost drip irrigation system fabricated with locally available materials) and basin method of irrigation Sheela (1988) observed no significant difference between conventional method and drip method.

Rajan (1991) studied the response of red and green varieties of amaranth to different water management practices and nitrogen doses. Combinations of four levels of irrigation (irrigation at IW/CPE of 0.75, 1.0 and 1.25 and farmer's practice of daily irrigation) and four levels of nitrogen (50, 75, 100 and 125 kg ha^{-1}) were evaluated and the results indicated that amaranth responded well to frequent irrigation and higher levels of N. Protein content was increased with increased frequency of irrigation and higher levels of N and maximum protein content was recorded at daily irrigation with 125 kg N ha^{-1}. The yield in amaranth was maximum under farmer's practice of daily twice irrigation with 8 litres m^{-2} day^{-1}.

Tomato

In surface method of irrigation, Nassar (1995) reported the optimum frequency of irrigation was at IW/CPE value of 1.2. However, by developing a surface pad irrigation system in tomato, the quantity of water used for surface method at any frequencies could be reduced.

Kingsley (2002) pointed out fertigation at 0.9 PE along with 100% recommended dose of fertilizer was found to be optimum for higher yield in tomato. If water is a limiting factor, irrigation at 0.6 PE with 150 % of recommended dose could be adopted.

Chilli

Drip irrigation @ 2 litres $plant^{-1}$ day^{-1} along with a nutrient dose of 100:40:33.3 kg NPK ha^{-1} resulted in highest yield and nutrient uptake in chilli variety Jwalamukhi (Shirly, 1996). Under acute scarcity of water and land, crops can be profitably raised in pots with modified drip irrigation @ 1.5 litres $plant^{-1}$ day^{-1}.

Roshni (1993) conducted a pot culture study to evaluate a low cost irrigation technique in chilli variety Jwalasakhi and to compare the efficiency of various techniques for economizing water use including three levels of irrigation (60,80 and 100 per cent field capacity), two methods of irrigation (indigenous auto irrigator using hospital drip and pot watering) and three moisture conservation methods (control, application of coir pith, and jalasakthi). One absolute control viz., wick irrigation was compared with other treatments. Maximum yield and profit were obtained in drip irritation at 100% FC, with coir pith mulching while maximum WUE was obtained in drip irrigation at 80% FC with the same mulching.

Brinjal

Sheela (1988) evaluated a low cost drip irrigation system with that of conventional basin method in brinjal and found that with half the quantity of water given in basin method, drip method has given equal or superior yield.

x) Other crops

Sugar cane

Alternate furrow irrigation with 5cm depth along with sugar cane trash mulch recorded the highest WUE, energy use and energy productivity (Thomas, 2001).

Betelvine

Studies conducted at Chalakudy revealed that substantial increase in yield and water saving could be achieved through drip irrigation in betelvine. It was found that drip irrigation at 100% PE resulted in 13.5 to 42.7 per cent increase in weight of leaves and 30.5 to 70.6 per cent saving in irrigation at 100% PE over conventional furrow irrigation in betelvine (Sreekumaran et al, 1998).

Fodder grass

Jacob (1999) observed higher fodder yield and nutrient uptake in irrigated fodder grass cv. congosignal. Irrigation at 45mm CPE was found to be optimum.

4. Onfarm water management studies

The onfarm water management studies in rice in the command areas of Chalakudy Irrigation Project was initiated during 1984-85 at Palisserry in Thrissur district. A compact area of 20.8 ha of rice fields belonging to 75 farmers constituted the study area. Scientific technologies like adopting channel to field rather than field to field irrigation, strict adherence to time schedule in various field operations, need based plant protection and adoption of cropping pattern suitable to the area depending upon the availability of water were implemented through collective approach of the farmers. A neighbouring paddy area was selected as control. The study was repeated at Thuravoor in Angamali during 1986-89 and at Mookannur in Ernakulam district during1989-93. In all the study areas, the yield obtained was double or more in all the seasons due to the adoption of the technologies. The farmers of the study areas and the nearby areas were convinced about the technologies and group approach in farming. The experience of the station has motivated the Govrnment of Kerala to accept the **group farming** technology for increasing the rice production in the fragmented holdings of Kerala (AICRP, 1984-96).

Table 15. Effect of group farming on yield of rice and WUE.

Treatments	Grain yield Kg ha^{-1}	Straw yield Kg ha^{-1}	Irrigation Requirement (mm)	WUE Kg hamm^{-1}	B:C ratio
Group farming	3069	3826	1259	2.50	1.11
No group farming	1810	2651	1660	0.93	1.38

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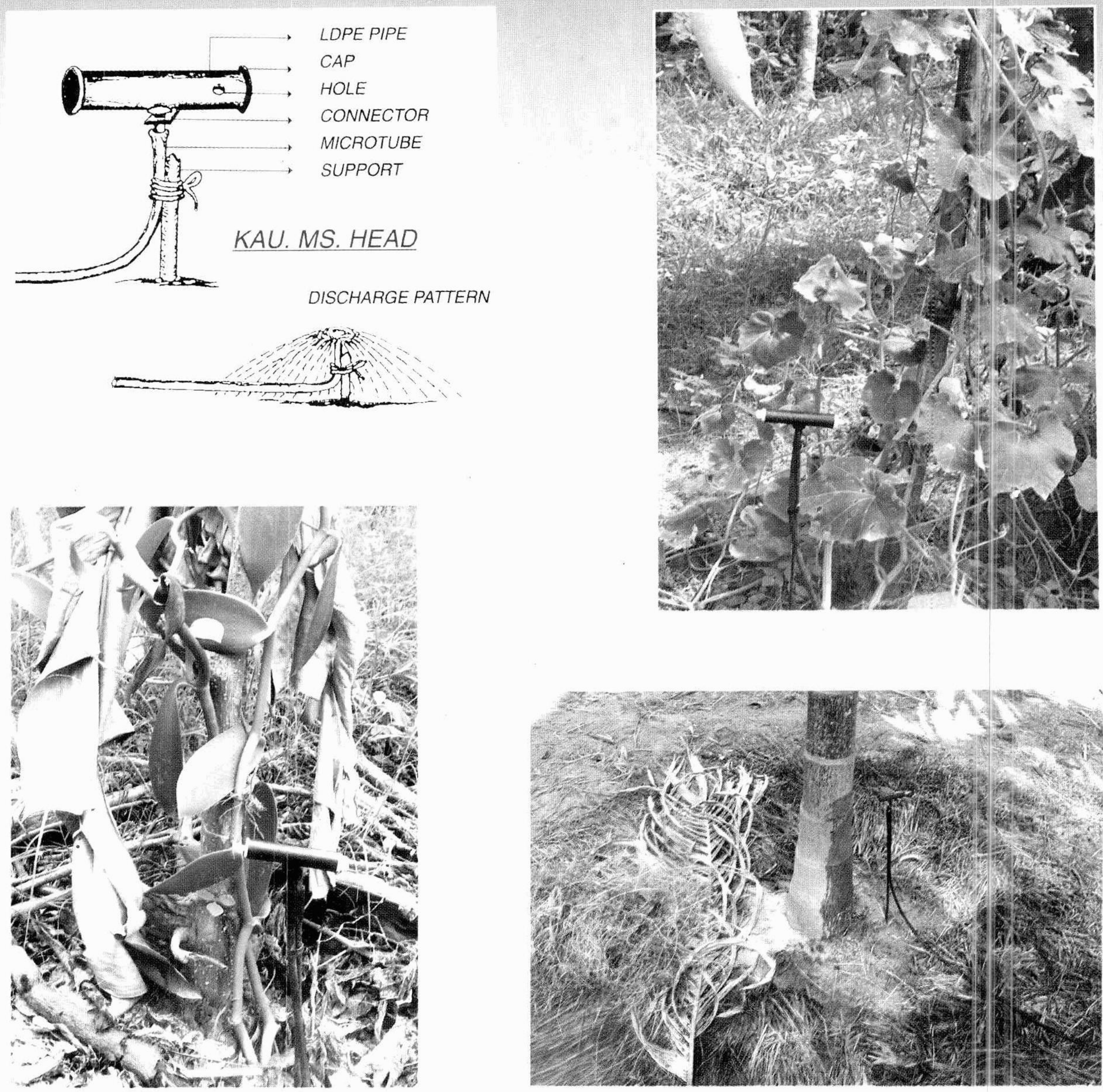
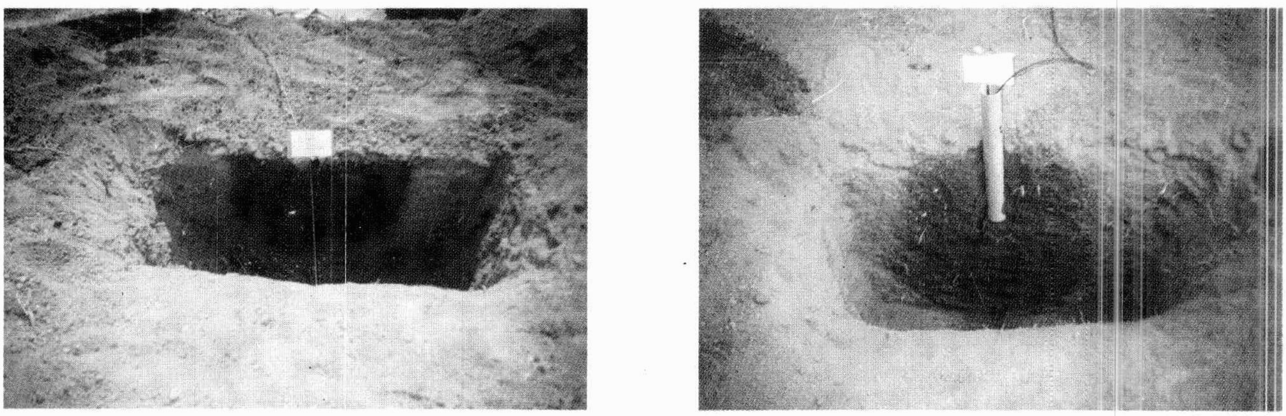


KAU Micro sprinkler design and installation in crops



Wetting area of surface and sub surface drip