Agricultural Water Management Research in Kerala

(1972-2015)

K. P. Visalakshi
Drisya J.
Kavitha P. R.
P. K. Sureshkumar
Soumya A. R.
Sandeep Kumar
Mary Regina F.

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Nodal Water Technology Centre
Kerala Agricultural University

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FOREWORD

With an annual precipitation rate of 3000 mm, 44 rivers, chains of water bodies, reservoirs, tanks, ponds, springs and wells, Kerala continues to be one of the wettest regions in India. However, the State is frequently facing severe drought followed by acute drinking water scarcity for the last three decades. Proper management of water resources of Kerala would certainly make the situation better. For ensuring food and nutritional security of our ever increasing population, adequate water supplies need to be made to match the actual water needs. Since the scope for expanding arable land is rather limited, it becomes imperative to make the best possible use of available natural resources, namely soil and water and to produce maximum from unit area per unit quantity of water.

Water demand for irrigation is determined by the requirement of water for agricultural production. This in turn is linked to the water use efficiency, determined by the type of irrigation water application, farming practices, as well as productivity of the land. Investments in the water sector have primarily been carried out to secure the country's food production, mostly through the development of new irrigation projects, soil and water conservation programmes and more recently also through the implementation of new irrigation technologies such as drip and sprinkler irrigation.

Agriculture is the major consumer of fresh water sources of the country and it is seen as the main factor behind the increasing fresh water scarcity. The utilisation of surface water resources for irrigation was 83% of the total in 2010, whereas the utilisation for domestic use, energy development and industry was only 4.5%, 3.5% and 3.0% respectively. In this background, water harvesting, conservation and judicious use of available water assume great significance. Though technologies for scientific agricultural water management were developed for different crops, they remain scattered and were not being adopted properly due to lack of awareness on this. At this juncture, this document will be of much use to the researchers and planners for their future endeavours.

The authors have collected and consolidated systematically the basic studies related to water resource management, conservation and utilization and the salient findings on water requirements of different crops. I congratulate the authors for making such a great attempt. The efforts taken by all the scientists and research scholars of different organisations of the state who have contributed significantly to bring out the review are well appreciated.

Prof. (Dr.) P. Rajendran
Vice Chancellor
Kerala Agricultural University

PREFACE

Up to date knowledge on different aspects of land and water resources is a basic need for optimum management and utilization of the resources. These have to be studied in terms of potential, present utilization and future requirements. Similarly, data on water requirement of different crops will assist the planning and development of irrigation projects and to identify potential areas for water conservation, enhancement of water productivity and for additional water resources development. Although Kerala Agricultural University and other State Organizations have taken up a lot of works in irrigation water management, all the information remains scattered. Hence the findings of basic studies related to irrigation water and the data on water management for different crops during the period from 1972 to 2015, available at different organizations like Kerala Agricultural University, Centre for Water Resources Development and Management, Central Plantation Crops Research Institute etc. have been collected and compiled to form this data base.

The contents have been divided into two main chapters – The basic studies and Water Management studies for different crops. In the chapter on basic studies, the results of various studies conducted with regard to water resource management, conservation and utilization have been included. In the second chapter, the water management practices for different crops recommended by Kerala Agricultural University and other salient findings by researchers on this aspect are incorporated. Some useful information/data required for computation of water requirement are also given as annexure.

We hope this data base will find use for reference by students, research scholars, planners and scientists working in this field. Future studies can be planned based on these and new technologies developed effectively for the development of innovative farming.

The authors acknowledge the Director, CWRDM, Calicut and the Director, CPCRI, Kasaragod for providing the research results of their organizations for inclusion in this compilation. We thank, Dr. T. R. Gopalakrishnan, the former Director of Research, KAU for his valuable suggestions and guidance in this venture. The financial assistance by Kerala State Planning Board is also acknowledged.

Authors

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Chapter - I

BASIC STUDIES ON WATER MANAGEMENT

Soil moisture characteristics of different soils

Soil moisture characteristic curves were developed for major soil types of Kerala namely, laterite (Thulasidharan, 1983), alluvial (Prameela, 1984) and red (Mathew, 1985) soils. Moisture retention studies on 2 mm sieved soil were made at 0.3, 1.0, 3.0, 5.0, 10 and 15 bars 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 content at field capacity (FC) and permanent wilting point (PWP) levels were 25.2 and 19.4 percent respectively.

Moisture percentage at 0.3 bars

$Y_1 = 80.988 + 0.7647X_1 + 1.1465X_2 + 1.2407X_3 + 0.8974X_4 + 0.9429X_5$ ($R^2 = 0.38$)

Moisture percentage at 15 bars

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

Where, X_1 – Organic carbon content (%); X_2 – Clay content (%); X_3 – Silt (%); X_4 – Fine sand (%); and X_5 – Coarse sand (%).

2. Alluvial soil

The overall mean of FC was 25.8 percent and PWP 13.9 percent

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 percent and PWP 7.75 percent

Moisture percentage at 0.3 bars

$Y_1 = 1.9228 + 0.2920X_1 + 0.3171X_2 + 0.002X_3 + 0.0186X_4 + 1.393X_5$ ($R^2 = 0.87$)

Moisture percentage at 15 bars

$Y_2 = 19.8026 + 0.0552X_1 + 0.0352X_2 - 0.1938X_3 - 0.2064X_4 + 0.01635X_5$ ($R^2 = 0.31$)

Integrated water management in the command area of Kuttiadi irrigation project

The hydraulic evaluation of canal network, evaluation of irrigation and drainage methods and testing, evaluation and demonstration of improved water management practices were done in the command area of Kuttiadi irrigation project (Vamadevan *et.al.* 1986). The seepage loss was found to be the minimum in the canal sections evaluated. However, percolation and seepage losses accounted for 50 to 70% of the water loss in paddy fields. The right bank canal, left bank canal and Kakkodi branch canal were observed to convey 12%, 66% and 69% of the designed discharge respectively. Majority of the areas at the tail reach of the command area were found to receive only 60% of the irrigation water requirement.

Hydraulics of border strip irrigation

The hydraulics of border strip irrigation in nearly level lands were studied to utilize the rice fallows for cultivating other crops in summer months. The study revealed that the discharge rate of 2l/s/m and the inflow cutoff length of 77% of the strip length are optimum for uniform distribution of water. The depth of irrigation could be limited to 5cm even in soils having high rate of infiltration. The recommended width and length of border strip are 4-6m and 45m respectively. The borders are to be laid in the direction of natural slope (Visalakshi K.P. and George T.P, 1987).

Hydraulics of KAU Drip Irrigation System

The study was done with the objectives of finding out the variation of emitter flow rate due to frictional loss and to determine the effect of pressure head and the effect of distributer on the flow rate and to develop standardized chart and design procedure for KAU drip irrigation system. In this, hydraulics of micro tube emitters were studied by using different lengths and diameters of micro tube. It was observed that the discharge rate was higher from the system with distributor than that of the micro tube having the same length. Clogging was higher in 1mm tube than others. (Susan Cheriyan, 1988).

Conveyance loss in irrigation channels

In surface irrigation, the conveyance loss of water is considered as the major impediment in achieving irrigation efficiency. Hence a study on different lining materials like brick pointed in cement mortar, polythene sheet and cow dung mixed with clay were done to assess their effectiveness in reducing seepage losses, durability and economics. The seepage loss in unlined channel was estimated to be 1.19 lpm/m^2, which corresponded to 88.5%. The polythene sheet recorded the minimum loss with less durability. The clay cowdung mixture was also not durable. Hence the

brick lined channel was found to be more economical with regards to durability and maintenance cost (AICRP 1984-96).

Evaluation of effective rainfall under different land uses

The effective rainfall was quantified under coconut, tapioca and rice-based land use systems employing both lysimetric studies and climatological approaches (Rao, 1989 and Rao *et.al.* 1988). From lysimetric studies at Calicut, the effective rainfall was found to be 66% during September to December, 77% during March to May and 43% during June to August under a coconut land use system. The corresponding values under a tapioca land use system were 36%, 58% and 46%. The effective rainfall for rice was 85% and 100% respectively for the 1st crop (May to August) and 2nd crop (September to December). From empirical calculations using climatic data, the effective rainfall as percentage of mean annual rainfall in a coconut-based land use system during SW monsoon (June-September), NE monsoon (October-December), Winter (January-February) and hot weather (March-May) for Calicut was found to be 13%, 58%, 100% and 43% respectively. The corresponding values for Palakkad were 24%, 46%, 100% and 70%; for Kochi were 15%, 34%, 79% and 40%; for Alappuzha were 17%, 29%, 72% and 35%; for Thiruvananthapuram were 39%, 39%, 72% and 50%, and the mean values for the State were 22%, 41%, 85% and 48%. The mean crop coefficient (Kc) computed using Penman, Radiation, Blaney Cridle and US Class A pan methods were 0.54, 0.59, 0.73 and 0.63 for coconut and 0.34, 0.38, 0.46 and 0.40 for tapioca respectively.

Development of rational formulae to predict the advance and recession flow in border irrigation method

This investigation was undertaken to develop the predictive relationship for water front advance and recession in field borders with cowpea as a test crop. Border strips of 2 m width and 40 m length were used for the study. The strips were laid out on 3 different slops (0.4%, 0.3% and 0.2%) and stream sizes of 4 lps, 3 lps and 2 lps per meter width were used to irrigate the strips. There were 9 treatments, each replicated twice. The study concluded that the treatment with 0.2% slope and 4 lps per meter width stream size showed the best uniformity of irrigation. Multiple regression analysis was done and rational formula to predict advance and recession times were developed from the results (Mary Regina, 1992).

Effect of land use on water yield from small agricultural water sheds of Western Ghats

This study was conducted to assess the effect of land use on water yield from small agricultural water sheds of Western Ghats of Kerala. For small watersheds

planted with cashew, rubber, coffee and tea were selected for the study. Different geomorphologic characteristics of the watersheds were worked out. The result of the study leads to the conclusion that the infiltrated rain water meets the impermeable layer and there it flows laterally through the soil and reaches the valley portion of the watersheds where it saturates the soil. Thus from the study it was concluded that land use has no significant effect on water yield from the selected small agricultural watersheds of Western Ghats of Kerala (Abdul Hakkim, 1993).

Infiltration and water advance studies under surge flow furrow irrigation

This experiment was conducted with the objectives of studying the infiltration and water advance characteristics under surge flow furrow irrigation system, to compare the system with continuous flow and to select suitable management parameters for the sandy loam soil of the area. In this, continuous flow was compared with surge flow of cycle ratios 1/2, 1/3 and 2/3 with cycle times 6, 9 and 7.5 minutes for discharges of 1.3, 1.7 and 2.1 lps. It was concluded that surge flow is advantageous compared to continuous flow in the sandy loam soils of the area under study and surging with cycle ratio 1/3 with a discharge of 1.3 lps was chosen as the best out of the selected treatments of the study (Rema, K. P. 1993).

Modification and evaluation of master control unit for different irrigation system

This was performed to evaluate 2 pop – up sprinkler head (full and quarter circle). A master control was modified for the automatic controlling of irrigation by pop – up sprinklers, micro sprinklers and drip irrigation system. The ON and OFF period for the pop – up sprinklers and the micro sprinklers were 3 minutes and 57 minutes respectively and 10 minutes and 50 minutes respectively for drip system. The master control unit is an effective means for reducing human supervision (Udayakumar, 1994).

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 problems, low water table and financial difficulties (Indiradevi and Geethakutty, 1996).

Impact of CADA in Neyyar and Malampuzha irrigation projects

The impact of CADA programmes in Neyyar (NIP) and Malampuzha (MIP) irrigation projects were quantified with respect to water availability, potential versus

actual area utilized. socio-economic aspects and agricultural productivity. The performance efficiency of the projects ranged from 0.6 to 1.4 under NIP and 0.83 to 1.15 under MIP. There was significant increase in the performance efficiency after improvement in the physical system under National Water Management Programme. The seepage losses in the field channel ranged from 10 to 40%. The conveyance efficiency was higher in lined field channel. The actual area utilized to the potential created was 46% and 78% at NIP and MIP, respectively. Social survey indicated better performance of the project after introduction of CAD programme (Varadan *et.al.*, 1998).

Effect of soil solarization using LDPE mulch on moisture conservation and soil temperature variation

In this experiment an attempt was made to study the effect of soil solarization on moisture conservation and weed control. Two thicknesses of transparent polyethylene (0.05 mm and 0.10 mm) and three durations (30 days, 40 days and 50 days) were used for the study. Bindhi crop was sown in the plots after solarization period. It was observed that solarization had significant effect in lowering the weed count as well as the dry weight of weeds for around 5 months after the period of solarization. The yield of bindhi was higher in the solarized treatments. This may be due to the drastic reduction in weed count and dry weight on account of solarisation (Anu Varghese, 1997).

Effect of different types of mulches on growth and yield of drip irrigated vegetables

The experiment included two types of irrigation methods (drip and surface), two colours of plastic mulches (black and transparent) and three levels of irrigation water (1.0 v, 0.8 v and 0.6 v volume). It was observed that all treatments with black mulch increased the yield. Drip irrigation with 0.8 v volume of water and black mulch gave 76.5% more yield. Most of the treatment with transparent mulch reduced the yield. In drip method 0.8 v volume of irrigation water level was the best. Drip along with mulching in summer vegetables can reduce the cost of cultivation through efficient water management, also the area of cultivation can be increased with available water in water scarce areas (Gilsha Bai, 1997).

Optimal cropping pattern for the better utilisation of minor irrigation schemes

A monthly irrigation planning model was formulated for determining the optimal cropping pattern in an existing lift irrigation scheme. Study deals with the use of linear programming technique for obtaining an optimal cropping pattern for a command area by the conjunctive use of surface water. The model is found very

flexible to alter the constraints or add anymore constraints according to the policy makers decisions from time to time based on socio - economic considerations (Bindu, J. 2000).

Optimal water use and cropping pattern for Thrithala regulator – cum – bridge project

This study has been undertaken for a regulator-cum-bridge at Thrithala, Palakkad with the specific objectives of determining the optimum water allocation of the reservoir for meeting various demands on it and obtaining the optimum cropping pattern for the command area. A linear programming model was operated to optimize reservoir operation. Using irrigation allocation from this model another linear programming model was formulated to obtain the optimal cropping pattern for the command area. The optimal operation plan with the incorporation of additional objective was found to be more socially acceptable and economically viable. The optimal cropping pattern showed that there is more than 100% increase both in the net benefit as well as in the net area irrigated (Saritha. E. K, 2001).

Performance evaluation of micro irrigation devices

In this experiment a total of 30 micro sprinklers were evaluated. The performance parameters used for this purpose were uniformity coefficient, coefficient of variation, distribution characteristics etc. It is generally concluded that only the manufactural data should not be taken into considerations while selecting the irrigation devices (Jacob Bijo Daniel, 2003).

Wetting front advance under surface and subsurface drip irrigation

The wetting front advance of soil moisture under surface and subsurface drip irrigation for drip emitters of 2, 4, 6 and 8 lph were studied (Visalakshi, *et.al.*, 2004). An inverse relationship was observed between discharge rate and area wetted. The lower the discharge rates, the wider were the area wetted and vice versa. The subsurface application (30 cm below) resulted in increased soil moisture content of 3-4% at the point of application, compared to that of surface application. The following mathematical models were developed relating the horizontal and vertical water front advance and the rates of discharge.

Surface application:

$X = 0.2083q^2 - 2.8475q + 38.225$ ($R^2 = 0.8885$)

$Y = -0.0812q^2 - 0.6025q + 29.775$ ($R^2 = 0.9712$)

Sub surface application:

$X = q^2 - 14.15q + 79.5$ ($R^2 = 0.998$)

$Y = -0.06875q^2 + 4.925q + 34.75$ ($R^2 = 0.9958$)

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)

Ground water conservation by sub-surface dykes

A feasibility study of sub-surface dyke for tapping ground water was undertaken at the Aromatic and Medicinal Plants Research Station, Odakkali, Kerala Agricultural University under the Swedish International Development Agency (SIDA) assisted ground water project during 1988-89. The dam was 75m long and constructed in brick masonry, the catchment being 1.2 ha. Black polyethylene sheet was also provided in the upstream side in front of the dam to test its feasibility as an alternate cheaper material to the costly brick masonry and also to augment the impermeability of the dyke. The static water level and the draw down during pumping observed in the observation wells in the upstream and downstream sides of the dyke and that in between the plastic sheet gave promising results with respect the leakage preventing qualities of brick as well as the plastic sheet. The harvested water is being utilized for irrigating coconut palms of the station through drip system. The facts that no water was available for irrigation at the site before the construction of the dyke is more than an indication of the suitability of this system for conserving ground water especially in Kerala with its unique topography having hills and valleys (Visalakshi, K.P. and Noble Abraham, 2005).

Suitability of soil moisture measuring equipment for Kerala soils

Various soil moisture measuring equipment were evaluated under different soils for identifying the appropriate equipment for field use. Tensiometer and Gypsum block methods were evaluated in forest loam soil, laterite soil, riverine alluvium, red soil and coastal sandy soil. The instruments were installed in different soils filled in large pots and their soil moisture readings were compared with readings of gravimetric methods of soil moisture estimation (Shamla Rasheed *et.al.*2006).

In forest loam, laterite soil, riverine alluvium, red soil and sandy soil, the tensiometers could read upto 17.5%, 21.7%, 13.7%, 19.3% and 1.5% soil moisture, while the gypsum block could read upto 14.8%, 18.2%, 16.4%, 19.1% and 1.2% respectively. The wilting points of the respective soils were 12.6%, 16.8%, 11.8%,

18.4% and 0.9%. The statistical analysis of the data showed that there was highly significant correlation between gravimetric soil moisture and tensiometer readings in different soils. In the case of gypsum block, there was significant correlation between gravimetric soil moisture and instrument readings only in forest loam, laterite soil and red soil.

Action research on on-farm water management for paddy through farmers' participation

The objectives of the project were to study water use efficiency of paddy under channel to field method of irrigation, identify factors that will promote adoption of the water management practice among farmers and to demonstrate the irrigation method among the farming community. During 2006 summer season, irrigation was provided using ferrocement irrigation channel for paddy in a selected farmer's plot under Kuttiyadi irrigation project in Kozhikode district. The study has shown a water use efficiency of 1.4 kg/mm under channel to field irrigation, compared to 1.2 kg/mm under field to field method. The total quantity of water used for the irrigated paddy crop under channel to field method was only half of that used under field to field irrigation.

Infrastructure assessment of Ichannoor sub distributor, which conveys water to the study area revealed its poor condition, leading to water loss through seepage and leakage to the order of 0.0115 m^3/sec/300m length of the canal. This can act as a disincentive in motivating farmers to adopt improved water management practices like channel to field method. The study has shown that only 12% farmers were aware of scientific irrigation scheduling for rice, while 73% farmers reported awareness on channel to field method of irrigation, 53% farmers agreed that channel to field is better than field to field method, primarily because of better water management through this method (Sandhya Reghunathan *et.al*, 2006).

Technological and institutional interventions in rainwater harvesting in Kerala

Studies were conducted to assess the efficiency, durability and acceptability of different types of roof catchments, storing capacity of different types of storage structures with respect to quality of water by establishing different rain water harvesting structures at KAU campus. The runoff coefficient of sloping aluminium sheet roof was observed as 0.91 and that of flat RCC roof slab as 0.73. Water quality analysis showed that the physico chemical parameters of rainwater stored in all types of storage structures were within permissible limits as per the BIS even after six months of storage, where as the microbial analysis showed that the water stored only in ferrocement tank and lined underground water tank were free from e-coli, colliform bacteria and streptococcus. The ferrocement tank and lined (750 micron HDPE sheet with food grade) underground tank could be recommended as rainwater storage

structures for drinking purpose and lined pond (with 300 micron geo membrane, covered by 75% shade net on top) for irrigation purpose. The evaporation loss from lined pond could be reduced upto 50% by providing 75% shade net on top, compared to the pan evaporation. An additional area of 0.8ha. could be brought under cultivation using rainwater collected in a renovated pond at the seed farm. Covering soil by geo textile and growing grasses like 'potha' and 'cenchrus' resulted in maximum runoff with minimum sediment transport (Visalakshi, 2007).

Feasibility studies on the use of precision porous pipes for subsurface irrigation

The experiment was done to check the feasibility of using porous pipe for subsurface irrigation. Porous pipe works at low pressure and low volume. It allows the wetting of large areas with small water sources. The type of soil in the study area was sandy loam with bulk density of 1.6 g/cc. This study concludes that the water use efficiency was highest in the treatment with sand envelop and paired row planting at the depth of placement 20 cm. The water use efficiency of drip irrigated treatment for double paired row planting was higher than that for porous pipe irrigated treatment (Eugine Spicer, 2007).

Standardization of design criteria of KAU Micro sprinkler

- A low cost micro sprinkler head, originally named as bubbler head was developed at the Agronomic Research Station, Chalakudy (KAU, 2006-11). In this, 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 a unit in between drip and mini-sprinkler systems, very simple in design and clog free, ensuring complete wetting of the basin area of the crop. The design criteria of the above sprinkler head, named as KAU Micro sprinkler was standardized with two models of 8 mm and 12 mm LDPE lateral pipes for better application and distribution efficiencies as follows:

Diameter	8 mm	12 mm
Length	5 cm	8 cm
Nozzle size	1 mm	1mm
Pressure required for working	0.3 to 1.0 kg/cm^2	0.3 to 1.0 kg/cm^2
Discharge rate	30-35 lph	40-45 lph
Wetting diameter	210-250cm	200-230cm
Height of riser pipes	30-90 cm	30-90 cm
Crops suitable	Leafy vegetables, ornamental plants, lawn etc.	Vegetable crops, banana, medicinal plants, coconut etc.

Development and evaluation of cablegation system for semi automation of surge irrigaion

A cablegation system for semi atomization of surge irrigation in furrows was developed (Visalakshi, *et al.*, 2010. KAU 2006-11). The main components of this system are a water storage tank, main conveyance pipe line, a closely moving inner pipe with concentric outlets as in the outer pipe and lever arrangement at the downstream side connecting both ends of the inner pipe through a steel cable. With the forward and reverse movement of the lever, surge flows can be created to sixteen furrows (eight each on both sides) at a cycle ratio of 0.50. The cycle time can be selected based on the soil type. The entire furrow length could be wetted by four surges. The moisture analysis at different points along the length of furrows before and after irrigation resulted in an application efficiency of 82% and distribution efficiency of 92.1%.

Soil and water conservation aspects of zero tillage cultivation practices on hill slopes of humid tropics

Strip tillage is found to be the most efficient and sustainable cultivation practice on hill slopes of humid tropics. As a result of intensive biotic activity and increased organic matter content in the soil, reduced tillage methods improve infiltration and reduce runoff and soil loss. These methods make agriculture more sustainable. It was also found that stem flow and leaf strip is important parameters that influence erosion process (KAU, 2006-11).

Design, construction and performance evaluation of low cost, naturally ventilated green house suitable for humid climate

Naturally ventilated low cost greenhouse made of bamboo/arecanut poles and covered with UV stabilized polyethylene sheets (200 micron) are found suitable for growing high value crops like capsicum, tomato, cabbage, cauliflower and cucumber round the year. An optimal design of low cost greenhouse suitable for Kerala homesteads is gable shaped structure with a floor area of 75 m^2 provided with roof and side ventilators oriented in north-south direction. The structure should have a ridge height of 4.35 m and gutter height of 2.25 m. The roof slope should be around 30^0, effective side ventilation not be less than 30% and effective roof ventilation not less than 9%. Ventilators should be provided with insect proof net. The side ventilators should be provided on either side of greenhouse at the floor level and roof ventilators should be provided at the ridge level throughout the length of greenhouse (KAU, 2006-11).

Hydro dynamics of porous pipe sub surface irrigation in medium soils

The water distribution pattern of porous pipes installed at different depths at an operating pressure of 0.8 kg/cm^2 was found out. The study revealed that porous pipe

installed at 22.5 cm depth. distributed water more uniformly in each horizontal layer compared to porous pipes installed at other depths (KAU, 2006-11).

Optimization of plant and lateral geometry for economizing micro irrigation (drip)

The economical analysis of different treatments with drip lateral spacing and plant spacing revealed that the treatment having a lateral spacing of 2.4 m and plant spacing of 30 cm x 30 cm gave higher benefit cost ratio and treatment with 1.2 m lateral spacing and 30 cm x 60 cm plant spacing gave lesser benefit cost ratio (KAU, 2006-11).

Optimization of field water requirements for efficient operations of wet seeder and cono weeder

Study for the efficient operation of drum seeder and cono weeder revealed that there should be 1 to 2 cm depth of water in the field. All the treatments using cono weeder both with and without standing water, gave significantly higher grain weight than hand weeding. Weeding at 20 DAS & 40 DAS using cono weeder and without standing water gave maximum grain weight and treatment with standing water and hand weeding gave minimum grain weight. All the treatments without standing water gave higher yield compared to the treatments with standing water. Among the treatments with standing water, weeding at 20 and 40 DAS was superior to other treatments. Among the treatments without standing water also, weeding at 20 DAS & 40 DAS got higher grain yield. Analysis on straw weight revealed that, all the treatments without standing water was having significantly higher straw yield compared to the treatment with standing water and hand weeding.

Both wet weight and dry weight of weeds for the treatments without standing water was significantly higher than the treatments with standing water. All treatments with standing water were having significantly lesser weed growth compared to the treatments without standing water. Weeding at 20 DAS & 40 DAS using cono weeder and without standing water have maximum weed growth and treatment with standing water and weeding at 15 DAS, 30 DAS & 40 DAS using cono weeder have minimum weed growth (KAU, 2006-11).

Impact assessment of land use practices and studies on sustainable development in Western Ghats of Kerala

The project was implemented to evaluate the land use changes in Pampa and Achenkovil river basins and their possible influence on river flow and total water balance of the watersheds. A decrease in lean flow is observed in these rivers over the years. This is mainly due to the increasing water consumption for domestic

needs. The analysis of river flow, rainfall and cultivation pattern here show that the lean flow and ground water storage is not sufficient to meet the water requirement of the area in summer months. Effective water resources development measures are to be implemented here to maintain the lean flow. Appropriate methods of irrigation also need to be developed based on cropping pattern and water availability. The existing irrigation schemes were planned for irrigating paddy. Now the cropping pattern and availability of water for irrigation has changed. A corresponding change in the irrigation system is required to improve the agricultural production and to uplift the socio-economic conditions of farmers (KAU, 2006-11).

Grey water treatment using constructed wetland

The SCW (Sub surface flow Constructed Wet land) system with Canna as macrophytes and fine river sand as filtering media is a good on-site grey water treatment method for rural communities which can reduce fresh water demand and make waste water available for secondary water uses. Also SCW systems have great potential to reduce the health risk by avoidance of breeding places of mosquito and other undesirable insects. Any locally available suitable macrophyte and filtering media can be used in small scale SCW system and effective treatment of waste water from households can be performed. Thus this can be an efficient means of reusing the wasted precious resource of nature (KAU, 2006-11).

Hydraulics and field performance of a Novel Micro Sprinkler

The work was undertaken to study the hydraulics and field performance of a micro sprinkler developed by Mr. Avaran, a farmer of Malappuram District. It is made by fusing one end of a 3 mm diameter, 4 cm long LDPE micro tube and making an incision just below the fuse end. Micro sprinkler samples of 4 different dimensions were used and tested for their hydraulic performance under 4 different pressures (0.5, 1.0, 1.5 and 2.0 kg/cm^2). This micro sprinkler was found suitable to irrigate most of the perennial and vegetable crops. To solve the deficiency of this sprinkler, standardized micro sprinklers through plastic injection moulding was manufactured. The same sprinkler was evaluated for its field performance with the crop cucumber by using different levels of irrigation in RBD design with 9 treatments and 3 replications. 75% irrigation with paddy straw mulching was the best treatment. It was concluded that this simple and low cost micro sprinkler is very effective for most of the vegetable crops of Kerala (Soumya Rani, T. 2012).

Design of a low cost organic fertigation system for homestead vegetable production

A three tier filtering mechanism and filtration procedure for organic fertigation was designed, fabricated and tested successfully with different micro irrigation

systems. The system was standardized with cow dung slurry. Quality of the organic filtrate was assessed and was compared with original form of manure. Studies on the discharge rates of filtrate through different micro irrigation systems were made and the discharge in organic fertigation was found almost as good as that of irrigation alone. All the micro irrigation systems were successfully operated without clogging under organic fertigation (KAU, 2011-14).

Development of a filter system for roof water harvesting

A roof top rain water purification system with upward flow micro mesh filter and filter combination with sand and charcoal were developed and tested. The results showed that after filtration, the turbidity and suspended solids concentration was reduced by 81% for mesh filter alone and 85% when secondary filter combinations of sand or charcoal was used. All the filter combinations were also capable of reducing the EC values of the roof water significantly. BOD test of the inflow and outflow water also showed considerable reduction of BOD in the outflow water. Coli form test revealed that raw roof water was having coli form bacteria, however, after the filtration, their presence was negligibly small. The study has proved that the micro mesh filter and the filter combinations with sand and charcoal are very effective in the purification of roof water and are also very user friendly from the point of view of cleaning (KAU, 2011-14).

Soil erosion studies under simulated rainfall conditions in a lateritic terrain

A rainfall simulator was fabricated which could produce rainfall intensities varying from 8.16 to 8.80 cm/h. The uniformity of rainfall varied from 89.01 to 92.70 per cent and the average drop size varied from 1.5 to 2.8 mm. A relationship between supply pressure and intensity of rainfall as well as intensity and uniformity of rainfall was developed. The soil loss and runoff was found to increase with increase in rainfall intensity and land slopes and there were no much variations on runoff and soil loss at 6 to 10 per cent land slopes. Linear and quadratic equations were developed by regression analysis and by the 3D surface plot analysis and it was seen that the causative factors namely slope and intensity are bearing direct impact on soil erosion (KAU, 2011-14).

Design, development and evaluation of an automated drip irrigation system

Under the study, two types of soil moisture sensors were evaluated out of which, one was developed as low cost soil moisture sensor based on electrical conductivity and the other was of capacitance type. The lowest value of electrical conductivity for electrical conductivity type sensor was 2.02 mS/m in distilled water and highest value 2.4 at the 9.9 mS/m. At lower EC values, the data followed a linear relationship

and as the EC values increased, the relationship became nonlinear and all conductivity sensors followed the similar trend. In case of the capacitive sensor for different concentrations of salt solutions (EC values) the data followed a linear trend. The lowest value of electrical conductivity for capacitor type sensor as measured by sensor was 7.0 dS/m in the distilled water and 13.6 mS/m at the 9.9 mS/m. It indicated that there is no effect of the electrical conductivity on the sensor performance. Measurements in different salt solutions demonstrated that the electrical conductivity and capacitance type soil moisture sensor measurements were accurate. Results suggested that there might be no need for a soil specific calibration. Limited sensor calibration requirements are important, when large networks of soil moisture sensors are being deployed (Navaneeth Sharma, 2014, KAU, 2011-14).

DRAINAGE STUDIES

AICRP on Agricultural Drainage-Studies at Karumady Centre, KAU

The following conclusions are made based on the studies (Mathew *et. al.*, 2004)

- Inability to leach the soil profile due to inherent high water table conditions is the main cause for poor productivity of the *kari* soils.
- Full potential of N efficiency can be realized only in conjunction with drainage.
- The density of open drains is not adequate to get the desired sub soil leaching. The open drainage density cannot be increased due to consequent loss of cultivable area and maintenance problem.
- The best cropping season depends on the quality of irrigation water, the salinity levels of which are determined by the movement of the saline waterfront from the Arabian Sea. August-November is considered to be the best season for paddy cultivation.
- The efficiency of the indigenous drainage pump sets presently used is very low to the tune of 20%. The excess energy consumed for drainage pumping using the present set-up is 6.7 million kwh, which is nearly 22% more than the actual requirement.
- The performance of clay tile drains are better than PVC drains even though mean port opening area is more than in PVC drains. The reason is thin slot width of the PVC drains that are clogged due to iron sludge deposition.
- The equivalent hydraulic conductivity was 0.167 m/day in the region under influence of the outside water bodies and 0.055 m/day in the regions beyond the influence of the outside water bodies.

- The drainable porosity decreased with mid-spacing water table heights and became almost constant at lower water table heights. The equivalent drainable porosity was 0.04.
- Hammad equation for thick layers was found to be the best suited for drainage system design for the area.
- Many of the crop growth parameters in the experimental area, particularly the grain yield and 100 grain weight was significantly superior to that of the control plot when subsurface drainage was provided.
- Drain spacing up to 30 m could significantly improve the productivity of the area.
- The overall increase in rice yield due to subsurface drainage is 1.1 t/ha over illdrained areas.
- Subsurface drainage could remove the heterogeneity in the soil chemical properties, which is the root cause for patchy crop growth and uneven ripening of rice crop in the area.
- The salinity in the soil could be controlled considerably by subsurface drainage.
- Subsurface drainage was also very efficient in leaching iron, sulphate, chloride, sodium, potassium, calcium and magnesium.
- The filter/envelope materials around the drains were not found to be an absolute requirement in these types of soils.
- The K_{18} culture was found to be the most suitable of the varieties tested in *kari* soils under subsurface drainage with a maximum yield of 3.16 t/ha. It was observed that the fertilizer dose of 120:60:60 of N:P:K per ha and a seed rate of 100 kg/ha was found to achieve the highest yield.
- Economic analysis for a 100 ha farm revealed that subsurface drainage system in the region is economically feasible with a B-C ratio of 2.45, NPW of Rs 5.17 million and IRR of 47%. The system can economically support if it can realize an additional yield of 0.41 t/ha from the present level.

Feasibility of channelling percolation water for irrigation

Studies were conducted at Agronomic Research Station, Chalakudy, Kerala Agricultural University to find out the possibility of channelling percolation water through subsurface drain for irrigating low lying tail end plots and 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 1984-96).

Chapter –II

WATER MANAGEMENT FOR CROPS

RICE

Paddy cultivation was part of the proud culture of Kerala State. Rice is the most important cereal and staple food produced and consumed in Kerala. Kuttanad is called as rice bowl of Kerala because of rice cultivation. Thrissur and Palakkad are the other two places in the State where large scale cultivation is done. Kerala has nearly 1.97 lakh ha under paddy cultivation and the production is about 5.083 lakh tonnes (Farm guide, 2015).

Water management as per Kerala Agricultural University Package of Practices Recommendations - Crops - 2011

Maintain water level at about 1.5cm during transplanting. Thereafter increase it gradually to about 5 cm until maximum tillering stage. Drain the water 13 days before harvest.

In areas where water for irrigation is assured and where acidity is high, draining and reflooding every 15 days is recommended. In flood prone areas, aged seedlings of Mahsuri or other varieties recommended for waterlogged conditions may be planted. The date of planting may be adjusted so as to avoid synchronization of the critical stages of maximum tillering or heading with the usual flood period in the tract.

During the mundakan crop season, water level of 5 cm need not be maintained continuously after the cessation of northeast monsoon. Five centimetre irrigation once in 6 days will be quite adequate for project areas where water is assured.

For summer rice (in situation where the ground water level is low, i.e., within 1 m from the surface), 5 cm irrigation two days after disappearance of ponded water is sufficient instead of 5cm continuous submergence throughout the crop period.

Irrigation schedule for rice under limited water resources

For summer rice under limited resources of water, phasic stress irrigation can be practiced to the advantage of saving substantial quantity of irrigation water without any significant reduction in yield. About 20-30 percent more area can be irrigated with the same water resources by adopting any of the following phasic stress irrigation schedules (Table.1). Depending upon the schedule, water saving ranges from 24-36 percent of the requirement for 5 cm continuous submergence throughout the crop growth. Grain yield reduction in the above practice is only 0.1 to 1.6 percent.

Table 1.Irrigation schedule for rice under limited water resources

Schedule	Stages		
	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	Hair cracking of surface*
Category IV	Hair cracking of surface*	Continuous submergence	Hair cracking of surface*

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

Experiments were conducted at the Agronomic Research Station, Chalakudy. (KAU, 1978-2001) to find out the water requirement of rice during virippu (*kharif*), mundakan (*rabi*) and punja (summer) season and results obtained are presented (Table 2).

Table 2. Water requirement (WR) of rice (mm)

	Virippu (97 days)	Mundakan (86 days)	Mundakan (94 days)	Punja (80 days)
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	21.5

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
The optimum irrigation scheduling for both short and medium duration rice during summer season at Pattambi was found to be intermittent 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 Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara.	Reena Mathew *et.al.* 2005. Three decades of research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

The irrigation experiment using drum culture technique showed that the seasonal water requirement for paddy was found to range from 800-1500mm. The evapo-transpiration of rice was of the order of 35-50% of the water requirement considering all the seasons	--	Agricultural water management, Three decades of activities of water management (Agriculture) Division, (1978-2007) Centre for Water Resources Development and Management, Kozhikode 2008 P18
Irrigating paddy at saturation point and applying N and potash fertilizers in 3 splits at basal, 15 days, and 38 days after transplanting can be adopted for medium duration rice crop in Rabi season for optimum yields. A study to find out the optimum water regime revealed that irrigation for second crop rice can be withheld even up to 5 days after the disappearance of ponded water with only slight reduction in yield, but with considerable savings in irrigation water under shallow water table condition and moderate rainfall. 5 cm irrigation at an IW CPE value of 1.0 upto 45 days (until the onset of monsoon) and thereafter 5 cm continuous submergence enhances the grain yield of dry sown rice raised during the first crop season. From a study to determine the fertilizer management practices under different water management practices it appears that application of nitrogen in 4 splits is better under continuous flow sub-mergence where as 3 splits will be adequate under continuous stagnant sub mergence and under 5cm irrigation one day after the disappearance of ponded water.	Annual Repon (1979-80) AICRP on Water Management, Agronomic Research Station, Chalakudy, pp 92-94	Agronomic Research Station, Chalakudy, Kerala Agricultural University

In rice. 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. In another experiment with 100% and 75% submergence in rice variety Jaya at different growth stages for different period, 100% submergence for 2 days and above at tillering stage was found to significantly reduce the yield. At panicle initiation stage, 100% submergence even for a day resulted in reduction in grain yield. However 75% submergence at the above stage did not significantly affect the yield upto 5 days of submergence. Experiments were conducted to find out the optimum requirement and time of application of N under different management practices. The results indicated that under continuous flow submergence, application of nitrogen in 4 splits at planting, active tillering stage, panicle initiation stage and booting stage was found to be beneficial for medium duration rice variety Jaya during Mundakan season. The quantity of N used was 90 kg/ha. The application of N can be limited to 3 splits under continuous stagnant submergence and 5cm irrigation at 1 DADPW. In Triveni 70 kg N/ha was found to be optimum under all water management practices viz., continuous submergence and irrigation at 1, 3 and 5 DADPW.	Annual Report (1984-96) AICRP on Water Management. Agronomic Research Station, Chalakudy.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala AgriculturalUniversity. Agronomic Research Station, Chalakudy.

In wet sown condition, short duration variety Triveni responded only up to 50 kgNha^{-1} applied in 3 splits. The optimum water management practice was 7 cm irrigation I DADPW in sandy loam soil under shallow water table conditions. Irrigating paddy (var. Jaya) at saturation point and applying N and K fertilizer at 90:45kgha^{-1} in 3 splits at basal, 15 days and 38 days after transplanting could be optimum for higher yield and WUE. Continuous submergence throughout the crop period in rice is considered to be the optimum water management practice for efficient weed management and maximum yield. Irrigation at I DADPW was found to be effective for weed control in dry sown rice during virippu season in sandy loam soil. Lysimeter studies conducted at Chalakudy to assess the ground water contribution in rice production 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.		
In *kole* lands of Thrissur district, the water requirement of rice variety Triveni during punja season was estimated. The average percolation loss was 17.15 mm/day and average ET was 7.42 mm/day. The total water requirement was estimated to be 2134.22 mm.	Chirayath, L.D. 1988. Forms of water loss and water requirement of rice in *Kole* lands. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

An experiment was conducted to study water use efficiency in irrigated rice under channel to field method compared to the traditional practices of field to field method of water distribution. The result showed that the quantity of water used in channel to field plot is 1505 mm/ha, while for the field to field irrigation plot it is 1879 mm/ha. The yield obtained under channel to field. Irrigation is 2087 kg/ha while it is 2252 kg/ha under field to field irrigation.	Final report. 2010. Action Research on On-Farm Water Management for Paddy through Famers' Participation CWRDM.	Water Management (Agriculture) Division Centre for Water Resources Development and Management (CWRDM). March 2010.
In a study conducted in the iron toxic lateritic rice soils during the second crop seasons, intermittent irrigation of 5 cm at 5 DADPW was found to be statistically on par with continuous submergence. This was in conjunction with NPK at 90-45-120 kgha^{-1} and silica 250 kgha^{-1}. This technique could produce 20-70% increasing yield over farmers practice and existing KAU recommendations of 90-45-45 kgNPKha^{-1}.	Bridgit, T. K. and Potty, N. N. 2001. A new production technology for iron toxic laterite soils. Saic News Letter, SAARC Agricultural Information Centre (SAIC).12(1):10.	Reena Mathew *et.al.* 2005. Three Decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
A study conducted in 1971-74 revealed that the water requirement of rice from transplanting to the milky stage of grain was about 1700 mm and consumptive use of water amounted to 821.7 mm. The amount of water lost in deep percolation per day was 12.01 mm where as the corresponding consumptive use was 10.4 mm.	Brijit, T. K., Gracy Mathew, P. K., Gangadhara Menon., Anilkumar, K., Beena, C., Jose Mathew, Alexander, D., Joy, P.P. and Balachandran, P.V. 2002. Management of rice in relation to growth and productivity. Chapter VII. 75 years of research, RARS, Pattambi, Kerala Agricultural University. pp.51-94.	Regional Agricultural Research Station, Pattambi, Kerala Agricultural University.

In another experiment conducted during 1973-74, the evapo transpiration and percolation were estimated respectively, as 4.88 mm and 3.91mm per day in the virippu crop season and 7.32 mm and 7.99 mm per day in the mundakan crop season. An investigation on the effect of flooding or water logging during the growth phases of transplanted rice revealed that the water logging during the vegetative phase markedly reduced the number of tillers per unit area. Plant height and number of grains per panicle were not significantly influenced by water logging. Grain yield tended to decline when the plants were subjected to water logging and the magnitude of reduction in yield on account of water logging at the vegetative, reproductive and ripening phases were 2 percent, 7 percent and 8 percent respectively compared to shallow submergence.		
A pioneer study on techno economic feasibility of micro irrigation in upland rice showed that the treatment with drip irrigation @100% Ep gave significantly higher grain and straw yield. which was on par with sprinkler at 125% Ep. Highest Field Water Use Efficiency was recorded under lower irrigation regime of 75% Ep. Moisture stress had negative influence on plant height, tiller production, yield attributes and yield of rice. Fertilizer dose of 60:30:30 N, P_2O_5, K_2O kg/ha recorded comparable yield to that at 90:45:45 N, P_2O_5, K_2O kg/ha. Weed incidence was less in drip	Visalakshi. K. P., Kavitha. P. R, Shahanila. P. P, Sureshkumar. P. K. and Prameela. P. 2015. Feasibility study of micro irrigation in upland rice. *Proceedings of International Rice Symposium*. 18th-20th November 2015, IIRS. Hyderabad. p.470.	Nodal Water Technology Centre, Department of Agricultural Engineering, College of Horticulture, Kerala Agricultural University.

irrigated plots compared to sprinkler and the sprinkler irrigation @ 125% Ep recorded maximum weed dry matter accumulation.		
The fertigation experiment in sprinkler irrigated upland rice in the variety Uma in sandy loam with a pH of 5.48 and available water holding capacity 36% revealed that irrigation at 125% E_p along with 60:30:60 N, P_2O_5, K_2O Kg/ha is suited for sprinkler irrigated upland rice cultivation as it gave higher yield and net returns. The yield of rice was low in this system as compared to that of flooded situation probably due to the moisture stress experienced by the crop even with 125% E_p irrigation.	Shahanila P. P, 2015. Fertigation in Sprinkler Irrigated Upland Rice (*oryza sativa* L.). M.Sc.Thesis. Department of Agronomy, College of Horticulture, Vellanikkara.	College of Horticulture, Kerala Agricultural University, Vellanikkara.

COCONUT

The Coconut production plays an important role in the state's economy and culture. Kerala has nearly 7.98 lakh ha under coconut cultivation and the production comes around 5799 million nuts. Coconut palms grow and bear well in different types of soils. The soils should have free drainage and allow unrestricted root development and aeration. Soil moisture is often the great limiting factor for the successful growth of coconut. During the first three years, seedlings should be watered adequately. Moisture stress at later stages leads to reduction in number of female flowers, shedding of buttons and dropping of immature nuts.

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops -2011

Irrigate the palms during summer months in basins around palms as shown in Table 3.

Table 3. Irrigation requirement of coconut

Parameters	Soil texture			
	Sandy	Sandy loam	Loam	Silty clay
Available soil moisture (cm/m)	8	12	17	21
Quantity of water / irrigation / palm in litres in a basin of 1.8m radius	600	900	1300	1600
Interval of irrigation (days)				
All areas in Kerala except north eastern portions of Thrissur and Palakkad districts	3-4	5	7-8	9
North eastern portions of Thrissur and Palakkad districts	2-3	3-4	5-6	6-7

Note: In coastal sandy soils, seawater can be used for irrigation.

In irrigated gardens, interruption of irrigation would lead to serious setback in yield and general condition of palms. Hence, when once started, irrigation should be continued regularly and systematically. In sandy loam soil, irrigating the crop with 500 litres of water through basin taken at 1.5 m radius at CPE value of 50 mm (approximate interval of 15 days) is most economical. Do not irrigate seedlings and very young palms with seawater.

Water requirement through drip irrigation is 40-50 litres per day for an adult palm with three to four drippers per palm.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation @ 0.5 IW/CPE and 50% of recommended dose of fertilizers were found to be optimum for economic production of banana and tapioca as intercrop in coconut garden. WUE of banana as inter crop range from 1.9 - 2.5 for un irrigated control and 2.3 - 3.6 for irrigated treatments. WUE of tapioca as inter crop range from 2.7 - 5.6 for un irrigated control and 2.8 - 7.1 for irrigated treatments.	Varadan, K. M. and Nafeesath, M. 1986. Leaching loss of nutrients under coconut based cropping system. *Proceedings of the workshop on slow release fertilizers in plantation crops*, 25-26 November, 1986 CPCRI, Kasaragod.	Agricultural water management. Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p10.
Results of the study on scheduling irrigation to the standing crop of coconut in sandy clay loam soil indicated that the crop responded well to irrigation during dry months (Jan-Mar) from the third year onwards. Irrigating the crop with 500 litres of water through basin of 1.8 m radius at CPE value of 50 mm (approximate of 12 days) was found most economical.	Annual Report (1987-1988) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 129.	Agronomic Research Station, Chalakudy. Kerala Agricullural University.
Measurements of transpiration rate and biomass of coconut were made using tritiated water as traces. The method of tracer injection into the coconut trunk and extraction of tririated water from coconut leaves were standar-dized. The transpiration rate of the 10 year old coconut tree was found to be 2.2 l/hr with a total biomass of 172 kg.	George Mathew., Vasu K., Vamadevan V. K. and Wahid, P. A. 1988. Measurement of transpiration rate in coconut palm with irrigated water: tritium profile in coconut crown. *J Nuclear agric biology*, 17:110-112.	Agricultural water management.Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, Page :14.

Basin irrigated (once in 5 days with 800l of water/irrigation) 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 (the whole area with 5cm of water once in 5 days) in littoral sand of Nileswar. In another experiment, when irrigated with 800 l of water once in 7 days during summer months, the average yield increase over 11 years from the commencement of irrigation was maximum in the low yield group (38.3 nuts) followed by the medium group (32 nuts). In general, the low and medium yielders are better responsive to irrigation.	Nair, R. R., Pillai, G. R. and Rajagopalan, A. 1988. Water Management in Coconut. Six Decades of Coconut Research (ed. Aravindakshan, M., Nair, R. R. and Wahid, P. A.) KAU pp 94-103.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy
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 0.50 (approximate interval of 19 days) recorded the highest yield. The interaction of fertilizer with irrigation was not significant. The quantity of water/ irrigation / palm was worked out for various soil types as • Sandy : 600 litres/irrigation/palm • Sandy loam : 900 litres/ irrigation/palm • Loam :1300 litres/irrigation/palm • Silty clay: 1600 litres/irrigation/ palm	Nair, R. R., Pillai, G. R. and Rajagopalan, A. 1988. Water Management in Coconut. Six Decades of Coconut Research (ed. Aravindakshan, M., Nair, R. R. and Wahid, P. A.) KAU pp 94-103.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Combination of irrigation at IW/CPE of 1.0 and a fertiliser dose of 0.5:0.5:1.0 kg NPK per palm per annum was found to be ideal for hybrid WCT x Ganga bondam.	Nair, R. R., Pillai, G. R. and Rajagopalan, A. 1988. Water Management in Coconut.	Reena Mathew *et.al.* 2005. Three decades of research on Water Management in Kerala Agricultural University.

	Six Decades of Coconut Research (ed. Aravindakshan, M., Nair, R. R. and Wahid, P.A.) KAU. pp 94-103.	Agronomic Research Station, Chalakudy.
Irrigation water requirement was optimum at IW/CPE ratio of 0.75 for basin irrigation. Mulching with green leaves @ 50 kg/ palm, with an irrigation interval of 30-45 mm CPE was ideal. Drip irrigation @ 30 l/palm/day was comparable with basin irrigation @ 600 l/palm/week. Coconut seedlings planted in pits buried with husk showed better growth than the treatment without husk.	Varadan, K.M., Madhav Chandran, K., Joseph, E. J. and Jayakumar, M. 1989. Effect of mulching and irrigation on soil moisture, soil temperature and yield of coconut. *Proceedings of the international workshop on evaporation from open water surfaces*, 7-14, Central Water Commission, Government of India and Department of Irrigation, Government of Gujarat, Vadodra, pp. 161-165.	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p18.
Irrigation during summer months increased the yield of coconut. Basin irrigation at IW/CPE value of 1.0 and drip irrigation @ 30 l/palm/day gave highest yield.	Satheesan, K.V. and Varadan, K. M.1994. Micro climate, crop growth response and yield of cardamom under sprinkler irrigation, *Proceedings of the International Symposium on Plantation Crops*, 30th Nov-3rd Dec 1994, Calicut.	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p19.

In case of coconut seedlings cv. *West Cost Tall*, shallow water table upto 45 cm from the soil surface as well as continued water logging upto 72 hours had no adverse effect on growth and dry matter production	Kokkal, K. and Varadan, K. M. 1996. A study on discharge measurements and transmission losses in selected branch canals of Malampuzha Irrigation project. *Proceedings of the VIII[th] Kerala Science Congress*, 27-29 January 1996, Ernakulam, pp 516-518.	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p20.
The study with different discharge rates (4 and 8 lph) and 3 combinations of emitter numbers (3, 4 and 6) found that the maximum vertical and horizontal advance was for 8 lph emitter compared to 4 lph emitter. The study revealed that 4 numbers of 8 lph emitters give more uniform distribution compared to all other treatments.	Priya, G. Nair. 2000. Optimal Number and Discharge Rate of Emitters For Coconut Palm in Sandy Loam Soil. M.Tech Thesis. Department of Irrigation and Drainage Engineering KCAET Tavanur. pp. 95.	KCAET, Tavanur. Kerala Agricultural University.
The irrigation levels significantly influence the nut yield in coconut. Irrigation at 25 mm CPE was found to be superior to 50 and 75 mm CPE respectively. (Total quantity of water applied 130, 65 and 45 mm respectively for irrigation at 25, 50, 75 mm CPE. No. of irrigations were 26, 13 and 9 respectively). Fresh mulches (coconut husk and coir pith) did not show any significant effect on the nut yield.	Annual Report (2005- 06) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 28.	Agronomic Research Station, Chalakudy. Kerala Agricultural University
The transpiration measured using sap flow system in about twenty five-year-old un-irrigated coconut was found to be 20 to 36 l/day during summer season and 38 to 52 l/day during rainy season in Kozhikode.	Shameer Muhammed, E., Deepa, H., Madhav Chandran, K., George Mammen and Joseph, E. J. 2006. Evaluation of an irrigation schedule developed	Agricultural water management,Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p17.

In mixed cropped field the coconut palm irrigated @ 96 l/palm/day with un irrigated black pepper showed higher transpiration rate.	for coconut, *Proceedings of 18th Kerala Science Congress*, 29-31 Jan 2006, CESS, TVM pp 75-77.	
The data obtained on the growth and yield parameters of a study on in situ rainwater harvesting through micro catchments and its effect on coconut yield reveals that the plants provided with micro catchment showed better performance. The studies conducted on soil moisture distribution reveals that the moisture content in the basins of plants under micro catchment is higher than the rain fed coconut palms and is almost in the same range as that of drip irrigation at 75% pan evaporation. This reveals that the gentle slope of micro catchment and thick mulch provided. in the basin helped to retain the moisture in the soil.	Research Report. 2006-11, Directorate of Research, Kerala Agricultural University, Vellanikkara, Pp. 239-243.	Agronomic Research Station, Chalakudy, Kerala Agricultural University.
In a coconut based cropping system where coconut, arecanut and nutmeg are grown together, arecanut and nutmeg required only 75% of recommended irrigation when coconut is given 75% irrigation. If arecanut and nutmeg are given 100% irrigation, coconut required only 50% of recommended irrigation though the yield was not statistically significant.	Annual Report (2009-10) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 11.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
The water requirement of coconut for the first year has been estimated as 16 litre/plant/day, for the second year 32 litre/plant/day and 50-60 litre/plant/ day from third year onwards. In an experiment with daily irrigation through drip and fertilizer dose as per the recommendations of the KAU Package of Practices for coconut, N: P: K 1: 0.5: 2 kg / palm-year in equal split doses in monthly interval, the conclusions are;	Annual Progress Report 2011-12, Precision Farming Development Centre, Tavanur, p 14.	PFDC, KCAET, Tavanur. Kerala Agricultural University.

Fertigation is to be done at monthly intervals with 80% of the recommended dose of fertilizer. Phosphorous is to be given through basal application in 6 split doses at an interval of 2 months. Nitrogen and Potassium is to be applied through fertigation. The quantity to be applied for hybrid plants after 2 years of age is 60 gm N and 130 gm K/plant/month. In low lying areas where the water table is high, fertigation can be done after water table recedes or two applications can be combined.		
Irrigation cum fertilizer experiment during the early growth stages showed that, In the light textured loamy sands, lesser quantity of water at shorter interval is more beneficial than larger quantity of water for longer intervals. Palms receiving 20 and 40 mm water recorded higher yield of nuts at IW/CPE 1.0. Highest soil moisture content was observed in 20 mm irrigation at IW/CPE 1.0. Irrigating WCT palms at IW/CPE 1.0 with 750:670:1600:170 g N, P_2O_5, K_2O and MgO/palm/yr is preferable at early stage of growth. In inadequate water supply condition, palms should be irrigated with 20 mm water at IW/CPE 0.75 and fertilizer with 1000:1000: 2250:170gN, P_2O_5, K_2O and MgO/palm/yr to obtain optimum yield.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME), Director, CPCRI).	Central Plantation Crops Research Institute, Kasaragod, Kerala.

Irrigation with 45 litre once in four days with red earth application in seedlings pit prior to planting resulted better seedling growth and young palm in sandy soil.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME), Director, CPCRI).	Central Plantation Crops Research Institute, Kasaragod, Kerala.
Vertical and horizontal movement of water directly related to the quantity and discharge rate. Vertical movement is more than horizontal movement. Placing the drippers on the surface could wet 8.4% of the volume of basin where as subsurface placement wetted 14.6% of the basin volume. Discharge rate of 4 lt/hr was found to be favourable for moisture movement and also minimize clogging of drippers due to self flushing nature by high force. COD x WCT responded better to irrigation with higher yield than WCT. Application efficiency is 90%. The most economic drip irrigation was observed at 66% E in terms of water saving with 6 emitters placed at equidistance. Mulching with coconut leaves also resulted in positive interaction with irrigation in coastal sandy soil. Laterite soil: Under North Kerala Condition, irrigate coconut palm through drip irrigation @ 27 l/palm/ day during Dec –Jan and 32 l/palm/day during Feb-May with 4 drippers at equidistance	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME), Director, CPCRI).	Central Plantation Crops Research Institute, Kasaragod, Kerala.

Fertigation:		
The fertilizer should be applied in the active absorption zone for which the emitter should be placed 1m away from the bole of the palm. Compared to conventional method, fertilizers can be saved upto 50 per cent through fertigation, because of the higher fertilizer use efficiency. Through fertigation, it is recommended to provide 91g urea, 33ml phosphoric acid and 170g muriate of potash per palm per application. When DAP is used it is recommended to provide 70g urea, 60g DAP and 170g muriate of potash for a single dose per palm. This should be applied at monthly interval from December to May in six equal split doses.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME), Director, CPCRI).	Central Plantation Crops Research Institute, Kasaragod, Kerala.

ARECANUT

Arecanut is one of the important cash crops of Kerala and about 57% of the arecanut cultivation of India is in Kerala. The economic produce is the fruit called betelnut or supari. In Kerala the area under cultivation is 1.01 lakh ha. and the production is about 1.18 lakh million nuts. (Farm Guide, 2015). Surface irrigation by ridge and furrow method is quite suitable.

Water management as per the Kerala Agricultural University Package of Practices Recommendations –Crops -2011

Irrigate the palms during hot and dry periods at regular intervals of 3-5 days depending upon the soil type.

The palms should be irrigated once in four to seven days depending on the soil type and climatic factors. In west coast, where major areas of arecanut gardens are irrigated, watering the garden once in seven or eight days during November-December, once in six days during January- February and once in three-five days during March-April-May is recommended. In each irrigation, give about 175 litres of water per palm. Where there is shortage of water, follow drip irrigation. Application of organic mulch to the garden helps conservation of soil moisture.

Construct drainage channels (25-30 cm deep from the bottom of pits) between the rows and drain out water during periods of heavy rainfall to prevent water logging.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation once in 3 days at 189.23 l of water/palm, giving a duty of 1309 ha/ cumec, gave the maximum profit. The water requirement of arecanut was 82.49 cm for basin type of irrigation once in 3 days, the minimum moisture was 24.84% and maximum tension at the root zone was 0.139 atm.	Sadanandan, A. K. 1973.Water requirement of arecanut. *Indian J Agrl. Sci.*43(5): 483-485	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
The crop coefficient values for young arecanut palms were 0.95-0.99 during January-May in laterite soil. Optimum depth of water required per irrigation was 26 mm based on an effective root zone depth of 50 cm.	Mahesha, A., Abdul Kader, K. D. and Ranganna, G. 1990. Consumptive use and irrigation requirement of arecanut palm, *Indian J. Agrl. Sci.* 60(9):609-611.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
Drip irrigation @ 20 l/tree/day and a fertilizer dose of 100:40:140g N, P_2O_5, K_2O per tree per year would be optimum for cocoa, in a mixed cropping system in arecanut.	Abdul Haris, A., Balasimha, D., Sujatha, S., Ravi Bhat and Khader, K.B.A.1999. The influence of drip irrigation and fertilizer levels on yield and photosynthetic characteristics of cocoa in mixed cropping in arecanut. *J.Plantn. crops*.27(2):131-135.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
All methods of irrigation viz. ferti-drip. drip and basin irrigation have resulted in shallow root development. Horizontal spread of root system was more in case of ferti-drip (75cm) and drip methods (71cm) than in basin methods. Vertical spread of root system was more or less the same with all method of irrigation (43-58cm).	Sujatha, S. and Abdul Haris, A. 2000. Root distribution as influenced by different method of irrigation in young palms. *J. Plantn. crops*. 28(2):117-122.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI, Kasaragod).

50% of the standardized fertilizer dose was found sufficient for pre bearing arecanut palms through ferti-drip irrigation thus saving considerable fertilizer dose.	Sujatha, S., Balasimha, D. and Ravi Bhat. 2002. Fertigation of arecanut during pre bearing stage. Plantation crops research and development in the new millennium. CPCRI, Kasaragod. pp.328-332.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist – in-charge (PME), Director, CPCRI).
The water requirement of arecanut was estimated as 1689.4mm in laterite soil. Yield and water use efficiency was higher for drip irrigation at 60% of the water requirement without mulch. Benefit cost ratio was higher for surface irrigation at 100% of the WR with plastic mulch.	PDC, 2003 Annual Report, Plasticulture development centre KCAET, Tavanur KAU. p 14.	PDC, KCAET, Tavanur, Kerala Agricultural University.
About 18% of the active root zone of arecanut could be wetted by the application of 20 litres of water per palm per day through 2 dripping points at a discharge rate of 6 and 8 lph.	Mathew, A.C., Sujatha, A.S. and Shajathnan. 2004. Water movement in the active root zone of arecanut under drip irrigation. *J. plantation crops*, 32 (suppl.), December 248-252.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME). Director, CPCRI).
Horizontal spread of root system was more in drip fertigation (135-144 cm), while it was only 121 cm in case of sprinkler and basin methods. Rooting depth was more in drip fertigation (101-136 cm) than in basin and sprinkler method (77-78 cm) Maximum distribution of roots both fine and thick was noticed within 50-100 cm distance and depth.	Bhat, R. and Sujatha. S. 2007. Root distribution of arecanut as influenced by drip fertigation in a laterite soil. *Indian J Agri. Sci.*78(9): 804-807.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist –in-charge (PME), Director. CPCRI).

With increase in distance from the base of the palm, the root weight density decreased. Extend of decrease was more with basin irrigation, followed by sprinkler compared to drip fertigation.		
Arecanut farmers have benefits like higher yields, resource use efficiency and profitability due to adoption of drip fertigation with 75% NPK at 10 days frequency. Adoption of fertigation not only increases productivity, but also ensures higher efficiency of the two most critical inputs, water and nutrient in crop production.	Ravi Bhat and Sujatha, S. and Balasimha, D. 2007. Impact of drip fertigation on productivity of arecanut. *Agricultural water management.* (90):101-111.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
Adoption of fertigation places nutrients in active root zone besides maintaining favourable soil moisture level resulting in much greater movement of P&K. Nutrient distribution pattern showed that both 50% and 100% NPK levels maintained more or less the same available phosphorous and potassium concentration in arecanut rhizosphere.	Ravi Bhat, Sujatha, S., Upadhyaya, A. K. and Ashalatha, B.V. 2007. Effect of ferti-drip irrigation on nutrient mobility in a laterite soil in arecanut basin. *J plantn. crops* 35 (2) : 68-72	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
Irrigation at IW/CPE value of 1 to a cumulative pan evaporation of 30 mm gave maximum yield followed by irrigation at the same ratio to a CPE of 60 mm.	Abdul Khadder, K. B. and Havangagi, G. V. Consumptive use of water in relation to cumulative pan evaporation with and without mulching in arecanut. *J. Plantn. crops.* 18 (September): 139-146.	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).
30 mm irrigation for 30 mm cumulative evaporation is recommended for arecanut. Under circumstances when water supply and energy become	Yadukumar, N., Khader K.B.A. and Sharma Bhat, K. Scheduling of	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut

critical, scheduling irrigation with 30mm water at 60mm CPE was also found beneficial.	irrigation for arecanut with pan evaporimeter CPCRI, Kasaragod.	emanated from research carried out in CPCRI. PP 13. (*Scientist-in-charge (PME), Director, CPCRI).

FRUIT CROPS

BANANA

Kerala has nearly 0.61 lakh ha. under banana cultivation and the production is about 5.1 lakh tonnes. Banana needs ample water all through the period as it produces very large leaves till the flower emerges. It can also survive the dry season quite well even though growth and fruiting are reduced. Good drainage is essential for banana to rescue it from deceases.

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

- During summer months, irrigate once in three days.
- Ensure good drainage and prevent water logging
- About 6-10 irrigations per crop may be given depending upon soil conditions.
- Banana var. Nendran (October planting) grown under deep water table conditions (below 2 m from ground level) needs 10 mm (40l/plant) irrigation once in two days during summer season to ensure higher bunch yield and better water use efficiency. Mulching the basin with 3.5 kg paddy straw (waste quality) will considerably improve the bunch yield.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigating banana variety Nendran with 200l of water in about 14 days interval is as good as irrigating the crop on alternate days with 40l of water per plant. Mulching with materials like paddy straw @ about 3.5 kg/plant is significantly superior to non mulched fields with respect to yield.	Annual Report (1978-79) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 74.	Agronomic Research Station,Chalakudy. Kerala Agricultural University.

Studies conducted in banana variety Nendran at RARS, Pilicode during 1987-1990 in clay loam soil showed that 20 mm (40 litres) irrigation in alternate days gave maximum yield and consumptive use (1240.7 mm). Application of 5 mm water by sub soil injection recorded the minimum consumptive use (300.4 mm) and maximum WUE (62.9 kg/ha.mm).	KAU. 1978-2001 Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Scheduling irrigation to banana variety Nendran at IW/CPE 0.9 was found optimum (ie. 5 cm irrigation at an approximate interval of 14 days) under the prevailing conditions. Mulching banana with 3.5 kg paddy straw at the commencement of irrigation produces nearly 22% more fruit yield.	Annual Report (1980-81) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 109.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Irrigation on alternative days with one cm depth of water along with straw mulching was found to increase bunch yield of banana.	Annual Report (1981-82) AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 105.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Studies with four levels of irrigation (5 cm irrigation at 20, 40 and 50 mm CPE and farmers practice of irrigating once in 2 days with 2 cm water) and 3 levels of N and K factorial combination concluded that. Nendran required 5 cm irrigation at 20 mm CPE at an approximate interval of 3-4 days 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.	Annual Report (1984-96) AICRP on Water Management. Agronomic Research Station, Chalakudy.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

August planted banana variety Palayamkodan responded well to irrigation during summer months. 40 mm 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 condition.	AICRP Annual Report (1984-96) on Water Management. Agronomic Research Station, Chalakudy.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
In a comparative trial between drip and basin methods of irrigation, 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 irrigation.	Varghese, K. 1985. Relative efficiency evaluation of drip and basin method of irrigation in Banana. M.Sc. Thesis, Kerala Agrl. University.	Reena Mathew *et al.* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Irrigation @ 0.5 IW/CPE and 50% of recommended dose of fertilizers were found to be optimum for economic production of banana and tapioca as intercrop in coconut garden. WUE of banana as inter crop range from 1.9 - 2.5 for un irrigated control and 2.3 - 3.6 for irrigated treatments.	Varadan, K. M. and Nafeesath, M. 1986. Leaching loss of nutrients under coconut based cropping system. *Proceedings of the workshop on slow release fertilizers in plantation crop* , 25-26 november,1986 CPCRI, Kasaragod.	Agricultural Water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p10.
In banana, the moisture stress during the period from flower initiation to shooting affected the bunch yield. Basin irrigation with 20 mm water at IW/CPE ratio of 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.	Jessy, M. D.1988. Effect of soil moisture stress on growth and yield of Banana *cv. Nendran*. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

Experiments were conducted in October planted banana variety Nendran 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 10 mm irrigation once in 2 days) with and without mulch (paddy straw). Irrigation in alternate days with 10 mm 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, G. R., Varghese, K., Mathew, J. and Santhakumari, G. 1989. Response of nendran banana to irrigation and mulching. *Agrl. Res. J. Kerala.*	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
In a moisture stress study, it was found that the highest yield was obtained from the plants which were adequately irrigated throughout the dry season (Dec-April), compared with those plants which were mulched and subjected to moisture stress for one month duration at the beginning (Dec.) and at the end of dry season (April). Temperature was the lowest in the irrigated mulched plot. Plants which were water stressed throughout the dry season except at the end (April) had the longest duration. Moisture stress of one month duration towards the end of dry season (April) had the shortest duration.	Jessy, M. D. 1989. Effect of soil moisture stress on growth and yield of Banana c v. Nendran. M.Sc. Thesis. Kerala Agricultural University.	College of Horticulture, Kerala Agricultural University. Vellanikkara.

In banana *cv. Nendran*, shallow water table upto 15 cm below the rhizome had no adverse effect on the bunch yield as well as total biomass production, though the transpiration rate of banana was less under shallow water table compared to the plants grown at field capacity.	Varadan, K. M., Nazimuddin, M., Kokkal, K. and George Chackacherry 1998. Water distribution, water management and socio economic aspects of irrigation projects under CADA - a case study of Neyyar and Malampuzha irrigation projects. *Journal of Water and Energy International*. 55: 39-46.	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p 20
Subsurface drip at 75% 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.	Thomas, D. 1999. Water and Fertiliser use efficiency in drip irrigated banana, Nendran. Ph.D Thesis, Kerala Agricultural University, Thrissur.	Reena Mathew *et.al.*, 2005. Three decades of research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Experiments in banana var. Nendran revealed that the water use efficiency and benefit cost ratio were maximum at 80% water requirement through drip irrigation with mulching. Fertigation through drip could save 20% of the recommended fertilizer dose for banana.	Annual Report. 2003. Plasticulture Development Centre, KCAET, Tavanur, Kerala Agricultural University, Vellanikkara	Plasticulture Development Centre, KCAET, Tavanur. Kerala Agricultural University.
Irrigating the plant @ 40 l/plant through basin method was on par with giving irrigation @ 20 l and 30 l per plant through drip method.	Annual Report (2010-11) AICRP on Water Management. Agronomic Research Station, Chalakudy. pp 11.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

The study on precision farming in banana (Musa AAB c v. Nendran) concludes that the highest nutrient use efficiency is obtained with the treatment soil application of rock phosphate and fertigation using urea and MOP. In water productivity, the treatment POP (package of practices) with drip irrigation was found to be the superior. NUE, WUE and WP (water productivity) were significantly enhanced by sub plot treatment of bunch spray with 2% SOP. Compared to basin irrigation, fertigation resulted in a saving of 73% in irrigation water and 40% in nutrition.	Shimi G.J., 2014. Input Management for Precision Farming in Banana. Ph.D.Thesis, Department of Agronomy. College of Agriculture, Vellayani	College of Agriculture, Vellayani, Kerala Agricultural University.

PINEAPPLE

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

During summer months, pineapple should be irrigated wherever possible at 0.6 IW/CPE ratios (50 mm depth of water). It requires five or six irrigations during dry months at an interval of 22 days. Mulching the crop with dry leaves at 6 t/ha will help to conserve moisture.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
An experiment conducted to study the performance of pineapple under different moisture regime with and without mulches 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 50 mm water at IW/CPE 0.6 during summer season. Mulching the basin of planted crop with dry leaves @ 6 t/ha is recommended for higher fruit yield and WUE .	Varhgese, K., Pillai, G R., Mathew, J., Santhakumari, G and Gopi, C. S. 1988. Effect of irrigation and mulching on growth and yield of pineapple. *Agri. Res. J. Kerala*.26	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

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 7 days followed by the treatment receiving irrigation once in 10 days.	--	Banana Research Station Kannara, Kerala Agricultural University

PAPPAYA

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

The crop should be irrigated in summer. The ring system of irrigation is better for papaya than the basin system because the ring system prevents irrigation water coming into contact with the stem, thus preventing collar rot.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
In an experiment with daily irrigation and fertigation at monthly interval along with recommended dose of fertilizer (Organic manure – 10 to 25 kg/plant/year N: P: K – 40:40:80g/ plant/year), 80% recommended dose of fertilizer through fertigation along with plastic mulching gave better performance than the other treatments.	Annual Progress Report 2011-12, Precision Farming Development Centre, KCAET, Tavanur. p17.	Precision Farming Development Centre, KCAET, Tavanur. Kerala Agricultural University.

SPICES AND MEDICINAL PLANTS

PEPPER

Pepper, popularly known as black gold holds a prime position in the world of spices. Kerala has nearly 0.85 lakh ha area under the crop and production is about 0.46 lakh tonne.

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Irrigating pepper plants of Panniyur-1 variety at IW/CPE value of 0.25 from November/ December till the end of March and withholding irrigation thereafter till monsoon break, increases pepper yield by about 50 percent. The depth of irrigation recommended is 10 mm

(100 litres of water per irrigation at an interval of about 8-10 days under Panniyur conditions). The water is to be applied in basins taken around the plants at a radius of 75 cm. The basins may be mulched with dry leaves or other suitable materials.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation at 20mm CPE was significantly superior to 40 mm and 60 mm CPE which were on par with respect to yield of pepper.	Annual Report (2005-06) AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 40.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Summer irrigation at IW/CPE ratio of 0.25 significantly increased pepper yield by over 90% and the effect was more pronounced in *cv* Karimunda than in Panniyur-1.	Sadanandan A.K. integrated nutrient ad water management for sustainable spice production-*Proceedings of the National Seminar on Soil, Water and Crop Management for Higher Productivity of Spices*, Feb. 2010, p. 39.	Proceedings of the National Seminar on Soil, Water and Crop Management for Higher Productivity of Spices, Feb. 2010, p. 39.

BUSH PEPPER

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Irrigating black pepper vines with 8 litres of water through drip per day during Oct-May enhances yield and quality in bush pepper with high B:C ratio. This is recommended for bush pepper grown as intercrop in coconut gardens.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Drip irrigation at 8 litres per day per plant was found to be more beneficial to three year old bush pepper compared to daily irrigation using 10 litres/day. The optimum % of available depletion of soil moisture was 50.	Thankamani, C.K. 2000. Influence of soil moisture regimes on growth and yield of bush pepper, Ph.D. Thesis, Kerala Agrl. University.	Reena Mathew *et al.* 2005. Three decades of research on Water Management in Kerala Agril. University. Agronomic Research Station, Chalakudy.

GINGER

Kerala is the largest producer of ginger in India and has nearly 0.045 lakh ha. area under ginger cultivation the production being about 0.22 lakh tonne. Ginger requires well drained soil. Rainfall supplemented by irrigation will give good yield. Sprinkler irrigation can be advantageously made use of.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Studies conducted to standardize the irrigation schedule and nitrogen level for irrigated green ginger showed that, the treatment with most frequent irrigation at IW/CPE 1.5 requiring 8 to 9 irrigation at an interval of 9 to 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 was applied up to 75 kg/ha beyond which the yield declined.	Sreekumaran, V., Mathew, R., George, A.G. and Santhakumari, 1998. Scheduling irrigation to ginger (*Zingiber officinale*) under varying nitrogen levels. *Proceedings of the 10th Kerala Science Congress*. Kozhikode, Jan.2-4. p.60	Reena Mathew *et.al*. 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Plant height increased with higher level of irrigation water. Irrigation at IW/CPE ratio of 1.2 recorded the maximum plant height followed by irrigation at IW/CPE of 1 and 0.8, which indicates that more water favours vegetative growth. As the irrigation levels increased from the water application at IW/CPE ratio of 0.8 to 1.2, the growth of plants as was expressed through the plant height, no. of leaves and tiller count showed an increasing trend throughout the growth of the plants.	Soorya, T., Kamalam Joseph and Pournami P. 2010. Studies on the effect of levels of irrigation and nutrient sources on the vegetative growth of Ginger. *Proceedings of the National Seminar on Soil, Water and Crop Management for Higher Productivity of Spices*, Feb 2010, p 81-87.	CWRDM, Kozhikkode

TURMERIC

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Lysimetric studies conducted to evaluate the effect of irrigation levels of IW: CPE ratio of 1.2, 1, 0.8 and source of nutrients (organic and inorganic) on the growth of turmeric during vegetative phase of plant showed that the irrigation levels slightly influenced the vegetative growth of plants. It was also revealed that organic sources of nutrients resulted in an improved performance of crop when compared to inorganic fertilizers, when irrigation was given at IW/CPE 1.0, the total quantity of water required during the vegetative phase was worked out to be 27,20,000 l/ha.	Lisha, K., Kamalam Joseph and Pournami, P. 2010. Studies on the effect of irrigation levels and nutrient sources on the vegetative growth of Turmeric (*Curcuma longa* L.). *Proceedings of the National Seminar on Soil, Water and Crop Management for higher Productivity of Spices*. Feb 2010, pp 112.	CWRDM, Kozhikkode.

CARDAMOM

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Sprinkler irrigation at 2.5 mm/day recorded highest yield. The crop water stress index (CWSI) for irrigation scheduling is 0.425 in Wayanad. The response to irrigation was found to be highly influenced by solar energy input, especially during morning hours (9.00-11.00 hours). The yield of cardamom under sprinkler irrigation was significantly correlated with fruit set and number of panicle per clump. The yield of cardamom under drip irrigation show statistically significant relationship with fruit set per clump and length of the panicle.	Satheesan, K. V. and Varadan, K. M. 1994. Micro climate, crop growth response and yield of cardamom under sprinkler irrigation, *Proceedings of the international symposium on plantation crop*, 30th Nov-3nd Dec 1994, Calicut.	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, P 19.

KACHOLAM

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A study with different levels of irrigation (rainfed control, 5 cm at 20 mm, 35 mm and 50 mm CPE and NPK - control without NPK; 50:50:50; 75:75:75; 100:100:100 NPK/ha) revealed the significant influence of various levels of fertilizer, while the effect due to different levels of irrigation has failed to exert any influence. The treatment received the highest level of fertilizer recorded the least yield of 1437 kg/ha and the unfertilized control gave the maximum yield.	Annual Report (1997-98) AICRP on Water Management Agronomic Research Station, Kerala Agricultural University. Chalakudy, pp 17.	Agronomic Research Station, Chalakudy Kerala Agricultural University.

VANILLA

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
The growth of vanilla is found better in 50% shade compared to 25% shade and open condition. In mist chamber experiments, the vegetative growth of vanilla in 75% shade was found to be more. Plants grown under 25% shade and supplied with sprinkler irrigation with an IW/CPE of 0.25 produced the maximum number of flowers as compared to all other treatments.	Research Report. 2006-11. Directorate of Research, Kerala Agricultural University, Vellanikkara, Pp. 239-243.	NARP Southern Zone, College of Agriculture, Vellayani, Kerala Agricultural University.

PULSES

Area under the crop is about 0.03 lakh ha. and production is about 0.013 lakh tonnes. 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.

COWPEA

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Giving two irrigations is highly beneficial; *i.e.*, at 15 days after sowing and at the time of flowering. Irrigation at the flowering stage induces better flowering and pod set.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Studies indicated that cowpea might be irrigated at IW/CPE of 0.5. This required 5 irrigations (180 mm water) in summer season at an interval of 16 days. The economic dose of P was found as 56.70 kg ha^{-1}.	Balakumaran, K. N. 1981. Response of cowpea to water management practices and nutrition. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Irrigation at an IW/CPE values of 0.3, 0.5, 0.75 & 0.6 for the 1st, 2nd, 3rd & 4th quarter respectively is found good for higher yield and WUE, when cowpea is raised in rice fallows during summer season.	Annual Report (1981-82) AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 92-94.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
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% of the yield. In the absence of irrigation, other inputs failed to increase the grain yield.	Joy, P. P., Bridgit, T. K. and Neema, V. P. 1991. Input contribution in summer cowpea. *Legume Research* 14 (1):33-36.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

Cowpea raised in summer rice fallows could be given irrigation with 5 cm water at IW/CPE of 0.75 (5 irrigations at an interval of 15 days) along with phosphorous @ 15 kg ha^{-1} or at critical stages of branching, flowering and pod formation. Irrigation at IW/CPE of 0.4 was sufficient for attaining vegetative growth for incorporation as green manure.	KAU,1998-2001. Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara	Reena Mathew *et.al* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
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 6-8 days through sprinkler at an intensity of 0.63 cm/hr for 2 hours. This scheduling gave an increase in yield of 36.4% over channel/flood irrigation.	KAU, 2002-03. Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station. Chalakudy.

VEGETABLE COWPEA

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Under red loam soils (Vellayani), maintaining a moisture regime of 75% of the field capacity throughout the crop growth period resulted in higher yield and yield contributing characters. A fertilizer dose of 30 kgN and 40 kg P/ha also contributed to the yield.	Jyothi, K.S.1995. Effect of phenophased irrigation on vegetable cowpea under graded dose of N and P. M.Sc.Thesis, Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

Highest yield of green pod was obtained by giving 10 mm daily irrigation compared to irrigation at 15 mm CPE and 20 mm CPE with plant density of 16.667 plants/ha.	Mini, C. L. 1997. Response of vegetable cowpea to phosphorus under varying moisture levels and plant density. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Study on response of cowpea *c v. Malika* to nitrogen and potassium under varying levels of irrigation revealed that, The maximum yield of green pod was obtained when the crop was irrigated through micro sprinkler at 20 mm CPE with a depth of 10 mm water. The N and K levels at 20 kg/ha 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 20 mm water through micro sprinkler. At 15-30 cm and 30-45 cm 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	Geetha, V. 1999. Response of vegetable cowpea to Nitrogen and Potassium under varying levels of irrigation. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

BLACK GRAM

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
In rice fallows, significant yield increase in black gram could be attained by giving 3 - 4 shallow irrigations and NPK applications at 30:60:40 kg/ha.	Annual Report (1974-75) AICRP on Water Management. Agronomic Research Station, Chalakudy. Kerala Agricultural University. pp 15	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
One interculture recorded numerically the highest water use efficiency (2.37 kg/ha mm) and was 35.82% higher over no interculture treatment. Among the two methods of irrigation, border strip scored an increase of 25.14% in water use efficiency over bed method of irrigation.	Annual Report (1979-80) AICRP on Water Management. Agronomic Research Station, Chalakudy.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Two black gram varieties Co-2 & T9 were found to be equally suitable for cultivation under irrigated conditions during summer season in rice fallows. The most economic water management practice will be scheduling irrigations at IW/CPE, 0.3, 0.5, 0.6 and 0.7 at successive interval of 25 days. Bed method of irrigation was found to be superior to border method of irrigation for black gram in the rice fallows during summer season.	Annual Report (1980-81) AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 109	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
In black gram an irrigation schedule of 3 cm during first 25 days and there after 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, K., Mathew, J. and Pillai, G. R. 1986. Response of black gram to water management practices in summer rice fallows. *Agri. Res. J. Kerala.* 24 (2): 175-178.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

OIL SEEDS

SESAMUM

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Usually the crop is grown under rainfed conditions. When facilities are available, the crop may be irrigated to field capacity after thinning operation and thereafter at 15-20 days interval. Stop irrigation just before the pods begin to mature.

Surface irrigation at 3 cm depth during the critical stages, viz., 4-5 leaves, branching, flowering and pod formation will increase the yield by 35-52 percent. Two irrigations of 3 cm depth each in the vegetative phase (4-5 leaf stage or branching) and in reproductive phase (at flowering or pod formation) are the best, registering maximum yield and water use efficiency. In the case of single irrigation, it can be best given in the reproductive phase. In the tail end fields in command area, best use of the sparingly available water can be made for augmenting sesame production.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
The fertilized crop has recorded an yield increase of 0.652-1.3q/ha over the crop grown on residual fertility in rice fallows. Yield progressively increased with the number of irrigation. The mean yield increase due to four irrigations is 1.1 q/ha over the crop irrigated once.	Annual Report. 1974-75 AICRP on Water Management. Agronomic Research Station, Kerala Agricultural University. Chalakudy, pp 15	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Surface irrigation given at 3cm depth during the critical stages of 4-6 leaves, branching, flowering and pod formation were found to increase the sesamum yield by 35 to 52%. Two irrigations of 3cm depth each given in the vegetative phase (at 4 to 6 leaf stage or branching) and in the reproductive phase (at flowering or pod formation) was the best registering maximum yield and water use efficiency	Annual Report. 1976-77. AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 95	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

In sandy loam soil irrigating sesamum at critical stages of 3-4 leaf stage, branching, flowering and pod formation stage or at IW/CPE 0.75 with 40 mm water ensured significantly higher yield as compared to un-irrigated crop and 30 kgN/ha was found to be optimum for higher grain yield in irrigated sesamum.	Mathew, J., Varhgese, K., Pillai, G. R. and Santhakumari, G. 1989. Response of sesamum to water management practices under varying levels of nitrogen. *Agri. Res. J. Kerala*, 27(1-2)	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Sprinkler irrigation at intensity of 0.63 cm/hr for 2 hours was found to be very effective and economic in increasing the yield in light soils. An increase in yield of 16.5% is realized over flood or channel irrigation through this system, in summer rice fallows.	KAU, 2002-03. Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
The study conducted in sandy tracts of Onattukara region revealed that giving 3 or 4 irrigations viz., 2 irrigations at vegetative phase and 1 or 2 irrigations at reproductive phase was found to be optimum for higher yield and water use efficiency.	KAU, 2003-04. Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

GROUNDNUT

The area under cultivation of groundnut is 0.0078 lakh ha and production is about 0.0097 lakh tonnes. Major cultivation of groundnut is in Palakkad district and is rarely cultivated in some other districts of Kerala.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation for ground nut in summer season in sandy loam soils of Chalakudy was found to be scheduled at 0.9 IW/CPE (5 cm depth) for increased pod yield. Application of 25 kg/ha. each of P_2O_5 & K_2O was	Mathew, J., Nair, K. P. M. and Kuriakose, T.F. 1983. The response of ground nut to Phosphorous and	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University.

found to be optimum under this water management practice.	Potassium under different water management practices *Agri. Res. J. Kerala*, 21(2): 27-31	Agronomic Research Station, Chalakudy.
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.	Annual Report (1984-96) AICRP on Water Management. Agronomic Research Station, Kerala Agricultural University. Chalakudy.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
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 stage delayed flowering and adversely affected nodulation.	Muktha, T. N. 1995. Productivity of groundnut (*Arachis hypogaea* L) in summer rice fallows under different frequencies of irrigation. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
During second crop season in uplands, 50 mm 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 was found to be optimum for groundnut in uplands.	Bhoopathy, T. 2003. Water nutrient interaction on productivity of groundnut. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

OIL PALM

Irrigation at 90 litres/palm/day resulted in increased yield contributing characters and palm oil production in oil palm.	Varghese, T. P. 1995. Effect of nutrition as influenced by irrigation on growth and yield of oil palm. Ph.D. Thesis, Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

TUBER CROPS

TAPIOCA

Tapioca is shrubby tropical perennial plant that is not well known in the temperate zone. Tapioca thrives better in poor soils than any other major food plant. Area of cassava in Kerala is about 0.69 lakh ha. and production is about 24.5 lakh tonnes.

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Under conditions of well-distributed rainfall, tapioca grows well as a rainfed crop and irrigation is not necessary. However, the crop has to be irrigated to provide sufficient moisture under conditions of prolonged dry periods after planting. When the crop is grown under irrigation, yield increase of 150-200 percent over the rainfed crop has been observed.

Furrow irrigation with 25 mm water at 100 mm CPE and alternate furrow irrigation with 50 mm water at 75 mm CPE require only less water and labour for optimum yield. Approximate irrigation interval schedules will be 27 and 20 days respectively on summer months.

Other findings

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Supply of irrigation in furrow once in 40 days at 5cm depth was found to fasten the maturity and increase the yield by 2 to 3 folds at 9 months growth.	Annual progress report. 1976-77. AICRP on Water Management, Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 95	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Tapioca planted in garden lands in October is found to be benefited by six irrigations (30 cm) given during the dry months from Dec. to May and the yield increase due to this irrigation is 7.199 t/ha. The irrigated crop recorded 22.16% (5.47MT/ha) more yield at 9 months than the un irrigated crop harvested at 11 months.	Annual progress report. 1978-79. AICRP on Water Management, Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp. 74	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

11 months crop of tapioca with 5 cm irrigation at IW/CPE 0.5 (19 days interval) is optimum for higher tuber yield. The supplemental irrigation for the 9 months harvested crop could produce an average yield increase of 46.01% (10.545 t /ha) over the unirrigated crop harvested at 11 months maturity.	Annual progress report. 1979-80. AICRP on Water Management, Agronomic Research Station, Chalakudy, Kerala Agricultural University. Pp.92-94	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Growing an intercrop of cowpea, green gram, black gram and groundnut will not adversely affect the tuber yield of tapioca. In this cropping system irrigation (5cm depth) at an IW/CPE ratio of 0.3 would be enough for optimum yield.	Annual progress report. 1981-82. AICRP on Water Management, Agronomic Research Station, Chalakudy, Kerala Agricultural University.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Optimum schedules of irrigation for a nine-month and eleven-month tapioca crops 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 days interval) provided an additional yield of 5.5 tonnes tubers over the nine-month crop.	Sushama, P. K., Pillai, G. R., George, T. P. and Mathew,J. 1982. Response of Cassava (*Manihot esculenta* crantz) to different irrigation schedules. *J. Root crops* 8 (1-2): 71-73.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
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.	Annual Report (1984-96) AICRP on Water Management. Agronomic Research Station, Chalakudy. Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

In tapioca, when the water table rose above 60 cm from the surface, there was a significant reduction in the tuber yield and the total biomass production.	Suvarnakumari, N., Varadan, K. M. and Nazeemuddin, M. 1996. Physical and agronomic observations in Chavara branch canal. A case study from Neyyar irrigation project. *Proceedings of the VIII[th] Kerala Science Congress*, 27-29 January 1996, Ernakulam, pp 223-224	Agricultural water management, Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p20.
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 50 mm CPE by surge flow method, with a cycle ratio 0.5 and was on par with continuous flow treatment at 50 mm CPE. Irrigation water use efficiency was found highest for surge irrigation treatment at 75 mm CPE, which was 21 per cent higher than that of continuous flow treatments 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, K. P., Mathew, R., Santhakumari, G. and Abraham, M. 2003. Comparative studies on continuous and surge flow furrow irrigation in Tapioca. *Proceedings of the 15[th] Kerala Science Congress*, Thiruvananthapuram, Jan. 2-4. p.29	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

SWEET POTATO

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A study conducted to identify the optimum combination of fertiliser and irrigation revealed that, sweat potato grown under irrigated condition in	Varhgese, K., Mathew, J., Pillai, G R and Santhakumari, G. 1987. Effect of	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala

summer fallows needed irrigation with 50 mm water at 1.2 IW/CPE (at an interval of 10 days). The application of nitrogen and potassium @ 50 kg/ha each was found to be optimum for higher yield.	irrigation on sweet potato under graded doses of N and Potassium. *J. Root Crops* 13(1):25-26	Agricultural University. Agronomic Research Station, Chalakudy.
The irrigation schedule for sweet potato was arrived at IW/CPE 0.75 along with a fertilizer dose of 100:75:100 kg/ha.	Oommen, M.1989. Cultural, Manurial and Water requirements for sweet potato. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Irrigation at an interval of 4 days during tuber initiation and tuber maturity phases was found advantageous.	Nair, G. M.1994. Nutrient moisture inter action under phasic stress irrigation of sweet potato in summer rice fallows. Ph.D. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

AMORPHOPHALLUS

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Amorphophallus was found to be irrigated (5 cm 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, J., Varhgese, K., Pillai, G. R. and Santhakumari, G. 1988. Response of amorphophallus to irrigation and mulching. *Agri. Res. J. Kerala*. 26	Reena Mathew *et.al.* 2005. Three decades of research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

VEGETABLES

BITTER GOURD

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
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 Research Report. Directorate of Research, Kerala Agricultural University, Vellanikkara	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
3 cm irrigation scheduled at an IW/CPE of 0.4 (irrigation interval of about a fortnight) using basin method of irrigation is sufficient for successfully raising bitter gourd in summer season.	Annual Report, 1979-80 AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University.pp 92-94	Agronomic Research Station, Chalakkudy. Kerala Agricultural University
Basin method of irrigation based on IW/CPE 0.4 which requires the least quantity of water can be used for raising bitter gourd successfully in summer fallows	Annual Report, 1984-86 AICRP on Water Management. Agronomic Research Station, Chalakudy. Kerala Agricultural University	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
The optimum irrigation schedule for bitter gourd during summer season in sandy loam soil was found to be 3cm irrigation at IW/CPE 1.2 and NPK at 60:30:60 kg/ha produced the maximum net profit. Soil moisture extraction was maximum from the top 30cm layer of the soil.	Thomas, G.C. 1984 Water management practices for bitter gourd (*Mormodica Charantia* L) under different fertility levels. M.Sc. Thesis, Kerala Agril. University, Vellanikkara	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy. Kerala Agril. University

Studies conducted at different irrigation levels-I_1 (IW/CPE (1), I_2 (0.75), I_3 (0.50), I_4 (conventional) and I_5 (Pitcher irrigation) revealed that, Irrigation need be given at IW/CPE value of 1, at 30 mm CPE (3-6 days interval) in bitter gourd raised in sandy clay loam soils. Irrigation at IW/CPE value 1 produced female flowers earlier, more female flowers, maximum number of fruits, highest fruit length and girth, high yield, more dry matter production and higher water use efficiency.	Sarah Jacob. 1986. Effect of date of sowing and levels of irrigation on the growth and yield of bitter gourd *var*.priya. M.Sc.(Ag.) Thesis, Kerala Agricultural University, Vellanikkara. 115 p.	College of Horticulture, Vellanikkara. Kerala Agricultural University.
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 was more economic considering the yield and quantity of water when planted in summer fallows.	Thampatti, K.C.M., Santhakumari, G., Mathew, R. and Chandrasekaran, P. 1993. Consumptive use pattern of soil moisture extraction and water use efficiency of bitter gourd under varying irrigation and nitrogen levels. *Agrl. Res.J.Kerala*.31.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
The efficiency of bubbler irrigation system (KAU Micro sprinkler) was compared with drip system of irrigation in bitter gourd with three levels of irrigation (100, 75 & 50% PE). The result showed that bubbler irrigation system was more efficient than drip method in bitter gourd grown under mound system of cultivation for realising increased yield. This system recorded water saving of 59% and 69% when irrigation was scheduled at 100% and 75% PE respectively over control.	Sreekumaran, V., Santhakumari, G., Jayakrishnakumar, V. and Reghu, P. K. 1998. Bubbler irrigation system (BIS)-An Innovative Micro Irrigation System. *Proceedings of the 10th Kerala Science Congress*. Kozhikode, Jan.2-4. p. 494-496	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

SNAKE GOURD

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
The optimum time of sowing in snake gourd for maximum yield and net return was found to be on November 16th with irrigation at IW/CPE value of 1.0. Consumptive use of water increased with frequency of irrigation. Top 15 cm of soil layer accounted for highest soil moisture depletion. The depletion was more from the deeper layer in drier regions.	Thankamani, C. K. 1987. Effects of dates of sowing and levels of irrigation in the growth and yield of Snake gourd. M.Sc.(Ag.) Thesis, Kerala Agricultural University, 102 p.	College of Horticulture, Vellanikkara. Kerala Agricultural University.
In an experiment to standardize the optimum dose of nitrogen (35,75,105 and 140 kg/ha), ethephon (0, 50,100 and 200 ppm) and drip irrigation (5 mm CPE and 10 mm CPE), it was observed that the suitable levels of inputs for realizing the maximum fruit yield and net income were 105 kg N/ha, 200 ppm ethephon and drip irrigation at 5 mm CPE.	Syriac, K. E. 1998. Nutrient-growth regulator interaction in snake gourd under drip irrigation. Ph.D. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

PUMPKIN

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation can be scheduled at 75% depletion of available soil moisture. Irrigating at cumulative pan evaporation values of 60-70 mm during vegetative stage followed by 45-55 mm during flowering and fruiting stage was more economic for higher yield.	Lakshman, R. 1985. Scheduling irrigation for cucurbitaceous vegetables. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

CUCUMBER

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Scheduling 3 cm irrigation at IW/CPE ratio of 0.4 (interval of 15 days) through basin method can be recommended for cucumber in summer season. Water equivalent to 40% of daily evaporation is sufficient.	Annual Report 1979-80 AICRP on Water Management. Agronomic Research Station, Chalakudy, pp 92-94	Agronomic Research Station, Chalakudy. Kerala Agricultural University.
Study conducted on the relative efficiency of a low cost drip irrigation system fabricated with the locally available materials and the conventional basin method was tested. 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% over drip method.	Andezhathu, S. 1989. Relative efficiency evaluation of drip and conventional method of irrigation in Ash gourd and Cucumber. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Studies indicated that the best schedule of irrigation in cucumber was to irrigate at 25 mm CPE. A fertilizer dose of 100 kg N and K/ha. 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% of total water used from the top 30 cm soil layer.	Rao, S. 1989. Water management and N and K nutrition in cucumber (*cucumis sativus* L). M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Evaluation of three levels of drip irrigation (2, 3 and 4 l/plant/day) four timings of irrigation (1, 2, 3 and 4 hrs) and two number of drippers per plant (1 and 2 dripper/plant) showed that, the duration for drip irrigation as 3 hours per day and one number of dripper per plant to be the best.	Lakshmi, S. 1997. Response of cucumber (*Cucumis melo L.*) to drip irrigation under varying levels of nitrogen and potash.	College of Agriculture, Vellayani. Kerala Agricultural University

The spread and depth of root system of cucumber plants raised under drip irrigation pointed out that the fertilizers as a ring around the base of the plant at a distance of 20 cm will be within the root zone of the plant. The yield of cucumber was highest at the drip irrigation level of 3 l/plant/day.	Ph D. Thesis, Dept of Agronomy, CoA, Vellayani	

SALAD CUCUMBER

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Drip irrigation with 2.0 litre/plant/day using 4 lph dripper, along wit0h 30 micron silver black plastic mulch gave better performance in naturally ventilated poly house.	Annual Progress Report. 2010-2011, Precision Farming Development Centre, Tavanur, Kerala Agricultural University. p.14	PFDC, KCAET Tavanur. Kerala Agricultural University.
Sub surface inline drippers along with coirpith mulching was found significantly superior to surface placement of laterals under no mulched or leaf mulched conditions in the yield of salad cucmber. Among three factor interactions, the combination of conventional fertilizer + sub surface placement of inline dripper + coir pith mulch recorded higher yield of 23.67 t/ha in salad cucumber. Moisture retention under coir pith mulching was significantly superior (16.42%) to no mulch (15.03%) condition and the yield, pH and B:C ratio under conventional fertilizers (Urea, MOP) and coir pith mulching were found good for salad cucumber.	Research Report. 2011-14. Directorate of Research, Kerala Agricultural University.	PFDC, KCAET Tavanur. Kerala Agricultural University.

The water requirement of salad cucumber was determined as 2.84 mm using the irrigation management and planning model CROPWAT. The study revealed that drip irrigation with 1.3 l/day or 65% of the daily irrigation requirement and fertilizer @ 100% of the adhoc fertilizer recommendation of KAU could give maximum production of salad cucumber in a naturally ventilated polyhouse. The maximum fertilizer use efficiencies were reported for the treatment with 90% fertilizer requirement. The study on effect of microclimate on the performance of salad cucumber showed that the most suitable temperature range for the optimum production was 22°C to 32°C and most suitable relative humidity was 80% to 95%.		

ORIENTAL PICKLING MELON

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation at 75 per cent depletion of available soil moisture was found optimum for salad cucumber. This comes about 5-7 days interval between two irrigations. In another approach using can evaporimeter, irrigation has to be given at 60-70 mm cumulative can evaporation values during vegetative stage followed by 45-55mm during flowering and fruiting stages.	Lakshman, R. 1985. Scheduling irrigation for cucurbitaceous vegetables. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Studies on different irrigation levels of IW/CPE - 0.4, 0.8, 1.2 and at critical	Veeraputhiran, R. 1996. Irrigation	Reena Mathew *et.al.* 2005. Three decades of

stages (branching, flowering, fruit development) revealed that, IW/CPE of 1.2 have maximum vine length, more number of leaves per vine, highest leaf area, highest LAI, more dry matter, mean length of fruits, highest girth of fruits, highest fruit weight, highest number of fruits, highest consumptive use, highest crop coefficient value and highest CWUE. Irrigation at IW/CPE 1.2 and 0.8 produced 114 and 56 per cent more yield. Higher levels of irrigation increased the N and K content of leaves up to 45 DAS and P content up to 75 DAS. Highest net profit and net return per rupee was recorded in IW/CPE 1.2. 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 1.2. Under conditions of scarcity of water, an equally beneficial alternative was incorporation of paddy waste or coir pith and irrigation at IW/CPE 0.8.	management related to subsurface moisture conservation technique in oriental pickling melon. M.Sc Thesis, Kerala Agricultural University.	research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
The quantity of water for irrigation could be reduced considerably by adopting drip irrigation using one emitter per plant @ 3 litres per day. Nitrogen @ 70 kg/ha and K @ 50 kg/ha was found optimum under drip irrigated conditions.	Lakshmi, S. 1997. Effect of drip irrigation and application of N and K fertilizer on the growth and yield of Cucumber. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy. Kerala Agricultural University.

Drip irrigation at 125% 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% yield increase, the treatment brought about 13% savings in water where 45 litres was applied per plant once in 3 days.	Gebermedhin, A. A. 2001. Drip irrigation and mulching in oriental pickling melon. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
In an experiment consisting of combination of 4 irrigation levels (50, 75 and 100% EP through drip irrigation and farmers practice of pot irrigation @ 10 l/ plant) and 3 fertilizer level (100, 150 and 200 % RDF), the results showed that, Maximum fruit yield (72.4 t/ha) was recorded at 100% EP given through drip irrigation along with 200% RDF. Maximum number of fruits per plant (2.8), maximum average weight and volume of fruit (710.2 g and 724.4cm^{3}) were observed at 100% EP.	Ningaraju, G.K. 2013. Fertigation in oriental pickling melon (*cuccumis melo* var.conomon (L.) Makino) under high density planting. M.Sc. Thesis, Kerala Agricultural University.	College of Horticulture, Vellayani. Kerala Agricultural University.
Among irrigation methods, oriental pickling melon responded least to wick method. Wick irrigation recorded higher fruit setting percentage than other method and recorded the highest mean fruit weight of 1236 g. Though basin irrigation retained higher moisture in soil, it was not reflected in fruit yield. The combination of mulching with black LDPE and irrigation methods was the better method. Best fruit yield and net profit were obtained when wick irrigation was combined with mulching entire inter space with black LDPE.	Anoop. N. C. 2009, Micro Irrigation and Polythene Mulching in Oriental Pickling Melon (*Cucumis melo var conomon* (L.) Makino). M.Sc Thesis. Department of Agronomy. College of Horticulture, Vellanikkara. pp. 102	College of Horticulture, Vellanikkara. Kerala Agricultural University

ASH GOURD

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation at 75% depletion of available soil moisture was suggested for ash gourd. This comes about 5-7 days interval between two irrigations. In another approach using can evaporimeter, irrigation has to be given at 60-70 mm cumulative can evaporation values during vegetative stage followed by 45-55mm during flowering and fruiting stages.	Lakshman, R. 1985. Scheduling irrigation for cucurbitaceous vegetables. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Irrigation at IW/CPE of 0.7 along with mulching was found to be optimum for higher yield in ash gourd.	Visalakshi, K. P. 1988. Studies on drip irrigation in Ash gourd. Research Highlights on vegetables. Kerala Agricultural University. pp.32-33.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
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. In drip as well as basin method, the irrigation schedule was IW/CPE 1.0, 0.7 and 0.4. There was 30% saving of irrigation water by drip method over conventional method of irrigation.	Andezhathu, S.1989. Relative efficiency evaluation of drip and conventional method of irrigation in Ash gourd and Cucumber. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
While assessing different levels of potassium (75, 150 and 225 % 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, M. G. 1990. Efficiency of K under different levels of irrigation in summer vegetable – Ash gourd. M.Sc. Thesis. Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

WATER MELON

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Water melon can be successfully raised in rice fallows if irrigated and sown in November. The crop when grown in November, had to be irrigated with 30 mm water at IW/CPE 1.0, which was comparable with daily irrigation with 10 l/plant/day with respect to growth and yield.	Neendissery, S.T. 1993. Influence of date of sowing and levels of irrigation on the growth and yield of water melon grown in rice fallows. M.Sc. Thesis. Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
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.	Ajith, C.B. 2000. Irrigation scheduling and moisture conservation in watermelon. M.Sc. Thesis. Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

BHINDI

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Daily irrigation in alternate furrows recorded the highest yield in area where water is not limited. 40 mm irrigation at 30 mm CPE could be economically adopted in command areas where rational supply of water is being practised.	Jayakrishna Kumar, 1986. Water management in relation to split application of Nitrogen on Bhindi. M.Sc. Thesis Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

A fruit yield of 24.88 t/ha was achieved when the crop was mulched and furrow irrigated at soil moisture tension of 0.08 Mpa. This accounted for 93.48% 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.	Sunil Kumar, 1998. Mulch cum drip irrigation system for Okra. M.Sc.(Ag.) thesis Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Performance of bhindi under plastic mulch and fertigation was good when compared to the conventional method practiced. The quantity of fertilizer needed through fertigation is as recommended by KAU and phosphorous is applied as basal and Nitrogen (as Urea) and Potassium (MOP) is to be given through drip in 16 split doses at 3 days interval.	Annual Progress Report 2011-2012, Precision Farming Development Centre, Tavanur, p16	PFDC, KCAET, Tavanur. Kerala Agricultural University
Sub surface drip irrigation at a depth of 10 cm below ground level and at a rate of application of 1.5 l/day/plant gave highest yield in sandy loam soils and is found the best treatment. The maximum horizontal and vertical waterfront advance in the root zone of okra was found to be 37.5cm and 52.5cm respectively, which indicated that the plants never had any water stress during the crop period under subsurface drip irrigation system.	Research Report. 2006-11, Kerala Agricultural University, Vellanikkara. Pp. 239-243.	Agronomic Researach Station, Chalakudy. Kerala Agricultural University.

A comparative study on the performance of online drip, inline drip and porous pipe in the bhindi fields (laterite soil) in respect of water distribution and yield of crop indicated that there was a significant reduction in the yield of the plants over years which was irrigated using porous pipe. In all the cases (porous pipe/inline dripper/online dripper), the yield of the plants irrigated with 100% PE was more than 75% PE. Maximum yield was obtained from the plants irrigated with inline drippers at 100% PE.	Research Report. 2006-11, Kerala Agricultural University, Vellanikkara. Pp. 239-243.	Agronomic Researach Station, Chalakudy. Kerala Agricultural University.
A study was undertaken to analyze the hydraulics of sub surface inline drip irrigation system, soil moisture distribution pattern, effect of depth of installation of laterals and levels of irrigation on growth and yield of ladies finger and to compare performance of surface and subsurface drip irrigation. In this, 5 depths of installations (0, 5, 10, 1 and 20 cm) and 3 levels of irrigation were studied (1, 1.5 and 2 lpd per plant). The study concluded that subsurface drip irrigation with 10 cm depth of laterals and 1.5 lpd per plant of irrigation was considered as the best treatment for okra in sandy loam soil.	Nisha. T. V, 2007, Subsurface drip irrigation of ladies finger in sandy loam soil. M.Tech Thesis, Department of irrigation and drainage Engineering KCAET, Tavanur Pp.111.	KCAET, Tavanur. Kerala Agricultural University.

AMARANTH

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
In a comparative study of drip (low cost drip irrigation system fabricated with locally available materials) and basin method of irrigation, no significant	Sheela, E. V. N. 1988. Evaluation of drip and conventional methods of irrigation in	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in

difference could be obtained between conventional method and drip method.	Amaranthus and Brinjal. M.Tech. Thesis, Kerala Agricultural University.	Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Combinations of four levels of irrigation (IW/CPE of 0.75, 1.0 and 1.25 and farmers practice of daily irrigation) and four levels of nitrogen (50, 75, 100 and 125 kg/ha) 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. The yield in amaranth was maximum under farmers practice of daily twice irrigation with 8 liters $m^{-2}day^{-1}$.	Rajan, S. 1991. Production potential of Amaranthus under irrigation and Nitrogen levels. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

TOMATO

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
IW/CPE ratio of 1.2 under subsurface pad irrigation resulted more number of green leaves, branches, maximum leaf area index. more flowers and highest total number of fruits/plant/ha. in surface method, irrigation at IW/CPE of 1.2, 0.9, & 0.6 produced 94, 129 & 162% more number of fruits respectively. Surface irrigated plants have more crop WUE and field WUE at IW/CPE of 1.2, 0.9, and 0.6.	Abdul Nassar, M. K. 1995. Development of subsurface pad irrigation system for tomato. M.Sc Thesis. Kerala Agricultural University.	College of Horticulture. Vellanikkara, Kerala Agricultural University.
Fertigation through drip 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	Kingsly, R.D. 2002. Response of tomato to varying levels of fertigation.	Reena Mathew *et.al.* 2005. Three decades of research on water management in Kerala

limiting factor, irrigation at 0.6 PE with 150% of recommended dose could be adopted.	M.Sc Thesis. Kerala Agricultural University.	Agricultural University. Agronomic Research Station, Chalakudy.

CHILLI

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A field study was conducted in chilli with three levels of irrigation (60, 80 and 100% FC), two method of irrigation (indigenous auto irrigator using hospital drip and pot watering) and three moisture conservation method (control, application of coir pith and jalasakthi). Maximum yield and profit were obtained in drip irrigation at 100% FC, with coir pith mulching while maximum WUE was obtained in drip irrigation at 80% FC with the same mulching.	Roshni, 1993. Evaluation of low cost techniques in potted vegetable grown in roof garden. M. Sc Thesis, Kerala agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Drip irrigation @ 2 lpd along with a nutrient dose of 100:40:33.3 kg NPK/ha resulted in highest yield and nutrient uptake in chilli variety Jwalamukhi. Under acute scarcity of water and land, crops can be raised in pots with drip irrigation @ 1.5 liters/ plant/day.	Shirly, C.M. 1996. Response of vegetable chilly cv. Jwalasakhi to graded levels of N and K under varying soil moisture. M.Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
A modified drip irrigation system giving 1.5 litres of water per plant per day was studied. The holes of the garden pots were plugged with rubber corks provided with holes. Water was stored in these pots and the flow was regulated @ 10 ml/minute for 2½ hours (1.5 l/plant/	Anitha, V. 1997. Nitrogen management in vegetable chilli grown in pots with modified drip irrigation system. M.Sc Thesis, Dept. of Agronomy, College of Agriculture, Vellayani.	College of Agriculture, Vellayani. Kerala Agricultural University

day) with the screw type pinch cork attached to the tube. Maximum yield was obtained for N_0 (12.6 g/plant) level of nitrogen, with poultry manure application and with Azospirillum inoculation. Profit per pot was maximum at N_0 level of nitrogen, with poultry manure application and without microbial application.		
Fertigation equipments like ventury, dosmatic fertigation unit and fertilizer tank were tested to study the hydraulic performance of the system. It is observed that venturi can be used if the discharge rate is greater than 14.6 lpm and dosmatic fertigation and fertilizer tank can be used if discharge rate is greater than 1.1lpm and 6.6 lpm respectively. The yield of chilli showed significant differences with different levels of irrigation and drip system layout.	Nadiya Nesihad 2012 Impact of Fertigation and Drip System Layout on Performance of Chilli (*Capsicum Annum*) M.Tech. Thesis, Department of Land and Water Resources and Conservation Engineering KCAET Tavanur pp. 111	KCAET, Tavanur, Kerala Agricultural University

BRINJAL

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation using clay emitters (made by mixing different proportions of clay and sand using a mould fabricated for the purpose) @ 5mm/day (2.25 l/plant/ day) gave a 70% higher yield when compared to conventional irrigation @ 21 mm at 3 day interval (9.5 l/plant once in three days).	Kokkal,K., Rajagopalan, P., Yamuna, P.S and Varadan, K.M. 1997. Evaluation of groundwater potential in the Edathodu watershed, Kasaragod district. *Proceedings of the 9th Kerala Science Congress*, Trivandrum.(1997) pp:44-45.	Agricultural water management,Three decades of activities of Water Management (Agriculture) Division, 1978-2007. CWRDM, p23.

On evaluation of a low cost drip irrigation system with that of conventional basin method in brinjal, it was found that with half the quantity of water given in basin method, drip method gave equal or superior yield.	Sheela, E. V. N. 1988. Evaluation of drip and conventional methods of irrigation in Amaranthus and Brinjal. M.Tech. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.
Significant effect of inline drippers (ID) was found on yield over drip tape (DT) and surface drip (SD) among different levels of irrigation. Irrigation at 100% PE was significantly superior to 70% in each emission device. In ID and SD irrigating the crop at 100% PE was significantly superior to 70%, but in DT both were on par.	Annual Report. 2007-08. AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 11	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

CAULIFLOWER

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Irrigation with online drippers recorded significantly superior yield and water use efficiency followed by inline drippers and surface irrigation, when plants were irrigated at 80% PE. Maximum yield was observed when irrigation was given at 60% PE through online drippers.	Annual Report. 2012. AICRP on Water Management. Agronomic Research Station, Chalakudy. pp 31	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

CABBAGE

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A comparative study of cultivation of cabbage inside NVPH and open field conditions using inline drippers of 4 lph discharge rate @ 1.8 l/plant/day revealed that,	Annual Progress Report. 2011-2012, Precision Farming Development Centre, Tavanur, Kerala	PFDC, KCAET, Tavanur. Kerala Agricultural University.

the quality of the produce as its size and the physiological parameters as biomass production inside the NVGH was significantly higher than outside. The crop inside the NVGH yielded early by three weeks. Fertilizer @ 80% of the KAU recommendation will be sufficient for application through fertigation.	Agricultural University. p18	
A study comprising 2 levels of irrigation (drip irrigation at 60% and 80% EP), 3 levels of fertilizer (75, 100 and 125% RDF) mulching, non mulching and control showed that, the highest net head weight (1.07kg/ plant) and harvest index (55.65) were maximum at 60% EP. Irrigation at 60% EP along with mulching and highest level of fertilizer gave the maximum yield and other parameters.	Mvoyaha Kaposha Nakaande. 2013. Fertigation and mulching studies in cabbage (*Brassica oleracea* var capitata L.) M.Sc.(Ag.) thesis, Kerala Agricultural University, 64p.	College of Agriculture, Vellayani. Kerala Agricultural University.

YARD LONG BEAN

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
An experiment laid out in split plot design with a combination of 2 irrigation levels (60 and 80% EP through drip irrigation) and 4 fertilizer levels (75, 100, 125% RDF and 100% RDF with water soluble fertilizer) with and without mulching revealed that, the number of pods per plant (42.49) and yield per plant (0.65kg) was recorded maximum at 80% EP given through drip where as length and weight of pods and number of seeds per pod were not influenced by the levels of irrigation.	Mahsuma Puthuppalli. 2014. Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var.sesquipedalis (L.) verdcourt). M.Sc. Thesis, Kerala Agricultural University, 105p.	College of Horticulture, Vellanikkara. Kerala Agricultural University.

OTHER CROPS

SUGARCANE

Sugarcane occupies the land for about 10-12 months and necessitates the irrigation application for realising good yields. In Kerala, planting is done from December to January.

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Irrigate the crop 8-10 times depending upon the availability of rains. In Chittoor area, more number of irrigations will be necessary. In early growth periods, irrigate the crop at more frequent intervals. However, avoid too much moisture and water stagnation especially during germination and early growth phases.

Alternate furrow with trash mulching could economise the use of irrigation water to the tune of 41 percent during the formative phase of spring planted sugarcane as compared to all furrow irrigation with trash mulching.

The optimum soil moisture range for sugarcane has been reported as 50% depletion of available water from 30-60 cm depth of soil layer. Irrigations are normally withheld 25-30 days before harvesting of canes.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Alternate furrow irrigation with 5 cm depth along with sugar cane trash mulch recorded the highest WUE, energy use and energy productivity.		Reena Mathew *et.al.* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

BETEL VINE

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Betel vine needs constantly moist soil, but there should not be excessive moisture. Hence, frequent light irrigations are given. The quantity of irrigation water should be such that the standing water should not remain for more than half an hour in the bed. If water logging by heavy rains or excess irrigation occurs, drainage should be arranged immediately. The best time for irrigation is morning or evening.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Drip irrigation at 100% PE resulted in 13.5 to 42.7% increase in weight of leaves and 30.5 to 70.6% saving in irrigation water at 100% PE over conventional furrow irrigation in betel vine.	Sreekumaran, V., Gopi, C.S., Santhakumari,G., Jayakrishnakumar, V. and Reghu, P.K. 1998. Bubbler irrigation system (BIS) – An Innovative Micro irrigation System. *Proceedings of the 10th Kerala Science Congress*. Kozhikode, Jan.2-4. p.494-496	Reena Mathew *et al* 2005. Three decades of Research on Water Management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

TEA

In Kerala the area under tea comes around 0.30 lakh ha and production is about 0.62 lakh tonnes.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A field experiment conducted with 5 levels of irrigation and 3 levels of frequencies revealed that, maximum yield of green leaf tea could be obtained when irrigation was done @ 3 mm per day at an interval of 7 days.	Varadan, K. M., Jayakumar, M., Boriah, G., Babu Mathew., Unni, P.N and Madhava Chandran, K. 1988. Irrigation scheduling for tea. *Proceedings of the National Symposium on Management of Irrigation Systems*, 24-27 February, 1988. CSSRI, Karnal	Agricultural water management,Three decades of activities of Water Management (Agriculture) Division. 1978-2007. CWRDM, P 16
In tea, 22.5 mm of water through sprinkler irrigation at an interval of 6 days gave maximum yield of dry leaves. Crop water stress index (CWSI) values of 0.246 and 0.261 may	George Mammen, Babu Mathew, Varadan, K. M. and Sundararajan, V. 2000. Canopy	Agricultural water management,Three decades of activities of Water Management (Agriculture) Division.

be used for irrigation scheduling of tea during March and April respectively.	temperature Technique for scheduling irrigation for tea (*Camellia sinesis*). *Proceedings of the Twelfth Kerala Science Congress*, 27-29 January 2000, Kumily. Pp. 55-57.	1978-2007. CWRDM, P 15.

CASHEW

Coastal states of the country are the main production centres. The important cashew growing states of India are Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Orissa and Tamil Nadu. In Kerala area under cashew comes around 0.542 lakh ha. and production is about 0.37 lakh tonnes.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Quantity of water applied was 24 mm, 44 mm and 72 mm respectively for IW/CPE ratio 0.5, 0.75 and 1.0 and the no. of irrigations were 6, 11 and 18 days respectively. Irrigation was found to significantly influence the nut yield of cashew but the irrigation levels were on par.	Annual Report. 2004. AICRP on Water Management. Agronomic Research Station, Chalakudy. Kerala Agricultural University. pp 26.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

COCOA

Water management as per the Kerala Agricultural University Package of Practices Recommendations – Crops - 2011

Cocoa grows well as a rainfed crop under conditions of well distributed rainfall and irrigation is not necessary. If sufficient moisture is not present in the soil due to prolonged drought or failure of rains, irrigation is to be given once in five days.

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Experiment conducted with 3 moisture regimes and 3 irrigation levels (25%, 50% and 75% of available moisture) revealed that irrigation at 75% available water was always found superior. This treatments recorded superiority in NAR (Net assimilation ratio). Plants in the wettest treatments always showed the highest total uptake of major nutrients.	Gopinathan, R. 1981. Effect of shade and moisture regimes on the growth of cocoa (*Theobroma cocoa* L.) M. Sc. Thesis, Kerala Agricultural University.	College of Horticulture, Kerala Agricultural University. Vellamkkara
Drip irrigation and nutrition are highly profitable in cocoa as mixed crop in arecanut plantation.	Sujatha, S. and Bhat Ravi. Cost-benefit analysis of drip irrigation in cocoa as mixed crop in arecanut plantation. Seminar on strategies for enhancing productivity of cocoa, 28-20 January 2011, CPCRI, Vittal. pp.89-91	Subaharan. K*. 2013. Compilation of data on water management in coconut and arecanut emanated from research carried out in CPCRI. PP.13. (*Scientist-in-charge (PME), Director, CPCRI).

FODDER

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Highest benefit - cost ratio was recorded for the treatment combination: irrigation at 45 mm CPE and recommended dose of manures and fertilizers (FYM @ 5.0 t/ha and NPK @ 150:50:50 kg/ha) when congosignal was grown as an intercrop in coconut garden.	Jacob, R. 1999. Intensive fodder production under irrigated conditions in partial shade. M. Sc. Thesis, Kerala Agricultural University.	Reena Mathew *et.al.* 2005. Three decades of research on water management in Kerala Agricultural University. Agronomic Research Station, Chalakudy.

An experiment conducted with 4 levels of irrigation at IW/CPE value of 1.0, 0.7, 0.4 and a control plot with residual moisture and 3 tillage treatments revealed that, in fodder maze cultivation with 40mm irrigation scheduled at IW/CPE ratio 1.0 with herbicide based zero tillage is superior with respect to fodder yield and net returns and suitable for summer rice fallows where water for irrigation is available.	Subba Reddy, B. 2013. Irrigation and tillage practices for fodder maze (*Zea mays* L.) in rice fallows. M.Sc. Thesis, Kerala Agricultural University, 98p.	College of Horticulture, Kerala Agricultural University. Vellanikkara.

SAPPAN WOOD

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Vertical mulching with layering mixture in polythene lined circular trenches and providing life saving irrigation once in three weeks with 33 litres of water or micro site enrichment and mulching with polythene and providing life saving irrigation once in four weeks with 33 litres of water is found beneficial for establishment and early growth of sappan wood.	Beena, J. S. 2005. In situ rain water harvest, conservation and utilisation for establishment and early growth of Sappan wood. Dept. of Agronomy, College of Agriculture, Vellayani.	College of Agriculture, Vellayani, Kerala Agricultural University.

CROPPING SYSTEM

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
Studies on the rice based cropping pattern indicated that bhindi, sesamum, cowpea and ground nut can be included in the cropping system after two rice crops. Rice requires irrigation only at 3 days after the disappearance of ponded water during rabi season and one day after the disappearance of ponded water during summer. Other crops in the season require frequent irrigation.	Annual Report. 1989-90. AICRP on Water Management. Agronomic Research Station, Chalakudy, Kerala Agricultural University. pp 107.	Agronomic Research Station, Chalakudy. Kerala Agricultural University.

Higher annual net return can be obtained by adapting either Rice-Rice-Bhindi sequence where Bhindi is raised during the third crop season with irrigation at IW/CPE ratio of 1.2 or Rice-Rice-Groundnut sequence where groundnut is raised during the third crop season with irrigation at IW/CPE ratio of 0.9.	Annual Report. 1990-91. AICRP on Water Management. Agronomic Research Station, Chalakudy. Kerala Agricultural University. pp 91.	Agronomic Research Station, Chalakudy Kerala Agricultural University.

CUT FLOWERS

Salient Findings/Method of Study	Original source/ Reference	Source/Station of Reference
A study in cut flowers grown in NVPH, showed no significant difference in on-line and in-line method of drip irrigation. But Drip irrigation system was superior over surface irrigation. When the flower production was compared, treatment with 100% and 80% recommended dose of fertilizer in both in-line and on-line drip irrigation system gave better results.	Research Report 2006-11, Kerala Agricultural University, Vellanikkara, Pp 239.	PFDC, KCAET, Tavanur. Kerala Agricultural University

Annexure – I

Available water capacity values for different soils

Sl. No.	Soil group	Textural classification	Field capacity (% by weight)	Wilting percentage (% by weight)	Available soil water (cm/m depth)*	Bulk density g/cc	Porosity (%)
1	Red loams	Sandy loam	10-18	4-10	9-16	1.3 – 1.5	45 - 50
2	Laterites	Loam to clay loam	18-32	8-16	14-25	1.3 - 1.7	38 - 52
3	Forest loams	Loam to silty loam	18-25	8-14	14-22		
4	Coastal alluvium	Sandy	5-10	2-6	5-10	1.2 – 1.5	33 - 40
5	Riverine alluvium	Sandy	5-10	2-6	5-10	1 – 1.5	42 - 55
6	Grayish onattukara	Sandy	5-10	2-6	5-10		
7	Brown hydromorphic	Clay	32-40	15-22	20-28		
8	Acid saline	Clay	24-32	11-16	17-25		
9	Black soil	Loam clay	32-40	15-22	20-28		

* The above table gives a range of values of soil water availability by this again depends on not only the properties of the soil but also the climatic demand which influences the evapotranspiration.

Source : Varadan, K.M. (1997). Irrigation scheduling. Manual of short course on 'On-farm Water management' CWRDM, Kunnamangalam, Kozhikode.

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