वार्षिक प्रतिवेदन
ANNUAL REPORT

2013-2014

जल प्रबंधन पर
अखिल भारतीय समन्वित अनुसंधान परियोजना

All India Coordinated Research Project on Water Management

जल प्रबंधन निदेशालय
(भारतीय कृषि अनुसंधान परिषद)
भुवनेश्वर, ओडिशा, भारत

Directorate of Water Management
(Indian Council of Agricultural Research)
Bhubaneswar-751023, Odisha, India
Website : http://www.dwm.res.in

भाकृ अनुप
ICAR

AICRP on WM

Annual Report 2013-14

Published by

Dr. Ashwani Kumar
Director, DWM, Bhubaneswar

Compiled & Edited by

Dr. Prabhakar Nanda
Dr. Ranu Rani Sethi
Dr. Pramod Kumar Panda

Hindi translation by

Dr. O.P. Verma

Correct Citation:

Annual Report AICRP (WM) 2013-14
DWM (ICAR), Bhubaneswar-751023, Odisha, India 115P

Printed by

Space Setter Press & Publicity Pvt. Ltd.
Bhubaneswar.

जल प्रबंधन निदेशालय
D. W. M

CONTENTS

Forward

Preface

EXECUTIVE SUMMARY (Hindi)	1-3
EXECUTIVE SUMMARY (English)	4-9
Assessment of water availability at regional level and to devise intervention for matching water supply with agricultural production system demand.	10-21
Design and evaluation of gravity and pressurized irrigation system under varying agro-ecological systems.	22-44
Management of Rain and other Natural Sources of Water	45-51
Basic Studies On Soil-Water-Plant Atmospheric-Environment Relationship	52-65
Water management for different agricultural production systems including Horticultural and other high value crops	66-103
STAFF STRENGTH AS ON 31.03.2013	104-104
Publications and Awards	105-114
Budget	115-115

Foreward.....

Water management in India possesses challenges to researchers from both the scenario of scarcity and abundance. India has largest area under irrigation in the world. Management of water in canal commands, economic use of water through pressurized irrigation system, rain water harvesting and multiple use of water have been gaining importance with passage of time. Water use by competing sectors would go a long way in ensuring water availability to the agriculture and other sectors. Water is one of the most important natural resources and it is, therefore, essential to properly conserve and manage this resource and regulate its use to obtain maximum benefits. Concrete efforts are necessary to maximize the existing water-use through judicial water management practices. As the future demand of food grain production from the irrigated agriculture would be heavy, the food security of the country could largely be met out through efficient irrigation water-use, improved *in-situ* rainwater conservation, and run-off recycling. Looking in to above, efficient use of irrigation water with higher productivity is crucial for the development of sustainable agriculture. Workable option is to develop water-use efficient easy-to-adopt technologies, which enhances productivity per drop of water. All India Coordinated Research Project on Water Management has made spectacular progress in developing a variety of strategies and technologies for improving sustainable use, planning and management of available water resources. Further, network project of AICRP on Water Management has to play a leading role in enhancing the water productivity of various production systems in different agro-ecological situations of the country.

It gives me a great pleasure to note that project Coordinating Unit of All India Coordinated Research Project on water Management is publishing its Annual Report 2013-14 with contribution from coordinating centres across the country. I express my sincere thanks to all the scientists working in the centres for their hard work and timely cooperation to run the project smoothly and trust that the scientists of the project will address hitherto uncovered aspects of irrigation water management to meet the challenges of irrigated agriculture in India. I place on record my sincere appreciation for the hard work done by Dr. P.Nanda, Principal Scientist under Project Coordinating Unit of AICRP on WM in managing day to day activities of the coordinating unit as well as editing the Annual Report. I also place in record my sincere appreciation to the team of scientists comprising Dr. Ranu Rani Sethi and Dr. P.K.Panda in compilation and editing the research findings for last one year at different centres for the benefit of researchers, planners and farmers.

Date: 20th June 2014

(**Ashwani Kumar**)
Director

Preface

The issue of water management has been a key factor in bring about stupendous progress in agricultural production. However, questions are raised on sustainability of irrigated agriculture since efficiency of irrigation system as well as its utilization is low, which is also accompanied with adverse environmental repercussions. Looking in to above, efficient use of irrigation water with higher productivity is crucial for the development of sustainable agriculture. Further, in order to reduce risk in agriculture and impart greater resilience to Indian agriculture against droughts and floods, efforts will be made for achieving greater flood proofing of flood prone agriculture and drought proofing of rain fed agriculture for protecting the farmers from vagaries of nature. For this purpose, contingency agriculture planning, use of water saving techniques, integrated watershed development programmes for drought prone areas will receive particular attention.

The All India Coordinated Research Project on Water Management has been emphasizing on increasing water use efficiency across the crops and regions in the country through on station, on-farm and participatory mode of water management projects spread over twenty five centers in the country. The coordinating centers have been representing diversified agro economic and geo hydrological situations. The AICRP (WM) since its inception has been catering to the research needs of water application in agriculture across the country. During last four decades of its operation, a number of technologies have been recommended to the state line departments for extension to extension personnel and farmers. The technologies have been discussed in the successive annual reports published under the scheme. The annual report of the scheme depicts the salient achievements of the coordinating centres during the reporting year. The results of the water management experiments, extension for the year 2013-2014 have been presented in current annual report theme wise and centre wise. The scientific teams working under the scheme across the country deserve appreciations for the hard work and timely submission of results for incorporation in the annual report. Dr. Ashwani Kumar, the Director, Directorate of Water Management has been the mentor and guiding spirit for the day to day management of the scheme and undersigned express their gratefulness to him. We also thank Mrs. A. Sunita for helping in compilation of the reports.

Prabhakar Nanda
Ranu rani Sethi
P. K. Panda

कार्यकारी सारांश

वर्ष 2013-14 के दौरान 25 केन्द्र क्षेत्रीय स्तर पर पानी की उपलब्धता का आकळन करने, दबाव सिंचाइँ प्रणाली का मुल्यांकन, बागवानी एवं उच्च मूल्य की फसलों में जल प्रबंधन, मृदा, पानी एवं पौधों के बीच संबंध, नहर और भूमिगत खारे पानि का संयुक्त उपयोग, पानी की उत्पादकता बढ़ाने के लिए जल निकास अध्यन, जल उत्पादकता बढ़ाने के लिए जल के बहुयामी उपयोग, उच्च वर्षा वाले क्षेत्रों में वर्षा जल प्रबंधन आदि विषयों पर अनुसंधान और विस्तार का काम कर रहे थे। वर्ष 2013-14 के दौरान मुख्य अनुसंधान उपलब्धियाँ नीचे दी गयी हैं:

भाटिंडा केंद्र पर 5 साल के अनुसंधान आंकडों का एक साथ विश्लेषण करने पर पता चला कि अंगूर की प्रजाति परलेट की उत्पादकता खराब गुणवत्ता वाले नलकूप के पानी से सिंचाई के तहत मिट्टी के स्वास्थ्य पर न्यूनतम प्रतिकूल प्रभाव के साथ अधिक प्राप्त हुई। इस खराब गुणवत्ता वाले पानी को या तो सल्फिटेसन प्रैसमड या नहर के पानी के साथ वैकल्पिप तौर पर उपयोग किया गया। परिणामों से पता चला है कि सिंचाई उपचारों CW/TW, TW+GR50,सल्फिटेसन प्रैस मड के प्रयोग से टैंक वाॅटर (RSC=6.4 MEQ/I, EC=2400 (μmhos/cm) तो सिंचाई की तुलना में अगूर की उपज में क्रमशः 28.3, 11.3 एवं 31.0% तक वृद्धि हुई। नलकूप की तुलना में अंगूर की उपज में क्रमशः 28.3, 11.3 एवं 31.0% तक वृद्धि हुई। नलकूप की पानी की सिंचाई मिट्टी के स्वास्थ्य पर प्रतिकूल प्रभाव डालती है जैसे उच्चतम पीएच (9.35), विद्यु चालकता (ईसी, 0.6 डेसी सिमन्स/मीटर), सोडियम अवशोषण अनुपात (एसएआर, 11.01) एवं मिट्टी में कम कार्बनिक कार्बन अंश (2.0 ग्राम/किलोग्राम) आदि। इस प्रयोग से प्राप्त परिणामों के आधार पर हल्की बनावट वाली मिट्टियों में अंगूर कीष्टतम उपज एवं वांछनीय गुणवत्ता प्राप्त करने के लिये खरे पानी की सिंचाई के साथ या तो जनवरी माह में कटाई छंडाई के बाद हर खाल सूखे वजन के आधार पर प्रति बेल 6 किलो सल्फिटेसन प्रैस मड का का प्रयोग या अच्छी गुणवत्ता नहर के पानी के साथ खारे पानी के चक्रीय उपयोग (1:1 अनुपात में) को मिट्टी के स्वास्थ्य पर प्रतिकूल प्रभाव को कम करने के लिये फल वाली फसलों को उगाने के लिये पैकेज में सिफारिश के तौर पंजाब कृषि विश्वविद्लायम द्वारा शामिल किया गया।

बेलवातगी केंद पर, 120 सेमी की ऊंची भूमि क्यारी विन्यास के साथ काफी अधिक शूद्ध आय (5426 रू./हेक्टेयर प्राप्त हुई जबकि अन्य 60 सेमी ऊंची भूमि क्यारी विन्यास के उपचार (रू.3807/हेक्टेयर) एवं सामान्य बुआई उपचार में (रू 4,747/हेक्टेयर) कम शुद्ध आय प्राप्त हुई। सिंचाई उपचार 0.8 आइडब्ल्यू/सीपीई अनुपात एवं 120 सेमी ऊंची भूमि क्यारी विन्यास उपचार के संयोजन से उच्च शुद्ध आय प्राप्त हुई जो अन्य उपचार 0.6 आईडब्ल्यू/सीपीई अनुपात पर सिचाई एवं 120 सेमी ऊंची भूमि क्यारी विन्यास (रू.507/हेक्टेयर) तथा सिंचाई उपचार 0.4 आइडब्ल्यू/सीपीई अनुपात और 120 सेमी ऊंची भूमि क्यारी विन्यास (रुपये 5644/हेक्टेयर के बरबर थी। अधिकतम लाभ लागत अनुपात 2.82 सिंचाई उपचार 0.8 आइडब्ल्यू/सीपीई अनुपात से प्राप्त हुआ। यह परिणाम सिंचाई स्तर 0.6 आइडब्ल्यू/सीपीई और 0.4 आइडब्ल्यू/सीपीई उपचार के साथ बराबर था। सिंचाई उपचार 0.8 आइडब्ल्यू/सीपीई अनुपात एवं सामान्य ऊंची क्यारी विन्यास उपचो के साथ 1.5 लाभ लागत अनुपात प्राप्त हुआ।

30 सेमी ड्रीपर दूरी के साथ 80 सीपी इ पर ड्रीप पद्धति द्वारा सिंचाई प्रयोग ने बताया कि इस पद्धति से 10027 किलो प्रकंद उपज प्राप्त होती है। यह उपज 60 सेमी ड्रीप्पर दूरी के साथ 80% सीपीइ पर ड्रिप सिंचाई से अधिक थी। ड्रीप्पर दूरियों के सभी अध्ययनों के मध्य 30 सेमी x 30 सेमी की ड्रीप्पर दूरी से प्रति हेक्टेयर 9867 किलोग्राम की उच्च प्रकंद उपज दर्ज की गई।

भवानीसागर केंद्र पर ही फसल प्रणाली आधारित प्रयोग में मूंग-मूँगफली-मिर्च फसल पद्धति के तहत माइक्रो स्प्रिंकलर सिंचाई एवं पोषक तत्व गतिशीलता का मूल्यांकन किया गया। इस फसल प्रणाली प्रयोग में मूंगफली में माइक्रो स्प्रिंकलर सिंचाई के माध्यम से तीन दिनों में एक बार 60 फीसदी सिंचाई के इष्टतम स्तर एवं उर्वरक की 100 कीसदी की सिफारिश की मात्रा के प्रयोग के साथ मूँगफली में 2482 किलोग्राम/हेक्टेयर फली उपज, 3.534 किलो/हे-मिमी जल उपयोग क्षमता के साथ 3.10 लाभ लागत अनुपात प्राप्त हुआ।

बिलासपुर केंद्र पर रेतीली दोमट एवं चिकनी मिट्टी में भरे हुए जल के सूखने के 3 से 5 दिन के बाद देरी से सिंचाई करने को एक बेहतर प्रबंधन उपाय माना जा सकता है। इस उपाय से लगातर कम गहराई जल भराव सिंचाई की तुलना में उपज मे बिना किसी कमी के 60% तक सिंचाई जल बचाया जा सकता है।

बिलासपुर केंद्र पर मिट्टी के उपचारों ने धान की पैदावार को काफी प्रभावित किया सतत जल भाव (52.22 क्विंटल/हेक्टेयर द्वारा DA1DPW और 3 DADPW सिंचाई उपचारों की तुलना में धान की काफी अधिक अनाज पैदावार का उत्पादन हुआ। विभिन्न नमी उपचारों जैसे 1 DADPW और 3 DADPW, पर सिंचाई से उपज में महत्वपूर्ण अंतर यानी कम पैदावार के लिये फसल की विभिन्न वृद्धि अवस्थाओं के दौरान अधिक तापमान सहने की वजह को जिम्मेदार ठहराया जा सकता है।

दापोली केंद्र पर सुपारी के पौधे की अधिकतम ऊंचाई (5.4 मीटर) सभी अन्य सिंचाई उपचारों की तुलना में L_3 सिंचाई उपचार (0.6 पीई) के तहत दर्ज हुई। जबकि विभिन्न वर्षों के दौरान भी पौधे की ऊंचाई में प्रतिशत वृद्धि L_3 उपचार में ही हुई है।

सिंचाई की रिंग विधि में सबसे कम पौधा ऊंचाई प्राप्त हुई। अधिकतम तथा परिधि (56.50 सेमी) भी सभी अन्य उपचार की तुलना में L_3 (0.6 पीई) सिंचाई उपचार के तहत दर्ज हुई। सुपारी के तने की परिधि में कुल मिलाकर प्रतिशत वृद्धि पिछले छह महीनों के दौरान शामिल सभी उपचारों में लगभग हुई वृद्धि के समान थी। इस अन्यतम में ड्रिप सिंचाई के माध्यम से L_1, L_2, L_3 सिंचाई स्तरों के प्रयोग से सिंचाई करने पर सिंचाई कि रिंग विधि के तुलना में क्रमशः 81, 62.5 एवं 44 फीसदी पानी की बचत हुई। परिणाम स्पष्ट रूप से देखा जा

सकता है कि रिंग विधि सिंचाई उपचार की तुलना में सुपारी की जल्दी परिपक्वता ड्रिप सिंचाई के माध्यम से पानी का प्रयोग करके प्राप्त की जा सकती है।

हिसार केंद्र पर बाढ़ विधि एवं कुंड विधि से सिंचाई की तुलना में ड्रिप विधि द्वारा 0.8 पीइ सिंचाई स्तर के सिंचाई करने पर उच्चतम कपास बीज उपज (2,674 किलो/हेक्टेयर) का उत्पादन किया जा सकता है। सिंचाई की अन्य विधियों के बजाय 0.8 के पीई सिंचाई स्तर पर ड्रिप विधि के माध्यम से जब सिंचाई की गयी तो पानी की उत्पादकता सबसे ज्यादा प्राप्त हुई।

हिसार केंन्द्र पर गेहूं के भूसे की पलवार का 4 या 6 टन/हेक्टेयर की दर प्रयोग करने पर काफी अधिक कपास बीज उपज हुई। पलवार के 4 एवं 6 टन/हेक्टेयर की दर से प्रयोग से बीच उपज/हेक्टेयर में ज्यादा अंतर प्राप्त नहीं हुआ।

जम्मू केंद्र पर लेजर लेवलिंग ने भूमि की सतह को समतल बनाया जो किसान के खेत में धान-गेहुं फसल पद्धति में खेत का अधिक समतल सूचकांक, आवेदन दक्षता (7.8%), वितरण क्षमता (18.8% एवं भंडारण क्षमता (14.7%) के मूल्यों के माध्यम से साबित हुआ। किसान के द्वारा किये गये समतल खेत की तुलना में लेजर लेवलिंग से धान (बासमती) एवं गेहूं की फसल में 20.3% में 20.4% की उपज में सुधार हुआ।

जम्मू केंद्र पर धान सघनता पद्धति (1.60 किलो/हेक्टेयर-मिमी) में पारंपरिक धान पद्धति (1.49 किलो/हेक्टेयर मिमी) की तुलना में अधिक जल उपयोग ३मता दर्ज की गई। बासमती धान को पारंपरिक बाढ़ विधि की तुलना में धान सघनता पद्धति से उगाने पर धान की उपज में 7% सुधार हुआ।

जोरहाट केंद्र पर रबी सब्जियों जैसे बैंगन के लिये आईडब्ल्यू/सीपीई अनुपात 1.4 पर प्रत्येक सिंचाई 4 सेमी गहराई की सिंचाई (18 दिनों के अंतराल) वाली 4-5 बार सिंचाई की आवश्यकता इष्टतम होती है। जबकि यहा किसान प्राय: 10 दिनों के अंतराल पर 3 सेमी गहराई की सिंचाई करते थे। इस विधि से सिंचाई करने पर 23 फीसदी की उपज में वृद्धि के साथ काफफ सिंचाई पानी की बचत (26 प्रतिशत) भी हुई।

जोरहाट केन्द्र पर ट्रीडल पंप का उपयोग पता चला यहाँ जिन क्षेत्रों में 5 मीटर भूमि जल स्तर गहराई ह वहाँ 100 मिमी स्ट्रोक एवं 0.79-1.24 लीटर/सेकंड निर्वहन क्षमता के साथ 89 मिमी जुड़वां बैरल ट्रीडल पंप की आवश्यकता है। प्रत्ब्ेक पंप सब्जियों एवं फूलों की फसल के फसल चक्र के अनुसार 0.25 हेक्टेयर का एक न्यूनतम क्षेत्र सिंचित कर सकते हैं। ट्रीडल पंप तकनीकी का लाभ लागत अनुताप को 5:1 है। इस तकनीकी की राज्य के लिये सिफारिश की गई है।

जोरहाट केन्द्र पर इस फसल के लिए सिंचाई का इष्टतम स्तर आईडब्ल्यू/सीपीई अनुपात 1.2 पर होना पाया गया। तदनुसार, 20 दिनों के अंतराल पर 4 सेमी गहराई की चार सिंचाइयाँ फसल के लिये अधिकतम हो सकती है। इस विधि से काफी सिंचाई पानी की बचत (41%) एवं उपज में वृद्धि (23%) के हुई।

मदुरै पर विभिन्न तकनीकों जैसे चावल गहनता पद्धति, मशीन द्वारा रोपाई, एकीकृत पोषक तत्व प्रबंधन, एक दिन के बाद पानी सूखने पर सिंचाई, टर्मिनल पानी स्ट्रैस प्रबंधन, पानी की चक्रण आपूर्ति एवं ड्रम बुआई ाादि के प्रदर्शन आयोजित किए गये। एसआरआई पद्धति के तहत इन सभी प्रदर्शित तकनीकों के परिणाम से अनाज पैदावार में 10.8 से 24.0% तक वृद्धि के साथ ही पानी की बचत की बचत का भी पता चला। कम से कम 14.0% पानी की बचत खेत में पानी शूखने के एक दिन बाद 5 सेमी गहराई तक की सिंचाई के साथ प्राप्त हुई। अधिकतम पानी की बचत (29.1%) टर्मिनल पानी स्टैस प्रबंधन एवं चक्रण पानी की आपूर्ति (27.0%) आदि तकनीकियों के साथ प्राप्त हुई। इन सभी प्रदर्शनों से उपज स्तरों में वृद्धि 5650 से 6850 किलोग्राम/हेक्टेयर/मिमी तक थी। इन तकनीकियों के कारण पानी की बचत में सुधार के साथ पानी की उपयोग दक्षता 5.70 से 7.20 किलोग्राम/हेक्टेयर/मिमी तक थी।

इसके अलवा मदुरै केंन्द्र पर मूंगफली की फसल के लिये स माइक्रो स्प्रिंकलर सिंचाई पद्धति द्वारा उपकृत सूक्ष्म सिंचाई पद्धति, सिंचाई एवं फर्टिगेसन के स्तरों के आकलन पर क्षेत्र प्रयोग किया गया। इस प्रयोग के परिणाम से 100% पीई पर तीन दिनों में एक बार सिंचाई करने पर अधिकतम फली उपज (2844 किलोग्राम/हेक्टेयर), जल उपयोग दक्षता (4.59 किलोग्राम/हेक्टेयर/मिमी) एवं लाभ लागत अनुपात (2.36) का पता चला। मूंगफली की फसल में सुझाई गयी 100% , 50% फॉसफोरस एवं पोटासियम बुआई के समय; संतुलित नाइट्रोजन, फॉसफोरस एवं पोटासियम जल घुलनशील उर्वरक के रूप में) उर्वरकों की मात्रा को 15 से 90 दिन के बुआइ के दौरान सप्ताह में एक बार फर्टिगेसन के द्वारा प्रयोग करेने से उच्चतम पलि उपज (2789 किग्रा/हेक्टेयर) के साथ अधिक जल उपयोग दक्षता (4.55 किलोग्राम/हेक्टेयर/मिमी दर्ज हुई।

इसके अलवा मदुरै केंन्द्र पर भूमि विन्यास के संबंध में पंक्तियों में मूगंफली की बुआई उपसतह ड्रिप फर्टिगेसन के लिये सबसे उपकृत थी। 100% पीइ सिंचाई सिइंई स्तर के साथ 100% नाइट्रोजन, 50% फॉफोरस डब्ल्यूएकएक के रूप में फर्टिगेसन एक बेहतर प्रबंधन उपाय था। इस उपाय से मूंगफली में उच्च उपज (3616 किग्रा/हेक्टेयर), शुद्ध लाभ (रू. 64088/हेक्टेयर), लाभ लागत अनुपात (2.25) प्राप्त होने के साथ अधिक जल उपयोग दक्षता (6.38 किग्रा/ हेक्टेयर/मिमी) प्राप्त हुई।

नवसारी केंन्द्र पर तीसरे वर्ष के दौरान दर्ज उपज एवं शुद्ध ााय के परिणामों के आधार पर यह निष्कर्ष निकाला गया कि तरबूज की फसल में ड्रिप सिंचाई + काली प्लास्टिक या सिल्वर या सिल्वर काली प्लास्टिक कि पलवार के साथ इसका युग्मि पंक्ति में रोपण उच्च सकाल आय प्राप्त करने के लिये जरूरी है। युग्मित पंक्ति रोपण, ड्रिप सिंचाई एवं पलवार के उपयोग से फल उपज में वृद्धि 48% थी और साथ ही 30 प्रतिशत की पानी की बचत भी हुई।

नवसारी केंन्द्र पर प्राप्त परिणामों से पता चला है कि काली प्लास्टिक की पलवार एवं 0.6 पीइ की दर से ड्रिप सिंचाई अपनाने से रबी सीजन के दौरान अरहर की फसल में पारंपरिक विधि की तुलना से 48 प्रतिशत अधिक पानी की बचत के साथ 70 प्रतिशत तक अरहर की बीज उपज में वृद्धि हुई।

इसके अलावा नवसारी केंन्द्र पर ही प्राप्त परिणाम ने बताया कि ड्रिप सिंचित अरंडी कि फसल का 2.4 मीटर की पंक्ति दूरी पर बुआई एवं 1.2 मीटर पंक्ति दूरी अंतर के साथ अंरडी (रबी) की बुआई तथा आठ बराबर भागों में 80 किग्रा नाइट्रोजन/हेक्टेयर की मात्रा को ड्रिप सिंचाई के साथ फर्टिगेसन करने पर जल उपयोग दक्षता में वृद्धि के साथ साथ अंरडी के बीज उपज में 13 प्रतिशत तक वृद्धि हुई।

पालमपुर केंन्द्र पर औसत के आधार पर ड्रिप सिंचाई पद्धति एवं फर्टिगेसन के कारण फलगोभी- शिमला मिर्च फसल अनुक्रम की जल उपयोग दक्षता सामान्य विधि की तुलना में 20.24% अधिक थी। इसका प्रमुख कारण 5.94 फीसदी उच्च शिमला मिर्च तुल्य उपज CEY एवं 11.82% कम TWU था। पालमपुर केन्द्र पर ही बैंगन की फसल में 75% सुझाई गयी नाइट्रोजन एवं फॉसफोरस उर्वरकों की मात्रा का गुरूत्वाकर्षण सहित ड्रिप सिंचाई प्रयोग से सामान्य विधि की तुलना में कम लाभ लागत अनुपात (34.76%) प्राप्त हुआ। इसके अलाव, बैंगन की फसल में ड्रीप सिंचाई (फर्टिगेसन 75% नाइट्रोजन एवं फॉसफोरस के साथ) से सामान्य विधि की तुलना में कम सिंचाई जल उपयोग (31.14%) हुआ एवं काफी अधिक पानी उपयोग क्षमता (54.04%) प्राप्त हुई।

पंतनगर केंन्द्र पर देरी से बोयी गयी गेहूँ की फसल में नम क्यारी एवं अधिक अनाज भरने के अवस्था पर एक अतिरिक्त सिंचाई की तुलना में फसल स्थापना के समय अनुकूल मौसम की स्तिति के साथ गीली या नम क्यारी विधि ने अनाज पैदावार एवं पानी उत्पादकता पर महत्वपूर्ण प्रभाव दिखाया। जबकि प्रतिकूल मौसम की स्थिति के तहत परागण के समय रासायनिक छिड़काव टार्मिनल गर्मी तनाव के प्रतिकूल प्रभाव को कम करने के लिये ने अनुकूल प्रभाव दिखाया। आर्थिक लाभ अत्यधिक अनाज पैदावार से जुडे थे। परागण अवस्था में 2% युरिया के घोल का पत्तों पर छिड़काव उच्च आर्थिक लाभ के लिये सबसे व्यवहार्य चिकल्प था।

इसके अलावा पंतनगर केंन्द्र पर प्रतिरोपित धान की फसल में अधिक अनाज उपज के लिये पानी सूखने के 1 दिन बाद सिंचाई ने 3 एवं 5 दिन के बाद सिंचाई करने के अन्य उपचारों की तुलना मेँ अपनी श्रेष्ठता दिखायी फसल में 90 किग्रा/हेक्टेयर नाइट्रोजन के प्रयोग की तुलना में 120 किग्रा/हेक्टेयर नाट्रोजन के प्रयोग से अनाज पैदावार काफी अधिक प्राप्त हुयी। फसल स्थापना की विधियों में से फ्लैट रोपण विधि ने ऊंची क्यारी 40/25 एवं 80/25 विधियों के उपचारों की तुलना में अधिक अनाज पैदावार का उत्पादन किया लेकिन धान की रोपाई ऊंची क्यारी विधियों में प्लैट रोपण विधि की तुलना में अधिक पानी उत्पादकता प्राप्त हुयी।

राहुरी केंन्द्र पर हल्दी की फसल में सुझाई गयी 75% उर्वरकों की मात्रा जल घुलनशील उर्वरक के रूप में फार्टिगेसन करने तथा 0.7 कम्पोजीट करक पर सिंचाई करने से फसल विकास एवं उपज में वृद्धि, पानी की बचत और उर्वरक उपयोग क्षमा आदि में बहुत सुधार प्राप्त हुआ। इससे मृदा स्वास्थ्य भी अच्छी तरण बना रहा। ऊपर के उपचार का प्रभाव 0.9 कम्पोजीट कारक पर सिंचाई और 100% उर्वरकों की सिफारिश के साथ खाद का प्रयोग पारंपरिक विधि के माध्यम से करने के बराबर था।

राहुरी केंन्द्र पर ही ड्रिप पद्धति के द्वारा एक वैकल्पिक दिन के आधार पर सिंचाई करने को उपज, गुणवत्ता, पानी की बचत, दक्षता एवं भंडारण के अध्ययन के लिये सबसे अच्छा पाया गया। इसके बाद माइक्रो स्प्रिंकलर सिंचाई को उपयोगी पाया। समन्वित पौषक तत्व प्रबंधन उपचार के तहत फार्म यार्ड खाद 5 टन्/हेक्टेयर की दर से प्रयोग के साथ उर्वरकों की 100% सिफारिश की मात्रा (100:50:50 किलो नाट्रोजन, फॅासपोरस एवं पोटासीयम/हेक्टेयर का प्रयोग अधिक उपज प्राप्त करने, गुनवत्ता और भंडारण के अध्ययन के लिये सबसे अच्छा पाया गया। ऊपर ध्यान में रखते हुए यह निष्कर्ष निकाला जा सकता है कि प्याज उगाने के लिए फार्म यार्ड खाद की 5 टन/हेक्टेयर की मात्रा का मिट्टी में प्रयोग के साथ 100% उर्वरकों की मात्रा को हर दूसरे दिन पर ड्रिप सिंचाई द्वारा प्रयोग करना उच, उपज, गुणवत्ता, पाानी की बचत, जल उपयोग क्षमता एवं भंडारण के लिये अधिक उपयुक्त हो सकता है।

मुला कमांड के तहत कपास की फसल में 75 मिमी सीपीई पर सिंचाई करने एवं सुझाई गयी उर्वरकों की मात्रा का प्रयोग करने पर उपज में 9.78 से 15.28% की वृद्धि हुई साथ ही जल उपयोग दक्षता भी 27.18 से 31.22 किग्रा/हेक्टेयर-मिमी के मध्य दर्ज हुई जो कि कंट्रोल प्लाट की तुलना में अधिक थी।

श्रीगंगनगर केंन्द्र पर तीन शाल के प्रयोग के आधार पर यह प्राप्त हुआ कि नीचे टनल के साथ 0.8 क्रॉप एवेपोट्रांस्पिरेसन तक सिंचाई पानी के स्तर में वृद्धि के से टमाटर की फसल मे फल उपज में काफी वृद्धि हुई। आगे सिंचाई पानी में वृद्धि के साथ टमाटर की उपज में अधिक वृद्धि नहीं हुई। आकडों का एक साथ विश्लेषण करने परपता चला कि 1.0 क्रॉप एवेपोट्रांस्पिरेसन पर ड्रीप सिंचाई करने पर टमाटर की अधिकतम फल उपज (566.54 क्विंटल/हेक्टेयर) प्राप्त हुई जो 1.2 एवं 0.8 क्रॉप एवेपोट्रांस्पिरेसन पर सिंचाई करने के बराबर थी।

इसके अलावा श्रीगंगनगर केंन्द्र पर जवार कि फसल में हरा चारा, शुष्क चारा, उपज एवं चारे के पौधों की ऊंचाई के स्तर से काफी प्रभावित होने का पता चला। जवार कि हरे चारे की उपज(493.19 क्विंटल/हेक्टेयर) सिंचाई पानी के स्तर में हर वृद्धि 0.9 आईडबल्यु/सिपिइ के साथ काफी वृद्धि हुई। आगे सिंचाई स्तर में और वृद्धि करने से धारा उपज उपज में अधिक वृद्धि नहीं हुई। इस प्रकार 0.9 आईटब्ल्यू/सीपीई सिंचाई स्तर पर स्प्रिंकलर सिंचाई को चारे की अधिक उपज के लिये उपयोगी पाया गया। इस अध्ययन में पानी खर्च दक्षता (81.86 किलोग्राम /हेक्टेयर-मिमी) अन्य सिंचाई उपचारों की तुलना में 1/1उपचार (0.5 आइडब्ल्यू/सीपीई) में अधिक थी इसके बाद यह 1/4(1.1आइडब्ल्यू/सीपीई) सिंचाई उपचार में अधिक थी।

EXECUTIVE SUMMARY

Salient Achievements AICRP on Water Managemenet during 2013-2014

During the year 2013-2014, 25 centers were carrying out research and extension work in the field of assessment of water availability at regional level, evaluation of pressurized irrigation system, water management of horticultural and high value crops, basic studies on soil, water, plant relationship and their interaction, conjunctive use of canal and underground saline water, drainage studies for enhancing water productivity, enhancing productivity by multiple use of water, rainwater management in high rainfall areas. Salient achievements during 2013-2014 are given below:

- At Bathinda, the pooled mean of 5 years research data revealed that the productivity of grapes *cv. Perlette* under poor quality tubewell water irrigation can be increased considerably with the application of either sulphitation pressmud or its alternate use with canal water with minimal adverse effect on soil health. Results revealed that treatments CW/TW, TW+GR_{50}, and TW + sulphitation pressmud significantly increased the grapes yield by 28.3, 11.3 and 31.0 per cent respectively, as compared to TW (RSC = 6.4 meq/l, EC = 2400 µmhos/cm) alone. Irrigation with tube well water caused detrimental effect on soil quality as it resulted in highest pH (9.35), Electrical Conductivity (EC, 0.6 dS m^{-1}), Sodium Adsorption Ratio (SAR, 11.01) and low organic carbon content (OC, 2.0 g kg^{-1}) of the soil. On the basis of the results of this experiment a recommendation "In light textured soils, to obtain optimum yield and desirable quality of grapes with sodic water, either application of sulphitation pressmud @ 6 kg/vine on dry weight basis every year after pruning in the month of January or cyclic use of sodic water with good quality canal water (1:1) is recommended to minimize any adverse effect on soil health" was included in PAU package of practices on fruit(pooled data) net income and on par with other treatments i.e., 0.6 IW/CPE ratio and 120cm raised bed (Rs 5,076 / ha) and also with irrigation treatment 0.4 IW/CPE ratio and 120 cm raised bed (Rs 5,644 / ha). The B:C ratio on land configuration obtained a higher 2.82 in respect of 0.8 IW/CPE. This result was on par with the irrigation level 0.6 IW/CPE and 0.4 IW/CPE treatments. The interaction effect between irrigation treatment 0.8 IW/CPE ratio and normal bed configuration treatment recorded higher B:C ratio (1.5) with other treatments

- At Bhavanisagar, the experiment revealed that drip

- At Bhavanisagar, In the cropping system experiment on "Evaluation of micro sprinkler irrigation and nutrient dynamics under green gram-groundnut-chillies based cropping system" indicated that optimum lhigher pod yield of 2482 kg/ha, WUE of 3.534 kg/ha.mm with a B:C ratio of 3.10.

- At Bilaspur, delaying irrigation up to 3 to 5 days after subsidence of ponded water can be considered to be the best water regime for paddy in clay-loam to clay soil as about 40 - 60 % of irrigation water can be saved without any loss in yield in comparison to continuous shallow submergence (± 5 cm ponded waterirrigation at 80 per cent PE with 30 cm dripper spacing recorded higher rhizome yield of 10027 kg/ha. It was comparable with drip irrigation at 80 per cent PE with 60 cm dripper spacing. Among the different spacing studied, the spacing of 30 cm x 30 cm recorded higher rhizome yield of 9867 kg/ha and this was comparable with the spacing of 30 cm x 25 cm. evel of irrigation at 60 per cent once in three days through micro sprinkler in groundnut with 100 per cent recommended dose of fertilizer resulted in).

- At Bilaspur, Soil moisture regimes significantly influenced the paddy yields. Continuous submergence produced significantly higher grain yield (52.22 q/ha) of paddy followed by irrigation at 1 DADPW and 3 DADPW. The significant difference in yield due to variable moisture regimes may be attributed mainly due to the temperature shock experienced during different physiological stages of the crop as a result of irrigation at 1 DADPW & 3 DADPW, which ultimately reflected in lower yields in these treatments.

- At Dapoli, the maximum plant height (5.4 m) was observed under I_3 (0.6 PE) as compared to all other treatment. The percent increase in plant height during the year was maximum in treatment I_3, whereas it was least in ring method of irrigation. The maximum stem girth (56.50 cm) was observed under I_3 (0.6 PE) as compared to all other treatments. Overall percent increase in the stem girth of arecanut was observed to be almost same in all incorporated treatments during last six months. Study resulted in the water saving of 81, 62.5 and 44 per cent, respectively in case of I_1, I_2, I_3 irrigation levels through drip irrigation over ring method of irrigation. The results clearly revealed that the early maturity of arecanut can be achieved with the application of water through drip irrigation as compared to the control (ring method) treatment.

- At Hissar, Irrigation applied at PE of 0.8 with drip produced highest seed cotton yield (2674 kg/ha) over flood and furrow methods irrigation. The water productivity of irrigation was highest when irrigations were applied through drip system at PE of 0.8 over other irrigation methods and schedules.

- At Hissar, use of wheat straw mulch either @ 4 or 6 t/ha resulted in significantly higher seed cotton yield over control, and the yield difference between mulching @ of 4 and 6 t/ha was not marked.

- At Jammu, the laser leveling improved the smoothness of land surface which is proved through leveling index and values of application efficiency (7.8%), distribution efficiency (18.8%) and storage efficiency (14.7%) over farmer leveled field in rice-wheat sequence. Laser leveling improved the yield by 20.4% in rice (Basmati) and 20.3% in wheat as compared to farmer leveled field. The experiment has been concluded with recommendations.

- At Jammu, it was found that SRI registered the WUE of the order of 1.60 kg/ha-mm as against the conventional practice which recorded 1.49 kg/ha-mm. The rice yield also improved by 7% with SRI as compared to traditional method of growing basmati rice.

- At Jorhat, Among for the *rabi* vegetables, brinjal, the optimum irrigation schedule was found to be 4cm depth of each irrigation at IW/CPE ratio 1.4 (18 days interval) requiring 4-5 irrigations against the farmers' practice of 10 days interval which required of irrigations of 3cm depth. The practice led considerable irrigation water savings (about 26 per cent) along with the yield increase of 23 per cent.

- At Jorhat, treadle pump use revealed that 89 mm twin barrel treadle pump of 100mm stroke for areas having water table within 5m. a discharge of 0.79 to 1.24 LPS is possible and each pump can command a minimum area of 0.25 ha per crop cycle for vegetables and flowers. Benefit cost ratio adopting treadle pump is 5:1. The technology was recommended for the state.

- At Jorhat, the optimum schedule of irrigation for this crop had been found to be at IW/CPE ratio 1.2. Accordingly, four irrigations of 4 cm depth each at an interval of 20 days may be optimum for the crop. The practice led to considerable irrigation water saving (about 41 per cent) and yield increase (about 23 per cent)

- At Madurai, demonstrations conducted were, System of Rice Intensification, machine transplanting, integrated nutrient management, irrigation to 5 cm one day after disappearance ponded water, terminal water stress management, rotational water supply and drum seeding. The results under SRI indicated that there was an increase in grain yield ranging from 10.8 to 24.0% in all the technologies demonstrated as well as saving of water. The minimum water saving of 14.0 % was observed with irrigation to 5 cm depth one day after disappearance. The maximum water saving (29.1%) was observed with terminal water stress management and rotational water supply (27.0%) technologies. Invariably the yield levels recorded was higher ranging from 5650 to 6850 kg/ha/mm in the above demonstrations. Due to the improved water saving technologies the water use efficiency was higher ranging from 5.70 to 7.20 kg/ha/mm.

- Also at Madurai, the results of the experiment on evolving appropriate micro irrigation method, irrigation and fertigation regimes for groundnut revealed that micro sprinkler irrigation at 100% PE once in three days registered the maximum pod yield (2844 kg/ha), WUE (4.59 kg/ha/mm) and B:C ratio (2.36). Fertigation of 100% RDF (50% P and K as basal, balance NPK as WSF) once in a week from 15 to 90 DAS recorded the highest pod yield (2789 kg/ha) and WUE (4.55kg/ha/mm) in groundnut.

- Also at Madurai, with regard to land configuration, sowing groundnut in ridges and furrow was best suited for subsurface drip fertigation. Fertigation of 100% N and 50% P and K as WSF with an irrigation regime at 100% PEwas the best management to get higher yield (3616kg/ha) and B:C ratio (2.25), net return (Rs.64088/-) and water use efficiency (6.38kg/ha/mm) in groundnut.

- At Navsari, Based on the results of yield and net income recorded during third year, it is concluded that planting of water melon in paired row with drip irrigation + mulching with either black plastic or silver black plastic is necessary for realizing higher net income. The magnitude of increase in fruit yield was 48 % with paired row, drip irrigation and mulching over control along with water saving of about 30 per cent.

- At Navsari, results revealed that with the adoption of drip irrigation@ 0.6 PEF + black plastic mulching could increase seed yield of pigeon pea to the extent of 70 per cent along with saving of water by about 48 per cent over conventional method of pigeon pea cultivation during *rabi* season.

- Also at Navsari, the results indicated that planting of drip irrigated castor (*rabi*) at a row spacing of 2.4 m and intra row spacing of 1.2 m along with fertigation

@ 80 kg N/ha in eight equal splits at an interval of 10 days found to increase seed yield of castor by about 13 per cent along with enhancing WUE.

- At palampur, on mean basis, WUE of cauliflower-capsicum cropping sequence was 20.24 per cent higher in drip irrigation and fertigation than in recommended practices, due to 5.94 per cent higher capsicum equivalent yield (CEY) and 11.82 per cent lower TWU.

- Also at Palampur, the B: C ratio (34.76 %) was significantly lower in brinjal crop grown under gravity fed drip irrigation with 75 per cent of recommended NPK fertigation than crop grown with recommended practices. Further, the brinjal crop grown with 75 per cent NPK fertigation under gravity fed drip irrigation resulted in significantly higher water use efficiency (54.04 %) due to lower irrigation water use (31.14 %) than recommended practices.

- At Pantnagar, In late sown wheat, under favourable weather condition wet bed method of crop establishment over moist bed and one additional irrigation at grain filling over irrigation till flowering showed significant effect on grain yield and water productivity. While, under harsh weather conditions, chemical spray at anthesis showed favorable effect to offset the adverse effect of terminal heat stress. The monetary advantages were highly linked to the grain yield. Foliar spray of 2% urea at anthesis stage was the most viable option for higher economic returns.

- Also at Pantnagar, for producing higher grain yield of transplanted rice, irrigation at 1 DADPW showed its superiority over the 3 and 5 DADPW treatments. Crop fertilized with 120 kg N/ha rerecorded significantly higher mean grain yield than 90 kg N/ha. Among the crop establishment methods, flat planting produced higher grain yield than raised beds 40/25 and 80/25 treatments, but raised bed systems of rice transplanting had higher water productivity than the conventional flat method.

- At Rahuri, turmeric crop irrigated with 0.7 composite factor alongwith fertigation of water soluble fertilizer at 75% the recommended dose of fertilizer was found to have higher yield, growth attributes, water and fertilizer use efficiency with its saving further maintaining the soil health. The above treatments are at par with 0.9 CF and 100% RDF through conventional method of fertilization.

- Also at Rahuri, the drip irrigation at an alternate day as per ETc is found to be the best for yield, quality, water saving and efficiency, and storage studies followed by microsprinkler irrigation on alternate day as per ETc. Amongst the INM treatments, the 100% recommended dose of fertilizer (100:50:50 kg ha^{-1} NPK) alongwith 5 tonnes of FYM ha^{-1} was found to be the best with respect to yield, quality and storage studies followed by 100% recommended dose of fertilizers alongwith application of vermicompost on N basis of FYM. In view of the above, it can be concluded that drip irrigation on alternate day as per ETc and 100% RDF alongwith 5 tonnes of FYM ha^{-1} can be more suitable for growing onion to get higher yield, quality, water saving and WUE and storage.

- Under Mula Command, Bt. cotton yield increased by 9.78 to 15.28 per cent over control plot by scheduling of irrigation at 75 mm CPE and recommended dose of fertilizer. The WUE ranged from 27.18 to 31.22 kg/ha.cm which was higher than control plot.

- At Sriganganagar, On the basis of three years of experimentation, it was observed that the fruit yield of tomato increased significantly with increasing level of irrigation water only up to 0.8 Etc with low tunnel. Further increase in irrigation water did not increase the yield of tomato significantly. In pooled data, the maximum fruit yield of tomato (566.54 q/ha) was recorded with drip irrigation at 1.0 Etc (LT) which was at par with the yield received with 0.8 Etc (LT) and 1.2 Etc (LT).

- Also at sriganganagar, the results revealed that the green, sun dry and oven dry forage yield and plant height of sorghum was influenced by the levels of irrigation significantly. The green forage yield of sorghum increased significantly with every increase in the level of irrigation water up to IW/CPE 0.9 (493.19 q/ha). Further increase in irrigation level increased in fodder yield but it was statistically not significant. Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum. The water expense efficiency (81.86 kg/ha mm) was higher in I_1 treatment (IW/CPE 0.5) followed by I_4 treatment (IW/CPE 1.1) as compared to rest of irrigation tre i.e., 0.6 IW/CPE ratio and 120cm raised bed atments tested in the study.

- At Belvatagi, land configuration with 120 cm raised bed showed significantly higher (pooled data) net income (5426 Rs / ha) when compared with the other 60 cm raised bed treatment (Rs 3,807 /ha) and normal sowing (Rs.4,747/ha). The interaction between Irrigation treatment 0.8 IW/CPE ratio and 120 cm raised bed configuration treatment recorded higher (pooled data) net income and on par with other treatments(Rs 5,076 / ha) and also with irrigation treatment 0.4 IW/CPE ratio and 120 cm raised bed (Rs 5,644 / ha). The B:C ratio on land configuration obtained a higher 2.82 in respect of 0.8 IW/CPE. This result was on par with the irrigation level 0.6 IW/CPE and 0.4 IW/CPE treatments. The interaction effect between irrigation treatment 0.8 IW/CPE ratio and normal bed configuration treatment recorded higher B:C ratio (1.5) with other treatments.

- At Bhavanisagar, the experiment revealed that drip irrigation at 80 per cent PE with 30 cm dripper spacing recorded higher rhizome yield of 10027 kg/ha. It was comparable with drip irrigation at 80 per cent PE with 60 cm dripper spacing. Among the different spacing studied, the spacing of 30 cm x 30 cm recorded higher rhizome yield of 9867 kg/ha and this was comparable with the spacing of 30 cm x 25 cm.
- At Bhavanisagar, In the cropping system experiment on "Evaluation of micro sprinkler irrigation and nutrient dynamics under green gram-groundnut-chillies based cropping system" indicated that optimum level of irrigation at 60 per cent once in three days through micro sprinkler in groundnut with 100 per cent recommended dose of fertilizer resulted in higher pod yield of 2482 kg/ha, WUE of 3.534 kg/ha.mm with a B:C ratio of 3.10.
- At Bilaspur, delaying irrigation up to 3 to 5 days after subsidence of ponded water can be considered to be the best water regime for paddy in clay-loam to clay soil as about 40 - 60 % of irrigation water can be saved without any loss in yield in comparison to continuous shallow submergence (± 5 cm ponded water).
- At Bilaspur, Soil moisture regimes significantly influenced the paddy yields. Continuous submergence produced significantly higher grain yield (52.22 q/ha) of paddy followed by irrigation at 1 DADPW and 3 DADPW. The significant difference in yield due to variable moisture regimes may be attributed mainly due to the temperature shock experienced during different physiological stages of the crop as a result of irrigation at 1 DADPW & 3 DADPW, which ultimately reflected in lower yields in these treatments.
- At Dapoli, the maximum plant height (5.4 m) was observed under I_3 (0.6 PE) as compared to all other treatment. The percent increase in plant height during the year was maximum in treatment I_3, whereas it was least in ring method of irrigation. The maximum stem girth (56.50 cm) was observed under I_3 (0.6 PE) as compared to all other treatments. Overall percent increase in the stem girth of arecanut was observed to be almost same in all incorporated treatments during last six months. Study resulted in the water saving of 81, 62.5 and 44 per cent, respectively in case of I_1, I_2, I_3 irrigation levels through drip irrigation over ring method of irrigation. The results clearly revealed that the early maturity of arecanut can be achieved with the application of water through drip irrigation as compared to the control (ring method) treatment.
- At Hissar, Irrigation applied at PE of 0.8 with drip produced highest seed cotton yield (2674 kg/ha) over flood and furrow methods irrigation. The water productivity of irrigation was highest when irrigations were applied through drip system at PE of 0.8 over other irrigation methods and schedules.
- At Hissar, use of wheat straw mulch either @ 4 or 6 t/ha resulted in significantly higher seed cotton yield over control, and the yield difference between mulching @ of 4 and 6 t/ha was not marked.
- At Jammu, the laser leveling improved the smoothness of land surface which is proved through leveling index and values of application efficiency (7.8%), distribution efficiency (18.8%) and storage efficiency (14.7%) over farmer leveled field in rice-wheat sequence. Laser leveling improved the yield by 20.4% in rice (Basmati) and 20.3% in wheat as compared to farmer leveled field. The experiment has been concluded with recommendations.
- At Jammu, it was found that SRI registered the WUE of the order of 1.60 kg/ha-mm as against the conventional practice which recorded 1.49 kg/ha-mm. The rice yield also improved by 7% with SRI as compared to traditional method of growing basmati rice.
- At Jorhat, Among for the *rabi* vegetables, brinjal, the optimum irrigation schedule was found to be 4cm depth of each irrigation at IW/CPE ratio 1.4 (18 days interval) requiring 4-5 irrigations against the farmers' practice of 10 days interval which required of irrigations of 3cm depth. The practice led considerable irrigation water savings (about 26 per cent) along with the yield increase of 23 per cent.
- At Jorhat, treadle pump use revealed that 89 mm twin barrel treadle pump of 100mm stroke for areas having water table within 5m. a discharge of 0.79 to 1.24 LPS is possible and each pump can command a minimum area of 0.25 ha per crop cycle for

vegetables and flowers. Benefit cost ratio adopting treadle pump is 5:1. The technology was recommended for the state.

- At Jorhat, the optimum schedule of irrigation for this crop had been found to be at IW/CPE ratio 1.2. Accordingly, four irrigations of 4 cm depth each at an interval of 20 days may be optimum for the crop. The practice led to considerable irrigation water saving (about 41 per cent) and yield increase (about 23 per cent)

- At Madurai, demonstrations conducted were, System of Rice Intensification, machine transplanting, integrated nutrient management, irrigation to 5 cm one day after disappearance ponded water, terminal water stress management, rotational water supply and drum seeding. The results under SRI indicated that there was an increase in grain yield ranging from 10.8 to 24.0% in all the technologies demonstrated as well as saving of water. The minimum water saving of 14.0 % was observed with irrigation to 5 cm depth one day after disappearance. The maximum water saving (29.1%) was observed with terminal water stress management and rotational water supply (27.0%) technologies. Invariably the yield levels recorded was higher ranging from 5650 to 6850 kg/ha/mm in the above demonstrations. Due to the improved water saving technologies the water use efficiency was higher ranging from 5.70 to 7.20 kg/ha/mm.

- Also at Madurai, the results of the experiment on evolving appropriate micro irrigation method, irrigation and fertigation regimes for groundnut revealed that micro sprinkler irrigation at 100% PE once in three days registered the maximum pod yield (2844 kg/ha), WUE (4.59 kg/ha/mm) and B:C ratio (2.36). Fertigation of 100% RDF (50% P and K as basal, balance NPK as WSF) once in a week from 15 to 90 DAS recorded the highest pod yield (2789 kg/ha) and WUE (4.55kg/ha/mm) in groundnut.

- Also at Madurai, with regard to land configuration, sowing groundnut in ridges and furrow was best suited for subsurface drip fertigation. Fertigation of 100% N and 50% P and K as WSF with an irrigation regime at 100% PEwas the best management to get higher yield (3616kg/ha) and B:C ratio (2.25), net return (Rs.64088/-) and water use efficiency (6.38kg/ha/mm) in groundnut

- At Navsari, Based on the results of yield and net income recorded during third year, it is concluded that planting of water melon in paired row with drip irrigation + mulching with either black plastic or silver black plastic is necessary for realizing higher net income. The magnitude of increase in fruit yield was 48 % with paired row, drip irrigation and mulching over control along with water saving of about 30 per cent.

- At Navsari, results revealed that with the adoption of drip irrigation@ 0.6 PEF + black plastic mulching could increase seed yield of pigeon pea to the extent of 70 per cent along with saving of water by about 48 per cent over conventional method of pigeon pea cultivation during *rabi* season.

- Also at Navsari, the results indicated that planting of drip irrigated castor (*rabi*) at a row spacing of 2.4 m and intra row spacing of 1.2 m along with fertigation @ 80 kg N/ha in eight equal splits at an interval of 10 days found to increase seed yield of castor by about 13 per cent along with enhancing WUE.

- At palampur, on mean basis, WUE of cauliflower-capsicum cropping sequence was 20.24 per cent higher in drip irrigation and fertigation than in recommended practices, due to 5.94 per cent higher capsicum equivalent yield (CEY) and 11.82 per cent lower TWU.

- Also at Palampur, **t**he B: C ratio (34.76 %) was significantly lower in brinjal crop grown under gravity fed drip irrigation with 75 per cent of recommended NPK fertigation than crop grown with recommended practices. Further, the brinjal crop grown with 75 per cent NPK fertigation under gravity fed drip irrigation resulted in significantly higher water use efficiency (54.04 %) due to lower irrigation water use (31.14 %) than recommended practices.

- At Pantnagar, In late sown wheat, under favourable weather condition wet bed method of crop establishment over moist bed and one additional irrigation at grain filling over irrigation till flowering showed significant effect on grain yield and water productivity. While, under harsh weather conditions, chemical spray at anthesis showed favorable effect to offset the adverse effect of terminal heat stress. The monetary advantages were highly linked to the grain yield. Foliar spray of 2% urea at anthesis stage was the most viable option for higher economic returns.

- Also at Pantnagar, for producing higher grain yield of transplanted rice, irrigation at 1 DADPW showed its superiority over the 3 and 5 DADPW treatments. Crop fertilized with 120 kg N/ha rerecorded significantly higher mean grain yield than 90 kg

N/ha. Among the crop establishment methods, flat planting produced higher grain yield than raised beds 40/25 and 80/25 treatments, but raised bed systems of rice transplanting had higher water productivity than the conventional flat method.

- At Rahuri, turmeric crop irrigated with 0.7 composite factor alongwith fertigation of water soluble fertilizer at 75% the recommended dose of fertilizer was found to have higher yield, growth attributes, water and fertilizer use efficiency with its saving further maintaining the soil health. The above treatments are at par with 0.9 CF and 100% RDF through conventional method of fertilization.

- Also at Rahuri, the drip irrigation at an alternate day as per ETc is found to be the best for yield, quality, water saving and efficiency, and storage studies followed by microsprinkler irrigation on alternate day as per ETc. Amongst the INM treatments, the 100% recommended dose of fertilizer (100:50:50 kg ha^{-1} NPK) alongwith 5 tonnes of FYM ha^{-1} was found to be the best with respect to yield, quality and storage studies followed by 100% recommended dose of fertilizers alongwith application of vermicompost on N basis of FYM. In view of the above, it can be concluded that drip irrigation on alternate day as per ETc and 100% RDF alongwith 5 tonnes of FYM ha^{-1} can be more suitable for growing onion to get higher yield, quality, water saving and WUE and storage.

- Under Mula Command, Bt. cotton yield increased by 9.78 to 15.28 per cent over control plot by scheduling of irrigation at 75 mm CPE and recommended dose of fertilizer. The WUE ranged from 27.18 to 31.22 kg/ha.cm which was higher than control plot.

- At Sriganganagar, On the basis of three years of experimentation, it was observed that the fruit yield of tomato increased significantly with increasing level of irrigation water only up to 0.8 Etc with low tunnel. Further increase in irrigation water did not increase the yield of tomato significantly. In pooled data, the maximum fruit yield of tomato (566.54 q/ha) was recorded with drip irrigation at 1.0 Etc (LT) which was at par with the yield received with 0.8 Etc (LT) and 1.2 Etc (LT).

- Also at sriganganagar, the results revealed that the green, sun dry and oven dry forage yield and plant height of sorghum was influenced by the levels of irrigation significantly. The green forage yield of sorghum increased significantly with every increase in the level of irrigation water up to IW/CPE 0.9 (493.19 q/ha). Further increase in irrigation level increased in fodder yield but it was statistically not significant. Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum. The water expense efficiency (81.86 kg/ha mm) was higher in I_1 treatment (IW/CPE 0.5) followed by I_4 treatment (IW/CPE 1.1) as compared to rest of irrigation treatments tested in the study.

Theme: I

Assessment of water availability at regional level and to devise intervention for matching water supply with agricultural production system demand

The centres of AICRP on Water Management continued research work under the theme of "*Assessment of water availability at region level and to devise interventions for matching water supply with the agricultural production system demand*" during the period of 2013-14. Selected studies were carried out to determine the regional availability of water in command area of distributories of major irrigation projects and interventions were devised to demonstrate technologies at farmers' field for reducing the water demand. Selected studies are presented below:

1.1 Belvatagi

The command area of 23rd block of Malaprabha Right Bank Canal at Hebsur village, Hubli taluka of Dharwad district is 221.88 ha with 13-R sub- distributaries and design discharges ranged from 0.0377 to 0.19 cumecs. The length of 13-R sub- distributaries is 4.15 Km. The designed ultimate potential of Malaprabha Project is 2, 20,000 ha. The potential created up to March, 2013 was 1, 93,588 ha (88% of ultimate potential created). Maximum rainfall received during 2013 was 801.9 mm as compared to normal rainfall of 555.4mm. The command received excess rainfall of 44.38 percent. The early onset of rainfall during April (31.8mm), more than normal during May (174.7mm), June (54.6 mm), July (42.6mm) , Aug (28.4mm) received during the *kharif* 2013. Hence, land preparation and *kharif* sowings activities were done in time by the Malaprabha command area farmers. This trend of rainfall continued during *rabi*-2013. Abnormal event of rainfall was recorded during September 2013 (360.1mm), Oct (107.2mm). During Nov and Dec, 2013 no rainfall received. The annual mean maximum and minimum temperature was recorded 33.50°C and 18.7°C respectively. During *Kharif* 2013, Maize was the dominant crop covering an area of 155.50 ha with 70.08 percent of the acreage. This was followed by cotton 41.0 ha and Onion 25.2 ha with 18.57 and 11.35 percent of the acreage. During *rabi* 2013 wheat was the dominant crop covering an area of 103.2 ha with 46.42 percent of the acreage. This was followed by Chickpea 70.50 ha and cotton 41.00 ha with 35.01 and 18.57 percent of the acreage. During 2013-14 periods the area remained less fallow (0.09 % & 3.24%) during *Kharif* and *rabi* due to the sufficient event of rains received for early sowing. The total amount of water required for maize (155.5 ha), cotton (41.0 ha) and onion (25.2 ha) crops for irrigation during *Kharif*-2013-14 was 73,292 m^3 (Table-1). Total effective rainfall received worked out was 75,390 m^3. Hence, the excess water supplied was worked out 2098 m^3. The current year (*Kharif*-2013-14) crop was noted that it was under satisfactory condition. During *rabi* 2013 the crops under observation were wheat (103), chickpea (70) and cotton (41). The total amount of water required for wheat (103), chickpea (70) and cotton (41) was worked out 59150.76 m^3. Net Canal supply was observed 47160.63 m^3. Total effective rainfall received worked out was 16357m^3. Hence, the excess water supplied was worked out 4366.87 m^3. The results revealed that, excess water applied during *Kharif* 2013 for the Maize crop was 3 percent, for cotton 1.6 percentages and for onion 2.9 percentage. During *rabi* 2013, the irrigation water supply was given by the farmers to wheat crop observed 2.56 percentage less and for chickpea it was observe 3.17 excess and cotton crop received 21 percent less. The production of the crops is under progress.

Table 1: Details of Byahatti Malaprabha Right Bank Canal during, *kharif* 2013-14

Sl. No	Crop.	Area (ha)	Irrigation (No)	Irrigation Method	*Quantity of water, cum*			
					Applied (rain fall)	Crop Water Demand	Excess (+) / Deficit (-)	Per cent Excess / deficit over recommended (%)
***Kharif* 2013-14**								
1.	Maize	155.32	--	-	52808.00	51225.96	+1582.04	+3.0
2.	Cotton	41.00	--	-	13953.91	13735.23	+218.68	+1.6
3.	Onion	25.20	--	--	8576.56	8332.27	+244.29	+2.9
	Total	**221.52**						
Rabi 2013-14								
1	Wheat	103	4	Boarder strip	32593	33451.12	-858.12	-2.56
2	Chick pea	70	2	Boarder strip	9550	9256.17	+294.10	+3.17
3	Cotton	41	4	Furrow	12974	16443.65	-3469.65	-21.0
	Total	**214**						

1.2Bhatinda

The Balluana minor of the Behman distributory of Bathinda branch was selected to evaluate irrigation system performance and to work out intervention for improvement of irrigation system and its management, improved and sustainable crop and water productivity. The Balluana minor takes off from the Behman distributory canal at 47918/R and have total length 10.804 km, which has cultivable command area (CCA) of about 6223.52 hectares covering Bathinda block of Bathinda district. The Balluana minor has 11 outlets in total with 24.63 cusec discharge. Out of 11 outlets in Balluana minor, 9 outlets (excluding 2 outlets i.e. 23925/R and 8200/L for Guruduara sahib and school respectively) are selected. The total running days of canal water was 147 days on each outlet with minimum 5718.4 ha-cm and maximum 9350.8 ha-cm at 35977/TR and 20170/L outlets, respectively during *Rabi* 2012-13. In *Rabi* Season, total 70.4 mm rainfall was received. The relative water supply (RWS) was less than one in all the outlets. It means water supply was less than demand in all the nine outlets. The water requirement was varying between 25990.8 and 42639.6 ha-cm, through rainfall and canal. In overall system RWS was 0.361. So, there is a need to replace large part of the area under wheat by barley, gram and *raya,* which require less water to match the water supply with water requirement during season at both outlets. In *Kharif* season, water requirement varied within 51596.6 and 84647.6 ha-cm. In overall system RWS was 0.648 and it was less than 1.0 which means demand is more than supply (Table-2). So there is need to either increase the supply of water or replacing high water requirement crops with low water requirement crops like cotton, *Guar* and *Bajra*.

Table I.9a: Relative water supply (RWS) during *Kharif,* 2013

Outlet No.	Canal water diverted (ha. cm)	Effective rainfall (ha. cm)	Total water supply (ha. cm)	Water Requirement (ha. cm)	RWS
3758/R	7422.9	35125.2	42548.1	65463.9	0.650
14025/L	6662.5	32054.1	38716.6	59740.2	0.648
14040/R	6409.0	30865.2	37274.2	57524.4	0.648
18163/R	6372.8	30625.9	36998.8	57078.5	0.648
20170/L	9414.4	45418.3	54832.8	84647.6	0.648
25000/L	7893.6	38142.0	46035.7	71086.5	0.648
26630/L	8762.7	42314.3	51076.9	78862.5	0.648
35977/TL	8871.3	42720.0	51591.2	79618.6	0.648
35977/TR	5757.3	27684.6	33441.8	51596.6	0.648
Total	67566.6	324949.5	392516.1	605618.9	0.648

Yield data of *Rabi 2012-13* and *Kharif-2013* from selected nine outlets of Balluana Minor under Behman Distributory is given in Table 3. Average grain yield of wheat, barley *and raya/sarson* recorded was 43.2 q/ha, 26.0 q/ha and 10.7 q/ha, respectively. Similarly, average seed cotton yield of Bt cotton hybrids and paddy yield recorded was 14.2 q/ha and 60.8 q/ha, respectively.

1.1 Chiplimia

Bargarh Distributary originating from the left of Bargarh Main Canal at 26.335 km RD was selected for water surplus-deficit analysis. The details of direct outlets, minors and sub-minors operating from the system are presented in Table 4. Department of Water Resources, Govt. of Odisha has proposed cropping pattern as per the water supply at different outlets for the season *rabi* 2013. The release of water from the canal and the adopted cropping pattern of the command area of individual minor/ sub-minor (including the direct outlets) during the *rabi* 2013 season were taken into account for the analysis.

Table 4. Details of outlets from the Bargarh Distributary System

Sl. No.	Name of Direct Outlets/ Minors/ Sub-Minors/	Discharge(cumec)	CCA(ha)	Reach
1	Bargarh Dist DO (Head)	1.358	1639.00	Head
2	Padhanpali Minor	0.917	1208.62	
3	Jamurda Sub Minor	0.275	347.43	
4	Barahgoda Sub Minor	0.244	262.07	
5	Amsada Sub Minor	0.237	321.09	
6	Tora Minor	0.266	339.81	
7	Dhanger Minor	0.380	532.61	
8	Bargarh Dist DO (Middle)	0.669	806.79	Middle
9	Malipali Minor	0.700	921.61	
10	Khandahata Sub Minor	0.390	553.92	
11	Argaon Minor	0.458	653.19	
12	Patrapali Minor	0.283	434.28	
13	Bargarh Dist DO (Tail)	1.770	2135.99	Tail
14	Talpali Minor	0.228	388.40	
15	Piplipali Minor	0.322	453.48	
16	Dekulba Minor	0.328	260.95	
17	Dekulba Sub Minor	0.346	555.29	
18	Jamdol Minor	0.222	351.47	
Total for the distributary		**9.393**	**12166.00**	

Deficit surplus analysis

The cropping pattern, water available and water demand under the command of each minor/ sub-minor of the Bargarh Distributary System is presented in table 5. Deficit status was observed for all the minors/ sub-minors of the distributary system at the head reach. Water is surplus at most of the minors located in the middle reach; whereas, mixed status was observed for the outlets in the tail reach. It is also observed that water deficit condition prevails in the distributary system as a whole, which is likely due to the deficit condition of all the outlets at the head reach. The water deficit is attributed because of selected cropping patterns in the command areas of the individual outlets.

Scenario – I

The optimal allocation of areas under different types of crops under this scenario for each outlet and the total system is presented in table 6. It can be observed from the table that, to maintain the optimality of water use (with no surplus or deficit), only about 66.5% of the total command area should be irrigated. However, there would be surplus water in the command area of Dekulba Minor even if the entire CCA is cultivated with heavy duty crops. This also indicates that the more water could be diverted to the Dekulba Sub-Minor or discharge in the Dekulba Minor could be reduced and the surplus water could be provided to the Jamdol Minor to increase the cultivated area under the later. Under this scenario only 10026.75 ha of the total command area of 12166 ha can be provided irrigation for the *rabi* season with average rate of net return of Rs 17,943/- per hectare of the irrigated area.

Scenario – II

The optimal allocation of areas under different types of crops under this scenario for each outlet and the total system is presented in table7. The results revealed that 100% of command area of the distributary can be irrigated, if the designed cropping pattern could be followed. This would ensure much more generation of employment of agricultural labourers than the other scenarios. However, similar to the first scenario, the use of irrigation water is not optimal for the Dekulba Minor. Though the total command area can be provided irrigation under this scenario, there would be reduced average rate of net return (Rs 16,426/-) per hectare of the irrigated area compared to the previous scenario.

Scenario – III

The optimal allocation of areas under different types of crops under this scenario for each outlet and the total system is presented in table 8. It is observed from the table that this scenario would give more net return than that of the first scenario, with provision of irrigation for 99.7% of the CCA. However, because of the constraint of 1/3rd area under heavy duty crops, the average rate of net return (Rs 16,365/-) per hectare of the irrigated area under this scenario is less than that of the second scenario.

Scenario – IV

The optimal allocation of areas under different types of crops under this scenario for each outlet and the total system is presented in table 9. The cropping patten under this scenario would give the maximum net agricultural return from the command area of the distributary with 100% land utilization and without any water deficit in any of the outlets. However, since no area is allocated for low duty crops, which includes pulses and oilseeds, this scenario may not be practicable.

The minor/ sub-minor/ outlet wise deficit-surplus analysis of canal water in the command area of Bargarh Distributary as per the suggested cropping pattern for *rabi* season of 2013 depicts that all the outlets are operating under sub-optimal conditions. As a measure of non-structural intervention, to minimize the demand-supply gap, optimal cropping pattern under four different scenarios for each outlet were determined. From the analysis of the scenarios the constraints of land and water availability are satisfied under all the scenarios except for the Dekulba Minor, which is water surplus. Hence, all the outlets of the distributary can be operated optimally with the adoption of the designed cropping pattern in the command areas of the individual outlets except for the Dekulba Minor. The optimal cropping pattern, suggested under Scenario I, is only 2/3rd of the CCA to be irrigated during the season, which may not be practicable in the field. Under Scenario – II, the entire CCA of the distributary can be used for cultivation with the designed cropping pattern assuring higher net return. Though the net return per unit area under this scenario is about 8.5% less than that of Scenario – I, it would generate more employment for the agricultural labourers. Restricting 1/3rd of the CCA for cultivation of heavy duty crops in Scenario – III, decrease the net benefit, net benefit per unit area and land utilization marginally compared to those of Scenario – II. The optimal cropping pattern for maximization of net benefit under Scenario – IV suggests allocation of 1/3rd and 2/3rd of the CCA under heavy and medium duty crops with no allocation for light duty crops. This again may not be advisable for the command area from the self-sufficiency point of view. Hence, it can be concluded that the cropping pattern obtained under Scenario – II may be adopted for the command area of the distributary for optimal land and water utilization, and generation of requisite employment. However, if the affinity of the farmers towards heavy duty crop cannot be avoided then Scenario – III can be adopted.

ario – III, decrease the net benefit, net benefit per unit area and land utilization marginally compared to those of Scenario – II. The optimal cropping pattern for maximization of net benefit under Scenario – IV suggests allocation of 1/3rd and 2/3rd of the CCA under heavy and medium duty crops with no allocation for light duty crops. This again may not be advisable for the command area from the self-sufficiency point of view. Hence, it can be concluded that the cropping pattern obtained under Scenario – II may be adopted for the command area of the distributary for optimal land and water utilization, and generation of requisite employment. However, if the affinity of the farmers towards heavy duty crop cannot be avoided then Scenario – III can be adopted.

Table 5. Deficit surplus analysis of the Bargarh Distribut ary System

Sl. No.	Name of Minor	CCA (ha)	Cropping Pattern (ha) *Rabi* 2013				Water Req. (ha-cm)	Water Av. (ha-cm)	Status
			Heavy	Medium	Low	Total			
1	Bargarh Dist DO (Head)	1639.00	1225.02	230.14	92.77	1547.93	136792	117331	Deficit
2	Padhanpali Minor	1208.62	784.00	299.00	58.00	1141.00	95090	79229	Deficit
3	Jamurda Sub Minor	347.43	257.40	10.00	40.00	307.40	27440	23760	Deficit
4	Barahgoda Sub Minor	262.07	166.50	95.00	0.00	261.50	21400	21082	Deficit
5	Amsada Sub Minor	321.09	270.90	35.00	14.00	319.90	29260	20477	Deficit

6	Tora Minor	339.81	307.90	21.00	0.00	328.90	31840	22982	Deficit
7	Dhanger Minor	532.61	426.10	87.00	16.00	529.10	47440	32832	Deficit
	Head	**4650.63**	**3437.82**	**777.14**	**220.77**	**4435.73**	**389262**	**317693**	**Deficit**
8	Bargarh Dist DO (Middle)	806.79	403.42	121.03	80.67	605.12	48814	57802	Surplus
9	Malipali Minor	921.61	460.83	138.22	92.16	691.21	55759	60480	Surplus
10	Khandahata Sub Minor	553.92	276.96	83.08	55.39	415.43	33512	33696	Surplus
11	Argaon Minor	653.19	326.59	97.98	65.31	489.88	39517	39571	Surplus
12	Patrapali Minor	434.28	217.15	65.12	43.43	325.70	26274	24451	Deficit
	Middle	**3369.79**	**1684.95**	**505.43**	**336.96**	**2527.34**	**203875**	**216000**	**Surplus**
13	Bargarh Dist DO (Tail)	2135.99	1068.00	320.42	213.59	1602.01	129229	152928	Surplus
14	Talpali Minor	388.40	194.20	58.27	38.83	291.30	23498	19699	Deficit
15	Piplipali Minor	453.48	226.75	68.02	45.33	340.10	27436	27821	Surplus
16	Dekulba Minor	260.95	130.47	39.14	26.09	195.70	15787	28339	Surplus
17	Dekulba Sub Minor	555.29	277.65	83.30	55.52	416.47	33596	29894	Deficit
18	Jamdol Minor	351.47	175.74	52.71	35.15	263.60	21264	19181	Deficit
	Tail	**4145.58**	**2072.81**	**621.86**	**414.51**	**3109.18**	**250809**	**277862**	**Surplus**
	Total	**12166.00**	**7195.58**	**1904.43**	**972.24**	**10072.25**	**843947**	**811555**	**Deficit**

Table 6. Optimal allocation of land for different crop types under Scenario – I

Sl. No.	Name of Minor	CCA (ha)	Cropping Pattern (ha)				WA (ha-cm)	WR (ha-cm)	Surplus/ Deficit	Net Return (Rs)	NR/ ha (Rs/ ha)
			Heavy	Medium	Low	Total					
1	Bargarh Dist DO (Head)	1639.00	1027.72	162.47	214.51	1404.71	117331	117331	0	25565683	18200
2	Padhanpali Minor	1208.62	665.63	239.82	22.49	927.94	79229	79229	0	17179781	18514
3	Jamurda Sub Minor	347.43	225.96	4.95	30.57	261.47	23760	23760	0	4960129	18970
4	Barahgoda Sub Minor	262.07	163.95	93.73	0.00	257.68	21082	21082	0	4684952	18181
5	Amsada Sub Minor	321.09	200.35	5.17	6.10	211.63	20477	20477	0	4157862	19647
6	Tora Minor	339.81	161.29	120.64	27.39	309.32	22982	22982	0	5364012	17342
7	Dhanger Minor	532.61	236.06	118.03	110.82	464.91	32832	32832	0	7821457	16824
8	Bargarh Dist DO (Middle)	806.79	470.49	154.57	100.79	725.85	57802	57802	0	12937911	17824
9	Malipali Minor	921.61	496.06	155.84	102.73	754.63	60480	60480	0	13491561	17878
10	Khandahata Sub Minor	553.92	278.34	83.77	55.80	417.91	33696	33696	0	7492854	17930
11	Argaon Minor	653.19	326.99	98.18	65.43	490.60	39571	39571	0	8797730	17932
12	Patrapali Minor	434.28	203.55	58.32	39.35	301.22	24451	24451	0	5417930	17987
13	Bargarh Dist DO (Tail)	2135.99	1244.86	408.85	266.65	1920.36	152928	152928	0	34229740	17825
14	Talpali Minor	388.40	165.85	44.09	30.32	240.27	19699	19699	0	4342255	18073
15	Piplipali Minor	453.48	229.62	69.46	46.19	345.27	27821	27821	0	6188591	17924
16	Dekulba Minor	260.95	260.95	0.00	0.00	260.95	28339	26095	2244	5218964	20000
17	Dekulba Sub Minor	555.29	198.91	129.46	117.67	446.04	29894	29894	0	7332208	16438
18	Jamdol Minor	351.47	120.01	110.00	56.00	286.01	19181	19181	0	4722186	16511
	Total	**12166.00**	**6676.59**	**2057.34**	**1292.82**	**10026.75**	**811555**	**809311**	**2244**	**179905807**	**17943**

Table 7. Optimal allocation of land for different crop types under Scenario – II

Sl. No.	Name of Minor	CCA (ha)	Cropping Pattern (ha)				WA (ha-cm)	WR (ha-cm)	Surplus/ Deficit	Net Return (Rs)	NR/ ha (Rs/ ha)
			Heavy	Medium	Low	Total					
1	Bargarh Dist DO (Head)	1639.00	897.00	268.57	473.44	1639.00	117331	117331	0	27649713	16870
2	Padhanpali Minor	1208.62	387.67	791.66	29.28	1208.62	79229	79229	0	19979746	16531
3	Jamurda Sub Minor	347.43	188.47	7.21	151.74	347.43	23760	23760	0	5698516	16402
4	Barahgoda Sub Minor	262.07	188.85	0.00	73.22	262.07	21082	21082	0	4655640	17765
5	Amsada Sub Minor	321.09	117.95	129.38	73.77	321.09	20477	20477	0	5184851	16147
6	Tora Minor	339.81	152.18	106.76	80.86	339.81	22982	22982	0	5615485	16525
7	Dhanger Minor	532.61	175.08	229.90	127.63	532.61	32832	32832	0	8481699	15925
8	Bargarh Dist DO (Middle)	806.79	412.49	236.19	158.12	806.79	57802	57802	0	13689971	16968
9	Malipali Minor	921.61	383.47	299.45	238.69	921.61	60480	60480	0	15025416	16303
10	Khandahata Sub Minor	553.92	188.50	194.17	171.25	553.92	33696	33696	0	8737562	15774
11	Argaon Minor	653.19	219.70	229.84	203.65	653.19	39571	39571	0	10285330	15746
12	Patrapali Minor	434.28	116.69	162.74	154.85	434.28	24451	24451	0	6633064	15274
13	Bargarh Dist DO (Tail)	2135.99	1090.44	625.85	419.69	2135.99	152928	152928	0	36233037	16963
14	Talpali Minor	388.40	70.06	157.14	161.19	388.40	19699	19699	0	5692692	14657
15	Piplipali Minor	453.48	158.03	157.71	137.74	453.48	27821	27821	0	7179140	15831
16	Dekulba Minor	260.95	260.95	0.00	0.00	260.95	28339	26095	2244	5218964	20000
17	Dekulba Sub Minor	555.29	127.53	215.41	212.34	555.29	29894	29894	0	8330003	15001
18	Jamdol Minor	351.47	84.82	134.96	131.69	351.47	19181	19181	0	5301087	15083
	Total	**12166.00**	**5219.89**	**3946.94**	**2999.17**	**12166.00**	**811555**	**809311**	**2244**	**199591915**	**16406**

Table 8. Optimal allocation of land for different crop types under Scenario – III

Sl. No.	Name of Minor	CCA (ha)	Cropping Pattern (ha)				WA (ha-cm)	WR (ha-cm)	Surplus/ Deficit	Net Return (Rs)	NR/ ha (Rs/ ha)
			Heavy	Medium	Low	Total					
1	Bargarh Dist DO (Head)	1639.00	854.30	417.99	366.71	1639.00	117331	117331	0	27756441	16935
2	Padhanpali Minor	1208.62	511.72	357.50	339.40	1208.62	79229	79229	0	19669632	16275
3	Jamurda Sub Minor	347.43	163.08	96.09	88.26	347.43	23760	23760	0	5762002	16585
4	Barahgoda Sub Minor	262.07	174.24	51.12	36.70	262.07	21082	21082	0	4692159	17904
5	Amsada Sub Minor	321.09	126.68	98.82	95.59	321.09	20477	20477	0	5163029	16079
6	Tora Minor	339.81	155.34	95.72	88.75	339.81	22982	22982	0	5607597	16502
7	Dhanger Minor	532.61	191.74	171.60	169.27	532.61	32832	32832	0	8440056	15847
8	Bargarh Dist DO (Middle)	806.79	421.27	205.43	180.09	806.79	57802	57802	0	13668002	16941
9	Malipali Minor	921.61	391.26	272.16	258.19	921.61	60480	60480	0	15005920	16282
10	Khandahata Sub Minor	553.92	192.12	181.51	180.30	553.92	33696	33696	0	8728513	15758
11	Argaon Minor	653.19	223.90	215.13	214.15	653.19	39571	39571	0	10274833	15730
12	Patrapali Minor	434.28	154.39	30.76	249.13	434.28	24451	24451	0	6538791	15057
13	Bargarh Dist DO (Tail)	2135.99	1113.66	544.62	477.72	2135.99	152928	152928	0	36175001	16936
14	Talpali Minor	388.40	129.47	0.00	225.09	354.55	19699	19699	0	5290374	14921
15	Piplipali Minor	453.48	161.09	147.00	145.39	453.48	27821	27821	0	7171494	15814
16	Dekulba Minor	260.95	260.95	0.00	0.00	260.95	28339	26095	2244	5218964	20000
17	Dekulba Sub Minor	555.29	189.08	0.00	366.21	555.29	29894	29894	0	8176136	14724
18	Jamdol Minor	351.47	123.38	0.00	228.09	351.47	19181	19181	0	5204687	14808
	Total	**12166.00**	**5537.67**	**2885.45**	**3709.04**	**12132.16**	**811555**	**809311**	**2244**	**198543630**	**16365**

Table 9 Optimal allocation of land for different crop types under Scenario – IV

Sl. No.	Name of Minor	CCA (ha)	Cropping Pattern (ha)				WA (ha-cm)	WR (ha-cm)	Surplus/ Deficit	Net Return (Rs)	NR/ ha (Rs/ ha)
			Heavy	Medium	Low	Total					
1	Bargarh Dist DO (Head)	1639.00	707.62	931.38	0.00	1639.00	117331	117331	0	28123150	17159
2	Padhanpali Minor	1208.62	375.96	832.65	0.00	1208.62	79229	79229	0	20009030	16555
3	Jamurda Sub Minor	347.43	127.77	219.65	0.00	347.43	23760	23760	0	5850260	16839
4	Barahgoda Sub Minor	262.07	159.56	102.51	0.00	262.07	21082	21082	0	4728860	18044
5	Amsada Sub Minor	321.09	88.44	232.65	0.00	321.09	20477	20477	0	5258620	16377
6	Tora Minor	339.81	119.84	219.97	0.00	339.81	22982	22982	0	5696350	16763
7	Dhanger Minor	532.61	124.03	408.59	0.00	532.61	32832	32832	0	8609330	16164
8	Bargarh Dist DO (Middle)	806.79	349.24	457.55	0.00	806.79	57802	57802	0	13848090	17164
9	Malipali Minor	921.61	287.99	633.62	0.00	921.61	60480	60480	0	15264110	16562
10	Khandahata Sub Minor	553.92	120.00	433.92	0.00	553.92	33696	33696	0	8908810	16083
11	Argaon Minor	653.19	138.24	514.95	0.00	653.19	39571	39571	0	10488980	16058
12	Patrapali Minor	434.28	54.74	379.53	0.00	434.28	24451	24451	0	6787912	15630
13	Bargarh Dist DO (Tail)	2135.99	922.57	1213.43	0.00	2135.99	152928	152928	0	36652731	17160
14	Talpali Minor	388.40	5.59	382.81	0.00	388.40	19699	19699	0	5853884	15072
15	Piplipali Minor	453.48	102.94	350.54	0.00	453.48	27821	27821	0	7316881	16135
16	Dekulba Minor	260.95	260.95	0.00	0.00	260.95	28339	26095	2244	5218964	20000
17	Dekulba Sub Minor	555.29	42.60	512.69	0.00	555.29	29894	29894	0	8542345	15384
18	Jamdol Minor	351.47	32.15	319.32	0.00	351.47	19181	19181	0	5432775	15457
	Total	**12166.00**	**4020.22**	**8145.78**	**0.00**	**12166.00**	**811555**	**809311**	**2244**	**202591082**	**16652**

1.4 Jammu

The Ranbir canal falling within Jammu district has insignificant contribution during *rabi* crop (wheat). It is concluded that canal command is totally rain dependent, when rainfall events during *rabi* 2012-13 were uniform and 48.4% more than *rabi* 2011-12, the corresponding area coverage having NDVI of 0.3 to 0.5 is 134% higher during *Rabi* 2012-13 as compared to *Rabi* 2011-12. Normalized difference vegetation index of 0.0 to 0.1 indicating no vegetation shows 794% times less vegetation during *rabi* 2011-12 as compared to *rabi* 2012-13 during which rainfall were 48.4% higher than year 2011-12. The overall estimated production of wheat having NDVI value of 0.3 to 0.5 is in the range of 4718 MT during *rabi* 2012-13 as compared to 2011.6 MT during *Rabi* 2011-12 which has a huge economic bearing on the wheat growing farmers of the Ranbir canal command. The study identifies problematic pocket of Ranbir canal command area during *Rabi* period from middle to tail end of the identified canal system from distributaries (D-10 to D-17) which has maximum command area in the NDVI value range of 0.0 to 0.1 during *rabi* 2011-12 as compared to *rabi* 2012 -13 having NDVI value of 0.2 to 0.5 when rainfall was 48.4% higher than 2011. In comparison to this crop condition for head reach of canal system from distributaries (D-1 to D-9) is having NDVI value range of 0.2 to 0.3 and 0.3 to 0.5 for both years of the study *rabi* 2011-12 and *rabi* 2012-13 irrespective of rainfall pattern. This is mainly due to residual moisture impact of adequate supplies of irrigation during *kharif* period in this segment of command area and is giving optimum performance during *rabi* period. The stake holders need to explore ground water potential available in the range of 8.0 to 10.0 meters within middle and tail reaches i.e distributaries (D-10 to D-17) of Ranbir canal system to augment irrigation supplies for sustainable and assured wheat crop production within the middle and tail reaches of canal system / study area.

1.5 Kota

For the Manasgaon distributary, monthly canal running days, water released, relative water supply and water availability at field level, for both Rabi and Kharif season during year 2012–13, are shown in table 2 & 3. The water supplied in the distributary during the month of February was maximum (13537.15 ha cm) and minimum in January (7807.27 ha cm). The relative water supply was maximum in December (62.36%), whereas in January with 20 days canal running it was minimum (39.89%). The canal water availability at field level during Rabi 2012-13 was 33004.99 ha cm and during *kharif* 2013 it was nil.

Table 11: Details of Manasgaon distributary

Month	Running days	Water re leased (ha. cm)		Relative water supply %	Water availability at field level (ha cm)
		Designed	Actual		
November,12	21	20551.23	12447.20	60.57	7468.32
December,12	22	21529.86	13425.58	62.36	8055.35
January,13	20	19572.60	7807.27	39.89	4684.36
Februar y,13	24	23487.12	13537.15	57.64	8122.29
March,13	17	16636.71	7791.12	46.83	4674.67

In *rabi* the total sown area was 1077.17 ha, out of which wheat and mustard occupied maximum area. Similarly in *kharif* the total sown area was 1004.57 ha, out of which soybean and paddy were grown in the major area. The total water requirement of the area was calculated based on the total irrigation water, farmers applied for a particular crop and then by adding the quantity of irrigation water applied to all the crops. In Rabi wheat, garlic and vegetables consumed most of the water while in *Kharif* paddy and vegetables. The season wise water availability at field level through canal as well as water requirement of the crops were worked out and given in table 12. The total water deficit of 9122.16 and surplus of 17508.2 ha cm was observed during Rabi and *Kharif* seasons, respectively.

Table 12: Availability, requirement and deficit of water at field level, Manasgaon distributary (2012-13)

Crop season	Available water (ha cm)	Rain (ha cm)	Requirement (ha cm)	Deficit / Surplus in water supply (ha cm)
Rabi	33004.99	-	42127.15	-9122.16
Kharif	-	70680.00	53171.8	17508.2

1.4 Sriganganagar

The Khetawali distributory (KWD) has been selected for undertaking the studies to evaluate irrigation system performance and to work out intervention for improvement of irrigation system and its management, improved and sustainable productivity and for equitable economic growth. The distributory takes off from the main Indira Gandhi Canal at 60.45 RD left, which has cultivable command area of about 3702 hectares at Rawatsar tehsil in Hanumangarh district. The distributory has two minors namely Khetawali minor and Amarpura minor with total 24 outlets.

Out of 24 outlets in Khetawali distributory system, 16 outlets are in Khetawali distributory itself, 6 outlets are in Khetawali minor and 2 outlets are in Amarpura minor. Position of off takes of Khetawali distributory (KWD), Khetawali minor (KWM) and Amarpura minor (ARM) are 60.45 RD left of main canal, 2 RD Right of KWD and 22.37 RD left of KWD, respectively. The design discharge of Khetawali distributory system, KWM and ARM are 65.52, 17.02 and 4.0 cusec, respectively. Total length of KWD system is 22341.84 m. During *Kharif* 2013 the canal run for 113 days and total water release was 183464.67 ha.cm

The flow in KWD, KWM & APM systems of Khetawali distributor during *rabi* 2012-13 was recorded as 72 cusec, 14.9 cusec and 2.5 cusec, respectively. The flow was almost constant during entire *rabi* season. The area covered by wheat crop was the maximum in the distributory, followed by mustard and barley. Some area under fodder and gram was also recorded. The relative water supply has been found low (0.83). There is need to replace part of the area under wheat by mustard or barley in order to match water supply with water requirement during season in all the irrigation systems.

Table 13: Temporal release of water in distributory command during Kharif 2013

Months	Weeks	Days	Total Q-12 KWD (cusec)	Q (cusec)		Water Release, ha cm		
				KWM	APM	KWD	KWM	APM
1	2	3	4	5	6	(7) = [(3)x {4-(5+6)}] x 24.46848	(8) = [(3x5)] x 24.46848	(9) = (3x6)] x 24.46848
April, 2013	01-02	2	72	14.9	2.5	2671.96	729.16	122.34
	13-26	14	50	7.69	2.0	13808.54	2634.28	685.12
May, 2013	26-31	6	72	14.9	2.5	8015.87	2187.48	367.03
June, 2013	01-11	11	72	14.9	2.5	14695.77	4010.38	672.88
	19-28	10	72	14.9	2.5	13359.79	3645.80	611.71
	30-30	1	72	14.9	2.5	1335.98	364.58	61.17
July, 2013	01-31	31	72	14.9	2.5	41415.35	11301.99	1896.31
August, 2013	01-05	5	72	14.9	2.5	6679.90	1822.90	305.86
	06-20	7	50	7.69	2.0	6904.27	1317.14	342.56
	24-28	5	50	7.69	2.0	4931.62	940.81	244.68
	29-31	3	72	14.9	2.5	4007.94	1093.74	183.51
September, 2013	01-04	4	72	14.9	2.5	5343.92	1458.32	244.68
	10-11	2	72	14.9	2.5	2671.96	729.16	122.34
	13-21	9	72	14.9	2.5	12023.81	3281.22	550.54
	28-30	3	50.	7.69	2.0	2958.97	564.49	146.81
Total		113				140825.65	36081.47	6557.55

Table 14- Relative water supply (RWS) during Rabi 2012-13

Name of system	Canal water diverted (ha.cm)	Water available at field(ha. cm)	Effective Rainfall(ha.cm)	Total watersupply(ha.cm)	Water Req. (ha. cm)	RWS
KWD	132261.93	81975.94	20200.8	102176.74	131727.5	0.78
KWM	36093.42	23222.50	5798.8	29021.3	38752.5	0.75
APM	6055.94	4016.90	790.4	4807.3	4992.5	0.96
Total	174411.29	109215.34	26790	136005.3	175472.5	0.83

Table 15 – Relative water supply (RWS) during *Kharif* 2013

Name of system	Canal water diverted (ha. cm)	Water available at field (ha. cm)	Effective rainfall (ha. cm)	Total water supply (ha. cm)	Water requirement (ha. cm)	RWS
***Kharif* 2013**						
KWD	144591	89617.5	75307.1	164924.6	144591	1.14
KWM	43207	27799.4	22380.3	50179.7	43207	1.16
APM	3908.5	2591.8	2517.4	5109.2	3908.5	1.31
Total system	191706.5	120008.7	100204.8	220213.5	191706.5	1.15

The overall relative water supply during *kharif* was sufficient (1.15). Some of the area under cotton has already been shifted to guar. This was the reason that water supply matched with water requirement during *kharif* 2013.

Theme II

Design and evaluation of gravity and pressurized irrigation system under varying agro-ecological systems

2.1 Bathinda

Evaluation of drip irrigation system in vegetable crops using brackish waste was carried out at Bathinda .The results revealed that maximum curd yield (221.4 q/ha) and average curd weight (825 gm) was obtained in CW (canal water treatment). Maximum water expense efficiency (WEE) was in CW treatment followed by 1 CW: 2 TW and lowest in TW treatment in Cauliflower.

Table 2.1.1. : Effect of different qualities of water on yield, yield attributing characteristics and water expense and water expense efficiency of cauliflower

Treatments	Profile water use (cm)	WE (cm)	Curd yield (q/ha)	WEE (q ha^{-1} cm^{-1})	Average curd wt. (gm)
CW	4.27	22.87	221.4	9.7	825
1 CW:1 TW	5.13	23.73	214.2	9.0	810
1 CW:2 TW	3.93	22.53	206.5	9.2	778
1 CW:3 TW	4.68	23.28	202.4	8.7	736
TW	5.32	23.92	195.7	8.2	764
CD @ 5%			NS		NS

Cw = Canal water, Tw= Tubewell water: 1, 2, 3 proportion of water

In cucumber, the maximum yield (173.0 q/ha) was obtained in CW (canal water) treatment and is significantly higher than TW (tubewell water) treatment. Maximum water expense efficiency (WEE) was in CW treatment followed by 1 CW: 1 TW and lowest in TW treatment.

Table 2.1.2: Effect of different qualities of water on yield, yield attributing characteristics and water expense and water expense efficiency of cucumber

Treatments	Profile water use (cm)	WE (cm)	Yield q/ha	WEE (q ha^{-1} cm^{-1})
CW	8.36	57.56	173.0	3.0
1 CW:1 TW	9.59	58.79	167.4	2.8
1 CW:2 TW	8.17	57.37	152.8	2.7
1 CW:3 TW	10.84	60.04	161.5	2.7
TW	9.62	58.82	142.7	2.4
CD @ 5%			19.8	

Cw = Canal water, Tw= Tubewell water: 1, 2, 3 proportion of water

2.1Chalakudi

Comparative study of drip method of irrigation on soil water status, growth and yield of coconut showed that nut yield of coconut was not significantly influenced by Irrigation at different levels. This may be due to well distributed high rainfall received during the growth period. However basin irrigation at 50 mm CPE recorded the highest yield followed by drip irrigation at 100%PE. Water use efficiency was found significantly higher for drip at 50% PE compared to all other treatments. Compared to basin irrigation, WUE was almost 70% higher for this treatment. Other observations were found non significant.The soil moisture variation in different treatments was studied at different distances and different depths from tree trunk. It was observed that Basin irrigation at 50mm CPE and drip irrigation @ 100% PE recorded maximum moisture content compared to all other treatments at deeper layers. Rainfed control could maintain a moisture status compared to Irrigation at 50% PE at all depths and distances. The pooled data from 2007 to 2012 and is presented in Table.1.

Treatment	Yield (nuts/plant/year)	Bunches / year	WUE (nuts/m^3 water)	B:C ratio
I_0 – Rainfed control	40	5.832	-	1.236
I_1 – Drip irrigation at 50% pan evaporation	42	6.375	10.15	1.175
I_2 – Drip irrigation at 75% pan evaporation	37	6.000	5.97	1.01
I_3 – Drip irrigation at 100% pan evaporation	46	6.283	5.52	1.253
I_4 – Basin irrigation at 50 mm CPE	48	7.250	5.98	1.13
CD (5%)	NS	NS	2.154	NS

2.2.2 Designing low cost organic fertigation system for homestead vegetable production

Designed and fabricated a fertigation unit for organic fertigation. The filtering mechanism which is the most difficult part in organic ferigation was standardised. It was found successful in filtering cowdung solution (1 kg cowdung in 30 litres of water and kept for 12 hrs. for settlement). The filtrate was then passed through different micro irrigation devices without any clogging problems. The organic filtrate was tested for quality parameters and compared with original manure solution. Nutrient levels were found comparable with that in original. Discharge rate of filtrate through different micro irrigation devices were also recorded. Data are presented in tables below.

Table 2.2.2: Discharge rate through different systems:

Micro irrigation systems	**Average values for discharge (ml in 5 minutes)**	
	Water	**Filtrate of fresh cowdung**
Dripper	904	838
Micro sprinkler	2203	2031
Mist	4422	4416

The discharge in organic filtrate was found as good as that of irrigation. All the micro irrigation systems were successfully operated without clogging with organic filtrate.The organic filtration unit has confirmed the feasibility of efficiently filtering organic manure solutions. The study also revealed that organic filtrates could be passed through micro irrigation systems and confirms the feasibility of the concept – Organic fertigation.

2.2.3 Minimising irrigation and fertigation through inline drippers

Statistical analysis of the data on yield showed significant influence only on installation of irrigation devices at different depth and placement of irrigation devices at 15 cm below surface level showed significant influence on yield compared to surface application. With respect to interaction both conventional and soluble fertilizers performed better under subsurface application. Initial soil pH of the experimental area was 4.88. Significant difference was observed in soil pH due to application of different types of fertilizers and mulches. Application of soluble fertilizer resulted in reduction of soil pH.

Table 2.2.3 :Yield, soil pH and soil moisture content as influenced by different treatments

Treatment	Yield (t/ha)	Final soil ph	Soil moisture content at 5 cm depth (%)
T_1 (conventional +below ground+leaf mulch)	17.67	4.707	15.567
T_2 (conventional +below ground+coir pith mulch)	20.20	4.710	10.100
T_3 (conventional +below ground+ without mulch)	19.69	4.560	9.257
T_4 (conventional +above ground+leaf mulch)	15.79	4.687	11.653
T_5 (conventional +above ground +coir pith mulch)	12.77	4.220	12.157
T_6 (conventional +above ground+ without mulch)	15.76	4.813	14.087
T_7 (soluble+below ground+leaf mulch)	18.90	4.660	9.020
T_8 (soluble+below ground+coir pith mulch)	21.91	4.390	11.137
T_9 soluble +below ground+ without mulch)	19.80	4.683	12.710
T_{10} (soluble+above ground+leaf mulch)	12.86	4.510	13.793
T_{11}(soluble+above ground+coir pith mulch)	16.04	4.367	11.850
T_{12} (soluble+above ground+without mulch)	13.01	4.243	12.960
CD (5%)	5.832	0.5742	4.734

2.3 Dapoli

To study the comparative performance of irrigation methods and levels of irrigation on growth and yield of Arecanut plantation

In this study the total amount of water applied per plant under treatment I_1 (0.2PE), I_2 (0.4PE), I_3(0.6PE) was 197, 393, 590 litres, while 1050 mm water was applied in case of control treatment (ring method). It resulted in the water saving of 81, 62.5 and 44 per cent, respectively in case of I_1, I_2, I_3 irrigation levels through drip irrigation over surface irrigation. The total evaporation during the study period was 982 mm. The monthly growth parameters i.e. plant height and stem girth of arecanut were recorded maximum under drip irrigation system and it increased with increasing water application. The yield of arecanut was recorded and is given in Table 2.1.6. The data reveals that the early maturity of arecanut can be achieved with the application of water through drip irrigation as compared to the control (ring method) treatment.

Table 2.3.1 : Yield of Arecanut during the year 2012-13

Treatments	**Arecanut yield**	
Drip Irrigation	**Number of nuts per plant**	**Weight of nuts kg per plant**
I_1	35	1.92
I_2	45	2.47
I_3	100	**5.5**
Control (ring method)	Nil	

Effect of irrigation and fertigation on yield and quality Parameters of Aonla (*Amblica officinalis* Gutn) Cv.NA-7 under drip irrigation system

Results revealed that total amount of water applied to Aonla crop under treatment I_1, I_2 and I_3 were 393, 314.3 and 235.7 mm, respectively. It resulted in water saving of 20% and 40% in I_2 and I_3 treatments respectively over I_1 treatment. The total evaporation during the study period was 982.4 mm.The treatment I_2 (80% ET_{crop} through drip) has shown the maximum plant height (3.42 m) at 100% RDF through drip irrigation. The treatment combination I_2F_1 has shown highest height of 3.81 m and yield (4.65 kg/plant) over other treatments. Irrigation increased yield of aonla crop by about 150%, fertigation increased the yield by 142% and I_2F_1 yield was more by 210% as compared to no irrigation. The results indicated that even though aonla is treated as rainfed crop, it responds very well to irrigation and fertigation. The highest water use efficiency (WUE) of 30.19 kg/ha-cm was observed in I_2F_1 treatment followed by 28.2 kg/ha-cm in I_3F_1 treatment and minimum water use efficiency (15.50 kg/ha-cm) was found in I_1F_1 treatment.

Table 2.3..2. Effect of irrigation and fertilizer levels on yield of Aonla (kg/plant) during year 2012-13

Treatments	Yield Aonla (kg/plant)			
	I_1	I_2	I_3	Mean
F_1	3.0	4.65	3.25	3.63
F_2	3.08	4.0	2.83	3.31
F_3	2.42	2.58	2.5	2.50
Mean	2.83	3.74	2.86	
	I	F	I x F	
SE (m)±	0.07	0.13	0.22	
C.D. at 5%	0.27	0.40	0.87	
Control				1.50

Performance evaluation of cucumber (Cucumis sativum) to deficit irrigation under drip irrigation system

The results revealed that Cucumber produced significantly higher yield when it was irrigated through drip irrigation with no stress and water saving was observed to the tune of 34.6% as compared to furrow irrigation (control treatment). Major critical stage to deficit irrigation was observed to be 60 and above DAS during which the fruiting stage falls. It was obvious, because more water is required for development of cucumber fruits as it contains more than 80% water. When cucumber was irrigated at 20% water deficit during all growth stages it resulted in reduction in yield ranging from 24.9% to 28.5%, while it increased in the range of 39.8 to 44.6% for 40% water deficit and it was in the range of 49.9 to 55.9% while cucumber was irrigated with 60% water deficit during its different growth stages, when compared to the yield of no stress condition. Whereas the water saving as compared to no stress condition was in the range of 1.4% to 8.8% for 20% water deficit, 2.8% to 8.5% for 40% water deficit and 4.2% to 26.5% for 60% water deficit.

Treatments	Cucumber yield (t/ha)	Depth of water applied (mm)	Water saving over control (%)	Water use ef ficiency (kg/ha-mm)
T_0 (control)	10.86	510.0	-	21.29
T_1	14.58	333.5	34.6	43.72
T_2	10.95	328.8	35.5	33.30
T_3	10.85	325.0	36.2	33.38
T_4	10.80	321.8	36.9	33.56
T_5	10.42	304.0	40.3	34.28
T_6	8.53	324.2	36.4	26.31
T_7	8.78	316.5	37.9	27.74
T_8	8.43	305.1	40.2	27.63
T_9	8.08	316.6	37.9	29.44
T_{10}	7.30	319.6	37.3	22.84
T_{11}	7.60	308.0	39.6	24.67
T_{12}	7.06	298.4	41.5	23.66
T_{13}	6.43	245.0	52.0	26.24
SE(m)±	0.310	-	-	
C.D. at 5%	0.906	-	-	

T_1- No deficit irrigation during all stages
T_2- 20% deficit irrigation during I-stage (20-30)DAS)
T_3- 20% deficit irrigation during II-stage (31-45DAS)
T_4- 20% deficit irrigation during III-stage (46-60DAS)
T_5- 20% deficit irrigation during IV-stage (61 and above DAS)
T_6- 40% deficit irrigation during I-stage (20-30DAS)
T_7- 40% deficit irrigation during II-stage (31-45DAS)
T_8- 40% deficit irrigation during III-stage (46-60DAS)
T_9- 40% deficit irrigation during IV-stage (61 and above DAS)
T_{10}- 60% deficit irrigation during I-stage (20-30DAS)
T_{11}- 60% deficit irrigation during II-stage (31-45DAS)
T_{12}- 60% deficit irrigation during III-stage (46-60DAS)
T_{13}- 60% deficit irrigation during IV-stage (61 and above)
Control : Furrow irrigation method - 30 mm depth at 5 days interval

2.4 Gayeshpur

Effect of drip irrigation and integrated nitrogen fertilizers on flower production of gladiolus (*Gladiolus spp.*)

The pooled data results revealed that drip irrigation at 100% of evaporation replenishment produced significantly the highest number of spikes/plot (70.5), number of florets per spike (9.6), longer spike length (64.5 cm) and spike yield (9797 kg/ha), which were found to be at par with the drip irrigation at 80% of evaporation replenishment. On the other hand, the traditional flood irrigation method registered significantly the lowest number of growth parameters, spike and flower yields.As regards to the single or combined application of organic and inorganic sources of nitrogen in the recommended fertilizer schedule, maximum number of spikes/plot (67.7), longer spike length (62.5 cm) and spike yield (9303 kg/ha) was obtained with the conjunctive use of 50% inorganic N plus 50% organic N through vermicompost. The least growth parameters and flower yield were registered with the sole application of 100% organic N as vermicompost. These findings indicate that a combined application of vermicompost and inorganic fertilizer N at 1:1 proportion in the recommended fertilizer schedule had significant impacts in promoting the growth, flower yield and yield contributing parameters of gladiolus. The highest water use (239.0 mm) was recorded in the conventional farmers' practice of flood irrigation and the lowest (146.8 mm) in drip irrigation at 60% of evaporation replenishment. On the contrary, the highest water use efficiency (56.06 kg/ha-mm) was recorded with drip irrigation at 60% of evaporation replenishment, whereas the lowest (33.31 kg/ha-mm) was obtained with the conventional flood irrigation. As regards to the nitrogen nutrition to crop, the use of 50% inorganic N plus 50% organic N (vermicompost) recorded the maximum water use efficiency of 49.25 kg/ha-mm and the minimum in 100% organic N (vermicompost) with value of 43.68 kg/ha-mm. The interaction between irrigation and nitrogen source revealed that drip irrigation at 60% of evaporation replenishment plus 100% inorganic N recorded the maximum water use efficiency (Table 2.4.1). In general, soil profile moisture contribution to crop decreased with increased amount of water application.

Table 2.4.1: Components of soil water balance, water use and water use efficiency of gladiolus under different irrigation schedules and fertilizer nitrogen nutrition during 2012-2013

Treatment	Profile contribution (mm)	Irrigation (mm)	Rainfall (mm)	Total water use (mm)*	Spike yield (kg/ha)	WUE (kg/ha-mm)
$I_1 N_1$	15.12	200.00	10.9	226.02	7267	32.15
$I_1 N_2$	15.33	200.00	10.9	226.23	8364	36.97
$I_1 N_3$	15.08	200.00	10.9	225.98	7880	34.87
$I_2 N_1$	15.37	158.40	10.9	184.67	8954	48.49
$I_2 N_2$	15.62	158.40	10.9	184.92	9840	53.21
$I_2 N_3$	15.46	158.40	10.9	184.76	9478	51.30
$I_3 N_1$	17.43	126.72	10.9	155.05	8495	54.79
$I_3 N_2$	17.16	126.72	10.9	154.78	9622	62.16
$I_3 N_3$	17.29	126.72	10.9	154.91	9243	59.67
$I_4 N_1$	20.17	95.04	10.9	126.11	7460	59.15
$I_4 N_2$	20.35	95.04	10.9	126.29	8034	63.61
$I_4 N_3$	**20.44**	95.04	10.9	126.38	8488	**67.16**

I_1: Farmers' practice (conventional flood irrigation)
I_2 : Drip irrigation at 100% Eo
I_3 : Drip irrigation at 80% Eo
I_4 : Drip irrigation at 60% Eo
(Depth of surface irrigation = 4 cm)
N_1 : 100% N as vermicompost
N_2 : 50% N as vermicompost N + 50% inorganic N
N_3 : 100% inorganic N

2.4.2 Effect of irrigation scheduling and nutritional levels on yields, water and nutrient economy of turmeric and ginger under guava plantation

The results showed that the highest yield of 18.11 t/ha for turmeric and of 11.05 t/ha for ginger was obtained with the irrigation schedule of IW/CPE 0.9.The effects of irrigation schedules at IW/CPE 0.6 and IW/CPE 1.2 in promoting rhizome yields was at par with each other for ginger, however, there was a significant difference in yields for turmeric. The highest rhizome yield of 17.36 t/ha for turmeric and 10.37 t/ha for ginger was recorded with the conjunctive use of 75% inorganic + 25% organic sources of fertilizers. It indicates that there is great possibility of substitution of 25% costly inorganic fertilizers with the organic fertilizer one *i.e.* through the use of vermicompost. The interactions between irrigation and fertilizer nutrition on rhizome yield was significant. However, maximum of 18.45 t/ha for turmeric and 12.36 t/ha for ginger was obtained from irrigation schedule of IW/CPE 0.9 at 75% inorganic plus 25% organic fertilizer integration in the recommended fertilizer dose.The highest water use was observed in conventional farmers' practice of ridge and furrow method of irrigation and the lowest in irrigation schedule at IW/CPE 0.6 in both crops. On the other hand, the higher water use efficiency of 43.43 kg/ha-mm for turmeric and 27.23 kg/ha-mm for ginger was obtained with irrigation schedule of IW/CPE 0.9, whereas the lowest WUE was registered for the farmers' conventional practice. The integrated use of 75% inorganic plus 25% organic fertilizer nutrition recorded maximum water use efficiency in both crops. The interactions between irrigation and fertilizer showed that the higher water use efficiency of 50.12 kg/ha-mm for turmeric and 33.24 kg/ha-mm for ginger was obtained with I_3N_2(Tables 2.4.2).

Table 2.4.2: Components of soil water balance, water use and water use efficiency of turmeric under different irrigation schedules and fertilizer sources during 2013-2014

Treatment	Profile contribution (mm)	Irrigation (mm)	Rainfall (mm)	Total water use* (mm)	Rhizome yield (t/ha)	WUE (kg/ha-mm)
$I_1 N_1$	15.18	300	181.45	516.63	13.72	26.56
$I_1 N_2$	15.09	300	181.45	516.54	14.12	27.34
$I_1 N_3$	15.35	300	181.45	516.80	12.60	24.38
$I_2 N_1$	17.63	150	181.45	369.08	13.34	36.14
$I_2 N_2$	17.37	150	181.45	368.82	15.38	41.70
$I_2 N_3$	17.48	150	181.45	368.93	12.95	35.10
$I_3 N_1$	17.31	200	181.45	418.76	16.43	39.23
$I_3 N_2$	17.56	200	181.45	419.01	18.45	50.12
$I_3 N_3$	17.49	200	181.45	418.94	14.86	35.47
$I_4 N_1$	17.63	250	181.45	469.08	14.51	30.93
$I_4 N_2$	17.35	250	181.45	468.80	18.14	38.69
$I_4 N_3$	17.54	250	181.45	468.99	13.67	29.15

including a common irrigation of 20 mm depth for seedling emergence

I1 (ridge and furrow)
I2 (IW/CPE 0.6)
I3 (IW/CPE 0.9)
I4 (IW/CPE 1.2)
N1 (100% inorganic)
N2 (75% inorg + 25% org)
N3 (50% inorg + 50% org)

2.5 Hissar

To study the performance of mini-sprinkler in mungbean-wheat sequence

The mini-sprinklers of varying flow rates were installed in wheat just after sowing .The flow rates varied from a minimum of 16 to a maximum of 144 lph having the corresponding wetting diameters of 2.4 to 6.0 m (Table 2.5.1). The depth of irrigation water varied from 0.28 to 0.39 cm/hr and accordingly the irrigation depth also varied during the entire crop season in different years depending upon the flow rate and environmental conditions. The initial cost of installation of mini-sprinklers varied depending upon the wetting area covered by individual mini-sprinkler. It was lowest (Rs. 5814/ha) with mini-sprinkler of wetting diameter of 6 m where as it was highest (Rs. 18488/ha) in case of mini-sprinkler having wetting diameter of 2.4 m due to increased number of laterals and mini-sprinklers.The grain yield was higher under all the micro-sprinklers over the surface method of irrigation. The maximum grain yield of 4388 kg/ha was recorded when irrigations were applied using 6.0 m wetting dia of micro-sprinkler. The increase was 142 kg/ha compared with surface irrigation. The average increase in grain yield with mini-sprinkles was 75 kg/ha over surface irrigation.The WP of applied irrigation water under surface method was calculated as 2.41 kg/m^3 and has increased to 2.98 kg/m^3 under 3.4 m wetting dia of micro-sprinkler. The averaged WP of all the micro-sprinklers has increased to 2.84 kg/m^3 .The WP of total water use did not vary among the different wetting dia of micro-sprinkler and the averaged value was 1.10 kg/m^3 against 0.98 kg/m^3 with surface irrigation. The initial cost of installation of mini-sprinklers and the value of additional yield obtained in the 1st year net profit of Rs 6390/ha was the maximum with 6 m wetting diameter mini-sprinklers and increased to Rs. 25275/ha in the 4th year. In other micro-sprinklers with lower wetting diameter the net profit was in –ve in the 1st year, but started increasing from 2nd year onward. In general, the net profit decreased with decrease in the wetting diameter of the mini-sprinklers.

Table 2.5.2: Average grain yield of wheat, depth of irrigation water applied and water productivity (WP) under different mini-sprinklers and surface irrigation

Wetting diameter (m)	Grain yield (kg/ha)	Water use, cm					WP (kg/m^3)	
		Irrigation	Rainfall	SMD	GWC	CU	Irrigation	Total
2.4	4342	15.8	11.2	7.3	5.2	39.5	2.75	1.10
3.4	4276	14.4	11.2	7.4	5.4	38.4	2.98	1.11
4.2	4309	15.4	11.2	7.2	5.4	39.2	2.80	1.10
5.6	4288	14.8	11.2	7.5	5.6	39.1	2.90	1.10
6.0	4388	15.8	11.2	7.1	5.6	39.7	2.78	1.11
Average	4321	15.2	11.2	7.3	5.4	39.2	2.84	1.10
Surface	4246	17.6	11.2	7.8	6.8	43.4	2.41	0.98

Note: Water table depth of the experimental field during the crop season varied between 1.4 to 2.1m

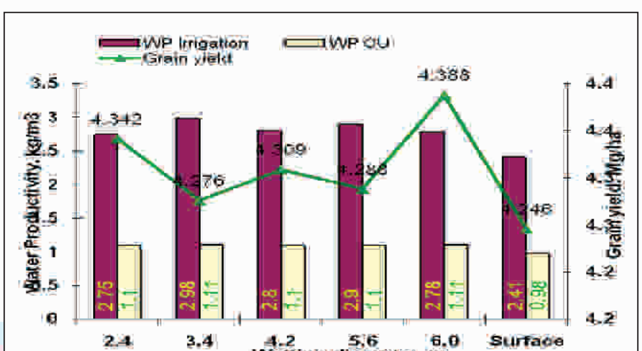

Fig. 2.5.1 Average grain yield of wheat, and water productivity (WP) under different mini-sprinklers and surface irrigation

2.6 Jammu

Evaluation of Sprinkler System in Potato (*Solanum tuberosum*)

Pooled data of two years showed sprinkler and skip furrow irrigation methods are at par but recorded significantly higher potato tuber yield over flooding method. The percent increase in tuber yield with sprinkler method was 18.75 as compared to flooding method whereas it was 5.83 with skip furrow method. Irrigation scheduling at 0.3 PE recorded significantly higher tuber yield over 0.7 PE but at par with 0.5 PE. On the basis of mean data of two years, sprinkler method saved 38.6% and 20% water over flooding and skip furrow methods. Also, sprinkler method recorded higher water use efficiency and produced 38.24 kg potato/ ha-mm water as compared to 22.73 kg potato/ ha-mm water with flooding and 32.45 kg potato/ ha-mm water with skip furrow method. In both years of experimentation, Rabi 2011-12 and 2012-13 scheduling irrigation at 0.3 PE resulted in water saving of 22% over 0.7 PE and 11% over 0.5 PE. Scheduling at 0.3 PE recorded higher water use efficiency and produced 34.27 kg potato/ ha-mm of water as compared to 0.7 PE (26.93 kg potato/ ha-mm water) and 0.5 PE (30.30 kg potato/ha-mm water).

Table: 2.6.1: Effect of irrigation methods and scheduling on potato (Pooled) (2011-12 and 2012-13)

Irrigation methods	Yield (t/ha)	Irrigation water Applied (mm)	Rainfall mm)	Total water Applied (mm)	Water use efficiency (kg/ha-mm)
Flooding	13.60	199.9	398.2	598.1	22.73
Sprinkler	17.15	50.2	398.2	448.4	38.24
Skip Furrow	16.15	99.4	398.2	497.6	32.45
CD (5%)	2.65				
Irrigation scheduling					
0.3PE	17.15	102.2	398.2	500.4	34.27
0.5PE	15.60	116.5	398.2	514.7	30.30
0.7PE	14.25	130.8	398.2	529.0	26.93
CD (5%)	1.67				

2.7 Jorhat

Effect of drip irrigation and nutrient management in garlic

The results revealed that average bulb yield of garlic recorded under the drip irrigation was 99.0 q/ha as against 63.0 q/ha under the farmers' practice (rainfed) resulting in 57.1 percent increase in yield.

Table 2.7.1 Bulb yield of garlic under demonstration

Treatment	Farmers' Practice (rainfed)	Drip irrigation
Bulb yield (q/ha)	63.0	99.0
% increase in yield	-	57.1

Feasibility of using vermiwash as liquid fertilizer in Assam Lemon under drip irrigation

esults revealed that Vermiwash (120 % of recommended dose of N) through low cost drip had given higher no. of fruits /plant as compared to other treatments. Treatments are non significant during 2010-11, 2011-12 (May be because the plants were very young (2-3 yrs old).Treatments were significant only in 2012-13 and are pooled. Impositions of treatments have been extended during 2013-14 and the experiment is going on.

Table 2.7.2: Effect of vermiwash as liquid fertilizer on yield of Assam lemon

Explanation	Treat ments	Yield (no. of fruits per plant)			
		2010-11	2011-12	2012-13	Pooled
Rain fed + Soil application (100% of RDF)	T_1	20.00	32.75	37.00	29
Fertigation (120 % RDF) conventional drip	T_2	18.25	33.50	55.00	35
Fertigation (100 % RDF) conventional drip	T_3	21.50	31.25	43.00	32
vermiwash (120 % of recommended dose of N) through low cost drip	T_4	24.0	34.00	59.00	39
vermiwash (100% of recommended dose of N) through low cost drip	T_5	24.75	30.50	49.00	34
vermiwash (75 % of recommended dose of N) through low cost drip	T_6	24.5	34.50	42.00	33
vermiwash (50% of recommended dose of N) through low cost drip	T_7	21.25	32.50	35.00	29
CD at 5 %		NS	NS	7.37	5.18
CV		31.22	21.20	10.81	18.11

2.8 Kota

Performance evaluation of Sprinkler and Mini sprinkler under different irrigation schedules for coriander - soybean crop sequence

The coriander yield is significantly affected by various treatments. The maximum and significantly superior coriander yield (16.33 q/ha) over surface irrigation was obtained under the Mini sprinkler irrigation; however this yield was statistically at par with yield obtained under Sprinkler irrigation. Mini sprinkler Irrigation at IW/CPE ratio of 0.6 gave maximum water use efficiency. Quality of produce was also better with mini sprinkler.

Table 2.8.1: Coriander Yield under different irrigation system and schedules

TREATMENTS	Grain Yield (q/ha)		
	2011-12	2012-13	Mean
A IRRIGATION METHOD			
SPRINKLER	14.35	17.09	15.72
MINI SPRINKLER	14.54	18.12	16.33
SURFACE METHOD	12.42	15.47	13.94
CD (P=0.05)	0.62	1.12	
B IRRIGATION SCHEDULE			
IW / CPE = 0.6	13.23	15.83	14.53
IW / CPE = 0.8	13.60	16.95	15.28
IW / CPE = 1.0	14.48	18.42	16.45
CD (P=0.05)	0.72	1.18	

The data indicated that soybean yield obtained under sprinkler and mini sprinkler method of irrigation being at par each other but these were better than the yield obtained with surface irrigation method. Among the irrigation schedules IW/CPE 1.0 produced the maximum soybean yield as compared to IW/CPE 0.6 and IW/CPE 0.8. Mini sprinkler Irrigation at IW/CPE ratio of 0.6 gave maximum water use efficiency.

Table 2.8.2 : Effect of irrigation schedules and method of irrigation on water use efficiency of Soybean

Treatments	Mean Yield (q/ha)	Depth of Irrigation (mm)	Water use efficiency (kg/ha-mm)			
			Mini Sprinkler	Sprinkler	Surface	Mean
IW/CPE=1.0	16.26	616	2.83	2.71	2.38	2.64
IW/CPE=0.8	16.13	566	3.08	2.94	2.59	2.87
IW/CPE=0.6	15.23	516	3.38	3.23	2.84	3.15
Mean			3.10	2.96	2.60	

Response of drip fertigation in Turmeric - Bitter gourd cropping sequence

Three years pooled data indicate that drip irrigation scheduled every third day, 100 % of PE and 100 % RDF of N & K application through fertigation produced maximum yield of bitter gourd. This yield was at par with 100 % PE and 75 % RDF of N & K through fertigation. Maximum water saving (46.67 %) was observed under Drip irrigation at 60%PE + 100% N & K through fertigation with 17.79 % reduction in yield as compared to best treatment.

Table2.8.3 : Water use efficiency & per cent saving of water under drip irrigation in Bitter gourd

Treatment	Mean Yield (q/ha)	Irrigation water applied (cm)	WUE q/ha-cm	% saving in irrigation water over Surface
Surface irrigation at 0.8 IW /CPE ratio + Entire NPK as soil application	212.26	45	4.72	-
Drip irrigation 100%PE + 75% N & K through fertigation	288.31	40	7.21	11.1
Drip irrigation 100% PE + 100% N & K through fertigation	301.39	40	7.53	11.1
Drip irrigation 80% PE + 75 % N & K through fertigation	274.27	32	8.57	28.89
Drip irrigation 80% PE + 100% N & K through fertigation	283.38	32	8.86	28.89
Drip irrigation at 60% PE + 75% N & K through fertigation	230.81	24	9.62	46.67
Drip irrigation at 60%PE + 100% N & K through fertigation	247.75	24	10.3	46.67

2.9 Navasari

Planting geometry and mulching study in water melon under drip irrigation

In pooled analysis, the growth parameters *viz*., length of vine and number of twigs per vine were affected significantly due to method of planting (I). In both the cases, normal planting (1m x 2m) recorded significantly higher values as compared to paired row planting (Table 2.9.1). Similarly, mulching effect was also turned out to be significant only on no. of twigs/vine in pooled analysis. Though, all the mulches were at par with each , but were significantly higher than M_0 (control 3.36), except M_3(3.89) which was at par with control(M_0).The control *vs* rest analysis was significant in case of no of twings/vine and treatment mean was better than control. The length, diameter and volume of fruit were not affected significantly due to I, M and IxM effects. However, control *vs* rest analysis showed significant difference between control and treatment mean of only volume of fruits (Table 2.19.1). The volume of fruit recorded with drip means (3733cm^3) was almost three times more than that of control mean (1222 cm^3). In case of parameters viz., average fruit weight, rind thickness, pulp : skin ratio and TSS (%) were not affected significantly due to either I or M or I x M effect or also in control *vs* rest analysis (Table 2.19.2).

Fruit yield:

The individual effects of I and it interaction with mulch (I X M) could not alter the fruit yield of water melon significantly during individual as well as in pooled analysis (Table 2.19.3). Among the mulching treatments, significantly higher yield of 36.9, 32.19,24.93 and 31.34 t/ha was recorded with M_2 (SBPM) during 2010-11,2011-12,2012-13 and pooled results, respectively, in comparison to no mulch control (M_0). However, M_2 was at par with M_1 *i.e.,* black plastic mulch in all the cases. The results further revealed that M_3 and M_0 were also at par with each other in all the cases. The control *vs.* rest analysis indicated that the difference in fruit yield between control and drip mean was significant during individual year and in pooled results as well. On pooled basis, the per cent increase in fruit yield was of the order of 48% with drip mean (27.1 t/ha) over surface control (18.26 t/ha).

Water use efficiency (WUE):

Based on mean data, water saving up to 29 per cent along with 93 per cent higher WUE was recorded with drip mean over surface control.

Economics:

The net income was calculated separately for I, M and control, as the I X M was not significant. Between I_1 and I_2, paired row planting of water melon (I_1) showed an edge over normal planting by recording about 5000 Rs/ha more net income than normal planting. Among the mulches, BPM and SBPM recorded more net profit of Rs. 1.27 lakh/ha (based on mean yield of M_1 and M_2) than no mulch (Rs. 1.02 lakh/ha) and trash mulch (Rs. 1.11 lakh/ha) treatments. In contrast, the net income realized with surface control was about Rs. 0.81 lakh/ha as against Rs. 1.27 lakh/ha with drip + mulch treatment *i.e.*, 57 per cent more net income than control.

Table 2.9.1: Water applied, WUE and water saving as influenced by different treatments 2013

Methods	Fruit yield(t/ha)	Water applied(mm)	WUE (kg/ha-mm)	Water saving over surface(%)
Drip	27.10	381	71.1	24.0
Surface	18.26	500	36.5	-
Pooled				
Drip	29.79	408	73.0	29.2
Surface	21.71	580	37.0	-

Feasibility of drip irrigation in pigeon pea *(rabi)* with and without mulch

The seed yield of pigeon pea was affected significantly due to individual effect of M and interactive effect of I x M (Table 2.20.4). Among the mulching treatments, M_2 showed superiority over M_1 and M_0 and M_1 over M_0 treatments. The magnitude of increase in seed yield with M_2 over M_0 was to the tune of 58 per cent. The treatment combination I_2M_2 recorded significantly higher seed of pigeon pea (2245 kg/ha) as compared to rest of treatments except I_1M_2 (1942 kg/ha), which was found at par with I_2M_2. In case of stalk yield, only I effect could influence it significantly. Here, I_2 (3057 kg/ha) and I_3 (2918 kg/ha) were at par with each other, but significantly higher than I_1 (2614 kg/ha) and I_4 (2490 kg/ha).

Water Use Efficiency (WUE)

The values of WUE reported in table 2.20.6 revealed that WUE was tended decline with increase in rate of water application *i.e,* 4.6 kg/ha-mm with I_1(0.4PEF) to 2.2 kg/ha-mm with I_4(0.8 IW/CPE). This was also true for extent of saving in irrigation water *i.e.,* 48 per cent with I_1 to 1_4 per cent with I_3 over I_4 treatments.

Table 2.9.2 : WUE as influenced by different treatments

Particulars	Seed yield(t/ha)	Water applied (mm)	WUE (kg/ha - mm)	Water saving over surface (%)
Irrigation level				
I_1- 0.4 PEF	1614	351	4.6	48
I_2- 0.6 PEF	1620	467	3.5	31
I_3- 0.8 PEF	1581	582	2.7	14
I_4- Surface irrigation (1.0 IW/CPE, IW:40 mm)	1518	680	2.2	

Study on levels of nitrogen and intra-row spacing on yield of drip irrigated castor (*rabi*)

The results revealed that the main effect of N levels was significant on no. of branches/plant, no of spike/plant and seed yield of castor. Among the N levels, the seed yield of castor was significantly higher with N_1 (3048 kg/ha) as compared to N_3 (2841 kg/ha) but was at par with N_2(2938 kg/ha). With respect to effect of intra-row spacing, it was significant on number of branches/plant, number of spike/plant and seed yield of castor. In case of the intra-row spacing, S2 (2963 kg/ha) and S_3 (3036 kg/ha) were at par with each other, but S_3 was significantly superior over S_1 (2828 kg/ha).Further, the level S_2 and S_1 were at par with each other. In all the cases, N x S interaction effect failed to exert significant effect on biometrics and seed yield of castor.The data were also analyzed for control *vs* rest analysis. With an exception of oil content in castor seed, rests of the parameters were significantly higher with drip mean in comparison to control mean.

Table 2.9.3 : WUE as influenced by different treatments

Treatments	Seed yield (kg/ha)	Water applied(mm)	WUE (kg/ha - mm)
Nitrogen level (kg/ha)			
N_1 (80)	3048	414	7.36
N_2(120)	2938	414	7.10
N_3(180)	2841	414	6.86
Intra-row spacing (m)			
S_1 (0.6)	2828	414	6.83
S_2 (0.9)	2963	414	7.15
S_3(1.2)	3036	414	7.33
Control	2698	414	6.52

Note: Water uniformity coefficient of the drip system were in the range from 90.50 % to 92.25 %

2.10 Madurai

Study of appropriate micro irrigation methods, irrigation regimes and land configuration technique for groundnut

The present investigation revealed that irrigating groundnut with micro-sprinkler (I_1) had registered the highest yield. Surface drip irrigation recorded the lowest yield (I_2). Fertigation of 100% RDF (50 per cent P and K as basal by straight fertilizer and the balance PK and full N as water soluble fertilizer) (F_3) was statistically superior to the rest of the methods of fertilizer application in registering the pod yield as well as haulm yield and Water use efficiency (4.55kg/ha/mm).Micro-sprinkler irrigation to groundnut (I_1) recorded the highest water use efficiency (4.59 kg/ha/mm).Surface method of drip irrigation recorded the lowest water use efficiency(I_2) (4.05 kg/ha/mm). From the four crops data it was observed that irrigating the groundnut crop by micro sprinkler at 100% PE once in 3 days recorded the highest benefit cost ratio of 2.36. As regards to methods of fertilizer application to groundnut application of P as basal and N and K through drip as Urea and MOP (F_2) at RDF recorded the highest B:C ratio of 3.13. Soil application of 50 per cent P and K as basal by straight fertilizer and the balance NPK as WSF (F_3) recorded the lowest B:C ratio of 2.78. From the results it can be concluded that micro sprinkler irrigation once in 3 days at 100% PE and fertigation of 100% RDF P as basal, N&K through Urea and MOP at weekly interval from 15 to 90 DAS can be recommended to groundnut.

Table 2.10.1 : Effect of irrigation methods and fertigation levels on WUE(kg/ha/mm) of groundnut of groundnut

Treatment	I Crop	II Crop	III Crop	IV Crop	Pooled Mean
Main Plot					
I_1	4.77	4.56	4.20	4.85	4.59
I_2	4.21	4.06	3.65	4.30	4.05
I_3	4.47	4.30	3.95	4.40	4.28
Sub Plot					
F_1	4.18	4.07	3.73	4.26	4.06
F_2	4.53	4.39	3.98	4.62	4.38
F_3	4.74	4.50	4.14	4.84	4.55

I_1- Micro sprinkler irrigation; I_2- Drip Irrigation; I_3 - Sub surface drip irrigation

F_1- Soil application of 100% RDF

ace irrigation with soil application of RDF was maintained for the comparison.

RDF: 17:34: 54 kg NPK ha^{-1}

NoteSurface irrigation was given at IW / CPE ratio of 0.8 with 5 cm depth.

Micro-irrigation was given once in 3 days at 100 PE.

Land configuration and irrigation regimes for groundnut

Data on pod yield also proved that subsurface drip irrigation at 100 % PE once in days under ridges and furrow (T_6) recorded higher pod yield of (3616 kg/ha respectively). Surface irrigation with soil application of fertilizers under conventional method of sowing (T_1) and sowing in ridges and furrow (T_2) recorded lower pod yield (2125 kg/ha respectively). The highest WUE was noticed in (T_6) treatment i.e. **s**owing in ridges and furrows under SSDI at 100% PE. The lowest WUE as recorded under surface method of irrigation. The land configuration of ridges and furrow was best suited for subsurface drip fertigation to groundnut. Fertigation of 100% N and 50% P and K as WSF in equal splits from 15 to 90 DAS with an irrigation regime of 100% PE was the best management to get higher yield, net return, B:C ratio and water use efficiency in groundnut.

Effect of Sub Surface Drip irrigation on cotton based intercropping system and Pigeon Pea sequence

The results showed that the highest cotton yield, intercrop yield and cotton equivalent yield were obtained in cotton intercropped with black gram under sub surface drip irrigation at 100% PE once in two days (T5). Similarly, water use efficiency was also found to be higher in this treatment. The benefit cost: Benefit ratio and net returns generated with cotton intercropped with black gram under sub surface drip irrigation at 100% PE once in two days (T_5) were found to be higher than other intercropping systems(**Table 3).** The maximum cotton equivalent of follow up crop pigeon pea with cotton plus blackgram cropping system (1080 kg/ha and 1059 kg/ha) and higher water use efficiency were registered under above sequence with sub surface drip at 100% PE once in two days than once in four days.

Table 2.10.2: Effect of subsurface drip irrigation levels on economics of cotton based intercropping

Treatments	Cost of cultivation (Rs/ha)		Gross income (Rs/ha)		Net income (Rs/ha)		B:C ratio	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	82550	75750	144248	146376	61698	70626	1.74	1.93
T_2	82550	75750	137484	140030	54934	64280	1.67	1.85
T_3	86150	79350	152649	152920	66499	73570	1.77	1.93
T_4	86150	79350	141144	143956	54994	64606	1.64	1.81
T_5	**86150**	**79350**	**162233**	**160796**	**76083**	**81446**	**1.88**	**2.03**
T_6	86150	79350	152452	150518	66302	71168	1.77	1.90
T7	100550	93750	150462	145274	49912	51524	1.50	1.55
T_8	100550	93750	139433	138056	38883	44306	1.39	1.47

T_1- Pure crop of cotton under sub surface drip at 100% PE once in two days-Pigeon pea

T_2- Pure crop of cotton under sub surface drip at 100% PE once in four days- Pigeon pea

T_3-Cotton + Green gram under sub surface drip at 100% PE once in two days-Pigeon pea

T_4 - Cotton + Green gram under sub surface drip at 100% PE once in four days-Pigeon pea

T_5 - Cotton + Black gram under sub surface drip at 100% PE once in two days-Pigeon pea

T_6 - Cotton + Black gram under sub surface drip at 100% PE once in four days-Pigeon pea

T_7 - Cotton + Onion under sub surface drip at 100% PE once in two days-Pigeon pea

T_8 - Cotton + Onion under sub surface drip at 100% PE once in four days-Pigeon pea

Optimization of plant population and planting method for sustainable sugarcane initiative (SSI) under subsurface drip fertigation system

The Sustainable Sugarcane Initiative (SSI) plant cane (2nd week of May, 2012 to 2nd Week of April 2013) results indicated that double side planting of seedlings at 60 cm plant spacing under subsurface drip fertigation exhibited better growth attributes like plant height, tiller count and number of millable canes.The yield attributes were significantly higher in double side planting at 60 cm plant spacing under subsurface drip fertigation system. Quality characters like juice Brix, CCS percentage were higher with single side planting at 60 cm plant spacing under subsurface drip fertigation but it was comparable with double side planting at 60 cm intra row spacing. Double side planting of seedlings at 60 cm plant spacing (T_6) recorded the maximum cane yield of 182.45 t/ha and also higher sugar yield. Lesser cane yield of 112.55 t/ha was recorded in planting of seedlings at 150 x 60 cm spacing under surface irrigation with soil application of fertilizers. Subsurface drip irrigation to SSI amounted to total water use of 1620 mm which is 20 per cent lesser than the total water used under surface irrigation to SSI (2023 mm). Higher WUE of 112.61 kg/ha / mm was recorded in 60 cm plants spacing with double side planting under subsurface drip irrigation (T_6). It also recorded higher net return of Rs.2,53,072 /ha with a B:C ratio of 2.25. Ratoon cane allowed from 3rd week of April 2013 to 2nd week of February 2014 also followed similar trend on plant height, tillers, Millable canes, individual cane weight, millable cane length, number of internodes, length and girth of internodes, juice brix, CCS%, cane yield, sugar yield, water use and water use efficiency, net income and B:C ratio.

Table 2.10.3: Effect of planting geometry and method of planting on water use and water use efficiency of SSI under subsurface drip fertigation system

Treatment	Plant cane (2012 – 2013)			
	IW (mm)	ER (mm)	Total water use (mm)	WUE (kg/ha/mm)
T_1	1463.4	196.8	1660.2	77.44
T_2	1463.4	196.8	1660.2	84.80
T_3	1463.4	196.8	1660.2	89.08
T_4	1463.4	196.8	1660.2	96.20
T_5	1463.4	196.8	1660.2	101.15
T_6	1463.4	196.8	1660.2	112.61
T_7	1750.0	270.6	2022.6	55.64

T_1 Single row planting of seedlings at 30 cm intra row spacing under subsurface drip fertigation system

T_2 Dual row planting of seedlings at 30 cm intra row spacing under subsurface drip fertigation system

T_3 Single row planting of seedlings at 45 cm intra row spacing under subsurface drip fertigation system

T_4 Dual row planting of seedlings at 45 cm intra row spacing under subsurface drip fertigation system

T_5 Single row planting of seedlings at 60 cm intra row spacing under subsurface drip fertigation system

T_6 Dual row planting of seedlings at 60 cm intra row spacing under subsurface drip fertigation system

T_7 Planting of seedlings at 150 x 60 cm spacing under surface irrigation

Surface irrigation: IW / CPE ratio of one with 5 cm depth

Drip irrigation: once in 3 days at 100% PE

Fertigation – once in 7 days from 15 to 210 DAP

RDF 275: 62.5: 112.5 kg NPK (50% P & K as basal, balance NPK through drip as WSF)

WSF : Poly feed (28:28:0), multi K (13:0:45) and urea

Optimizing irrigation schedule for Redgram under drip fertigation system

The results indicated that transplanting of redgram seedlings under drip irrigation system at 60% PE and fertigation of RDF exhibited better growth. The yield was higher in the treatment transplanting with drip irrigation at 60% PE and fertigation of RDF. Transplanting under drip irrigation at 60% PE and fertigation of RDF recorded higher yield of 1430 kg/ha. The higher net returns (Rs.39.724/ha) and B:C ratio (2.07) were accounted with sowing of redgram with drip irrigation at 60% PE and fertigation of RDF. Transplanting of seedlings recorded minimum total water use compared to conventional sowing irrespective of irrigation regimes. The minimum total water use of 265 mm was amounted with transplanting of seedlings with drip irrigation at 40% PE once in 3 days and fertigation of 100% RDF. The highest WUE of 4.79 kg/ha/mm was recorded with transplanting with drip irrigation at 40% PE and fertigation of RDF (T_6).

Table 2.10.4 : Effect of treatments on water use of redgram

Treatments			IW (mm)	ER (mm)	Total water use (mm)	WUE (kg/ha/mm)
T_1	:	Conventional sowing and surface irrigation at 0.6 IW/CPE ratio with soil application of RDF	500	71.63	571.63	1.77
T_2	:	Transplanting and surface irrigation at 0.6 IW/CPE ratio with soil application of fertilizer sowing	450	49.1	499.1	2.11
T_3	:	Conventional sowing under drip irrigation at 40% PE and fertigation of RDF	298.8	49.5	348.3	3.48
T_4	:	Conventional sowing under drip irrigation at 60% PE and fertigation of RDF	458.1	44	502.1	2.79
T_5	:	Conventional sowing under drip irrigation at 80% PE and fertigation of RDF	610.9	38.5	649.4	1.69
T_6	:	Transplanting under drip irrigation at 40% PE and fertigation of RDF	234.7	30.2	264.9	4.79
T_7	:	Transplanting under drip irrigation at 60% PE and fertigation of RDF	352.1	26.5	378.6	3.78
T_8	:	Transplanting under drip irrigation at 80% PE and fertigation of RDF	469.5	22.7	492.2	2.26

2.11 Morena

Effect of Micro and surface irrigation system on growth and yield of Turmeric in Chambal Command

The results revealed that maximum turmeric yield was recorded with porous pipe irrigation method (199.8 q/ha) and with irrigation schedules of 0.8 IW/CPE ratio. The economic analysis indicated that maximum gross returns, net returns and additional income were achieved in porous pipe irrigation method and irrigation schedules of 0.8 IW/CPE. The maximum B: C ratio was also observed under porous irrigation method and with irrigation schedules of 0.8 IW/CPE ratio.

Treatments	Yield of Rhizomes (q/ha)			Pooded average of two years				
	2012	2013	Pooled Average	Gross Income (Rs.ha)	Cost of cultivation (Rs./ha)	Net income (Rs./ha)	Additional income (Rs./ha)	B:C ratio
Methods of irrigation								
Porous pipe	196.3	206.2	199.8	399600	71796	327804	184708	5.60
Drip irri.	138.4	145.7	142.0	284000	71736	212264	66368	3.95
Furrow irrig.	184.4	198.2	191.3	382600	70301	312299	166303	5.43
Check besin	103.8	112.5	108.2	216400	70304	146096	-	3.07
Sem±	5.50	6.20	5.85	-	-	-	-	-
CD(P=0.05)	11.35	12.77	12.06	-	-	-	-	-
Irrigation schedules								
0.4 IW/CPE	128.9	136.3	132.6	265200	67852	197348	-	3.90
0.6 IW/CPE	153.5	161.5	157.5	315000	69544	245456	46608	4.52
0.8 IW/CPE	182.7	190.3	186.5	373000	70435	302565	103717	5.29
1.0 IW/CPE	158.0	166.0	162.0	324000	71274	252726	53878	4.54
Sem±	2.82	2.92	2.87	-	-	-	-	-
CD(P=0.05)	5.82	5.94	5.88	-	-	-	-	-

Market rate of fresh turmeric @ RS. 2000/qt.

2.12 Palampur

Effect of depth of water applied and NPK fertigation through drip on soil water dynamics and productivity of capsicum – cauliflower sequence in an acid Alfisol

On mean basis drip irrigation and fertigation of cauliflower resulted in significantly higher curd yield (8.68 %) leading to significantly higher water use efficiency (1.51 times) than recommended practices mainly due to 27.42 per cent less total water use An increase in the level of NPK fertigation resulted in a consistent increase in both the curd yield and WUE of cauliflower during all the years as well as on mean basis. Increase in depth of irrigation water from 0.8 times to 1.0 and 1.2 times CPE decreased WUE mainly due to increase in total water use. Irrigation depth of 0.8 times CPE resulted in water use efficiency of 31.67 kg cauliflower ha-mm^{-1} of water used which was significantly higher than

WUE obtained with irrigation depth of 1. 0 and 1.2 times CPE (16.35 and 31.57 %). On mean basis, irrigation depth of 0.8 CPE resulted in water use efficiency of 20.87 kg cauliflower ha-mm^{-1} of water used which was significantly higher than WUE obtained with irrigation depth of 1. 0 and 1.2 times CPE (7.97 and 13.67 %).

Capsicum

During all the years and also on mean basis, though drip irrigation and fertigation resulted in slightly higher capsicum yield than recommended practices, yet the differences in yields were statistically non significant. Water use efficiency (WUE) was 7.56 per cent and 9.45 per cent higher in drip irrigation and fertigation than in recommended practices, where 4 cm of flood irrigation was applied as per crop need along with recommended fertilizers, due to slightly higher yield (5.89 % & 5.29 %) and lower total water use (1.63 % & 3.79 %) in the former treatment On mean basis WUE was 8.81 per cent higher in drip irrigation and fertigation than in recommended practices, due to 5.30 per cent higher yield and 3.21 per cent lower TWU. An increase in level of NPK fertigation resulted in consistent and significant increase in capsicum yield and water use efficiency.On mean basis also, fertigation with 66.6 per cent NPK produced 11.89 per cent more yield and gave 11.95 per cent more WUE than fertigation with 33.3 per cent NPK. Again fertigation with 100 per cent NPK produced 8.51 & 21.40 per cent more capsicum yields and 8.43 & 21.39 per cent more WUE than fertigation with 66.6 per cent and 33.3 per cent NPK An increase in depth of irrigation water from 0.8 times to 1.0 and 1.2 times of cumulative pan evaporation (CPE) resulted in consistent increase in capsicum yield during first and third years and on mean basis. On mean basis also, irrigation depth of 1.0 time cumulative pan evaporation produced 6.21 per cent more capsicum yield than irrigation depth of 0.8 times of cumulative pan evaporation. Irrigation depth of 1.2 times cumulative pan evaporation produced 2.23 & 8.59 per cent higher capsicum yields than irrigation depth of 1.0 and 0.8 times cumulative pan evaporation . Increase in depth of irrigation did not influence WUE of capsicum on mean basis. Highest water use efficiency of 15.68 kg capsicum ha-mm^{-1} of water was obtained with irrigation depth of 1.2 times CPE. It was 2.08 and 7.18 per cent higher than that obtained with irrigation depth of 1.0 and 0.8 times cumulative pan evaporation. It was 6.36 and 20.71 per cent higher than that obtained with irrigation depth of 1.0 and 1.2 times cumulative pan evaporation .

So for maximizing production and water use in cauliflower – capsicum cropping sequence, each crop should be irrigated at three day interval with pressurized drip irrigation system. The quantity of water applied per irrigation should be equal to 1.0 time of cumulative pan evaporation of preceding three days. Soil test based recommended NPK dose should be used for eight fertigations with an interval of 11 days between two successive fertigations.

Effect of varying drip irrigation depth and fertigation on productivity of broccoli with gravity fed irrigation system

The broccoli crop grown with NPK fertigation under gravity fed drip irrigation resulted in significantly higher broccoli yield (21.47 % & 9.23 %) than crop grown with recommended package of practices i.e. fertilization with recommended soil test based NPK and surface irrigation of 5 cm at 11 day interval. The broccoli crop grown with NPK fertigation under gravity fed drip irrigation resulted in significantly higher water use efficiency (2.10 & 2.29 times) due to lower irrigation water use (40.91 & 49.40 %) than recommended practices. Net returns (20.82 & 55.59 %) and B:C ratio (42.8 & 73.21 %) were lower in broccoli grown with NPK fertigation than recommended practices mainly due to higher cost of soluble fertilizers. However, the decrease in net returns due to NPK fertigation under gravity fed drip irrigation system was not significant during first year.During both the years, an increase in irrigation depth resulted in consistent increase in broccoli yield. However, difference in yield was not significant when irrigation depth was increased from 0.6 time CPE to 0.8 time CPE during first year. Likewise during second year, increases in yield were not significant when irrigation depth were increased from 0.4 time CPE to 0.6 time CPE and again from 0.8 time CPE to 1.0 time CPE. During both years, significantly highest broccoli yield was recorded with irrigation depth of 100 per cent CPE. On the contrary, during both years, water use efficiency decreased with increase in irrigation depth due to increase in irrigation water use. However, the decrease in WUE was not significant when irrigation depth was increased from 0.4 time CPE to 1.0 time CPE during first year. Highest WUE of broccoli (3.47 & 4.02 Mg m^{-3} water) was obtained with water depth of 0.4 times CPE.

For maximizing production, broccoli crop should be irrigated at three day interval with gravity fed drip irrigation system. The quantity of water applied per irrigation should be equal to 1.0 time of cumulative pan evaporation of preceding three days. Hundred per cent of soil test based recommended NPK dose should be used for eight fertigations with an interval of at least 11 days between two successive fertigations.

Optimizing micro-sprinkler irrigation scheduling in Pea with varying NK fertigation:

During first year, irrigation and fertigation of pea with micro-sprinkler resulted in statistically similar pod yield as in case of recommended practices, yet, it saved 56.05 per cent water resulting in significantly higher WUE (2.41 times). On the contrary, irrigation and fertigation with micro-sprinklers resulted in significantly lower net returns (18.84 %) and B:C ratio (43.03 %) than recommended practice mainly due to the higher cost of cultivation in former. The progressive increase in irrigation depth decreased WUE progressively. However, under fertigation with 100 per cent NK, decrease in WUE was not significant when irrigation depth was decreased from 0.6 to 0.8 times CPE during first year.Irrespective of the year, highest WUE was obtained in crop irrigated with water depth of 0.4 times CPE and fertigated with 100 per cent of recommended NK. However, during second year, there was no difference in WUE obtained either with 50 or 100 per cent of recommended NK treatments.This clearly indicates that to achieve higher WUE, sprinkler irrigated pea crop should be irrigated with irrigation depth of 0.4 CPE and fertigated with 100 per cent of recommended NK.

For saving irrigation water and increasing WUE, garden pea should be irrigated with micro-sprinklers. For maximizing production and economics micro-sprinkler irrigated pea crop should be irrigated with water depth of 0.8 times cumulative pan evaporation. For obtaining higher net returns pea crop should be fertigated with 50 per cent of recommended NK. Interaction effects on pod yield and economics also indicate clearly that saving of 50 % of recommended NK can be achieved, if sprinkler irrigated pea crop is irrigated with water depth of 0.8 times CPE.

Table 2.12.1: Interaction effect of NK fertigation and irrigation schedule on net returns (`/ha^{-1}) of green pea

Irrigation schedule	NK fertigation			
	2011-12		2012-13	
	50 % of Rec.	100 % of Rec.	50 % of Rec.	100 % of Rec.
CPE = 0.4	78110	109350	106716	101880
CPE = 0.6	107610	83850	115816	108846
CPE = 0.8	117610	116850	143682	114980
CPE = 1.0	106860	79600	108116	103113
CD (P = 0.05)	23356		7694	

Table 2.12.2 : Interaction effect of NK fertigation and irrigation schedule on WUE of green pea (kg of green pods m^{-3} of irrigation water used)

Irrigation schedule	NK fertigation			
	2011-12		2012-13	
	50 % of Rec.	100 % of Rec.	50 % of Rec.	100 % of Rec.
CPE = 0.4	5.60	7.34	6.72	6.89
CPE = 0.6	4.60	4.14	4.72	4.78
CPE = 0.8	3.67	3.84	4.10	3.71
CPE = 1.0	2.75	2.41	2.71	2.78
CD (P = 0.05)	0.62		0.23	

2.13 Rahuri

Effect of fertigation and irrigation regimes on soil properties, yield and quality of Turmeric

The studies revealed that significantly highest no.of tillers and plant height were observed under 0.9 CF. The no.of tillers, and plant height were significantly highest under the treatment 100% GRDF through W.S.F. The yield kg plot^{-1} were significantly highest under the treatment 0.7 CF being at par with the treatment 0.9 CF. The treatment with 100% GRDF through WSF was significantly highest for above parameter. The data pertaining to water applied and WUE are depicted in Table 2.13.1 which revealed that the highest total water was applied in the treatment 0.9 CF while highest WUE was in the treatment 0.5 CF. Similar trend was also observed in water saving due to drip irrigation as compared to surface irrigation i.e an saving of water in the range of 52 to 67% was observed. Secondly, as far as fertigation levels are concerned, highest water use efficiency was observed under the treatment 100% GRDF through WSF. The available N is significantly highest under the treatment 0.7 CF. Significantly highest Ec was observed under 100% GRDF through conventional method. The available N content was significantly highest under the treatment with 100% GRDF through WSF. The interactions was significant for available N. The fertilizer use efficiency was highest under the treatment drip irrigation with 0.7 CF, highest FUE was observed under the treatment 100% GRDF through WSF with P and K as basal dose and only urea through drip. The fertilizer saving was attained upto 25% due to WSF. This could save

25% of fertilizers. The highest curcumin content was observed in the treatment with 0.7 CF. The treatment with 100% GRDF through WSF has the highest curcumin content. Drip irrigation with 0.5 CF treatment had more nutrient balance. While in fertigation levels also the nutrients were in balance for GRDF through conventional and only urea through drip and 50% WSF treatments. So for Irrigating turmeric crop with 0.7 composite factor along with fertigation of water soluble fertilizer at 75% the recommended dose of fertilizer was found to have higher yield, growth attributes, water and fertilizer use efficiency and water and fertilizer saving further maintaining the soil health. The above treatments are at par with 0.9 CF and 100% RDF through conventional method of fertilization.

Effect of nitrogen splitting and foliar sprays using surface and drip irrigation methods for yield maximization in Bt. cotton under command areas:

Application of RDF of nitrogen in 6 splits (T_5) through drip irrigation was found to be beneficial as regards to the growth parameters, yield attributes, quality and soil health over the surface irrigation. The data in table 14 regarding the water applied and water use efficiency revealed that the total water applied under surface irrigation was 85.64 cm for all the treatments but under drip irrigation total water applied was only 55.75 cm. The WUE was highest under the treatment T5 (60.31 kg ha^{-1} cm) under surface irrigation. The WUE in drip irrigation was highest under the treatment T_5 (100.30 kg ha^{-1}-cm). There was overall water saving of 35% as well as the reddening intensity was also low through drip irrigation over surface irrigation. The treatment with application of nitrogen in 3 equal splits with support of foliar application of 2% KNO_3 at 60, 75 and 90 DAS also recorded at par results with T_5 treatment, under drip as well as surface irrigation.

Effect of integrated nutrient management under different irrigation methods on soil health, yield and storability of *rabi* onion

The drip irrigation at alternate day as per ETc is found to be the best for yield, quality, water saving and efficiency and storage studies followed by micro-sprinkler irrigation.The data in Table 11 revealed that the highest water was applied in surface irrigation as compared to drip and sprinkler irrigation, but the highest water use efficiency amongst the irrigation methods was observed in drip irrigation followed by micro sprinkler irrigation. The highest WUE was also observed under the treatment RDF along with 5 tonnes of FYM ha^{-1} and at par with vermicompost. The lower WUE was in control plot. The water saving was also highest under the treatment drip irrigation compared to micro sprinkler irrigation. Amongst the INM treatments, the 100% recommended dose of fertilizer (100:50:50 kg ha^{-1} NPK) along with 5 tonnes of FYM ha^{-1} was found to be the best with respect to yield, quality and storage studies of rabi Onion.

Table 2.13.1: Water applied and water use efficiency for *rabi* Onion as influenced by irrigation regimes and fertilizer levels

Treatment	Yield (t ha^{-1})	Water applied (cm)	Effective rainfall (cm)	Total water applied (cm)	Water use efficiency (kg ha^{-1} cm)	Water saving (%)
a) Irrigation Methods						
1. Drip irrigation at alternate day as per ETc	33.55	79.97	00	79.97	419	34.15
2. Micro sprinkler irrigation at alternate day as per ETc	26.93	88.86	00	88.86	303	26.83
3. Surface irrigation at 50 mm CPE	21.21	121.43	00	121.43	175	-
b) INM						
Control	12.50	96.75	00	96.75	129	20.32
RDF through NPK	24.46	96.75	00	96.75	253	
AST (As per Soil Test)	30.19	96.75	00	96.75	312	
RDF through NPK + FYM @ 10 t ha^{-1}	36.76	96.75	00	96.75	380	
RDF through NPK + PMC (on the basis of N content of FYM)	26.93	96.75	00	96.75	278	
RDF through NPK + Vermicompost (on the basis of N content of FYM)	32.15	96.75	00	96.75	332	

2.14. Sriganganagar

Studies on irrigation scheduling in winter planted tomato under low tunnel in cotton based drip irrigation system

The studies revealed that the maximum water (826.1 mm) was used in surface irrigation treatment and the least water (431.3 mm) was used in 0.6 ETc treatments.The water expense efficiency was higher in the drip-irrigated (without low tunnel) treatment (20.77 kg/ha mm) as compared to flood irrigation and drip-irrigated with low tunnel treatments (Table 2.14.1).

Table 2.14.1 : Effect of different irrigation treatments on water use and expense efficiency (2012-13

Irrigation schedule	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm)*	WEE (kg/ha mm)
I1 = 0.6 Etc (LT)	96.1	335.2	431.3	11.91
I2 = 0.8 Etc (LT)	96.1	428.5	524.6	13.25
I3= 1.0 Etc (LT)	96.1	523.3	619.4	12.60
I4 = 1.2 Etc (LT)	96.1	612.8	708.9	10.58
I5 = 1.0 Etc (WLT)	96.1	541.5	637.6	20.77
I6 = Control	96.1	730.0	826.1	14.54

*Including 100 mm pre-sowing irrigation in flood irrigation

It was observed that the fruit yield of tomato increased significantly with increasing level of irrigation water only up to 0.8 Etc with low tunnel. Further increase in irrigation water did not increase the yield of tomato significantly. In pooled data, the maximum fruit yield of tomato (566.54 q/ha) was recorded with drip irrigation at 1.0 Etc (LT) which was at par with the yield received with 0.8 Etc (LT) and 1.2 Etc (LT).

Table 2.14.2: Effect of drip irrigation on fruit yield of tomato

Treatments	2010-11	2011-12	2012-13	Pooled
0.6 Etc (LT)	530.06	826.05	51.36	469.16
0.8 Etc (LT)	613.64	970.25	69.51	551.13
1.0 Etc (LT)	630.00	991.60	78.02	566.54
1.2 Etc (LT)	650.93	939.88	75.00	555.27
1.0 Etc (WLT)	744.51	268.73	132.41	381.88
Control	525.49	202.47	120.12	282.70
SEd	29.90	34.50	5.97	26.50
CD at 5%	65.16	75.17	13.00	57.73

Etc through drip (LT) ; Control (Surface irrigation at IW/CPE 1.0) (LT)

Optimum irrigation schedule for fodder sorghum under sprinkler irrigation system:

The experiment revealed that the water expense efficiency (81.86 kg/ha mm) was higher in I_1 treatment (IW/CPE 0.5) followed by I_4 treatment (IW/CPE 1.1) as compared to rest of irrigation treatments. The green, sun dry and oven dry forage yield and plant height of sorghum was influenced by the level of irrigation significantly. The green forage yield of sorghum increased significantly with every increase in the level of irrigation water up to IW/CPE 0.9 (493.19 q/ha). Further increase in irrigation level increased in fodder was not significant. Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum.

Table 2.14.3: Effect of different irrigation treatments on water use and expense efficiency

Treatments	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm) *	WUE (kg/ha mm)
0.5 IW/CPE (3)**	211.7	280	491.7	81.86
0.7 IW/CPE (4)	211.7	340	551.7	75.22
0.9 IW/CPE (5)	211.7	400	611.7	74.383
1.1 IW/CPE (6)	211.7	460	671.7	80.77
Control (Surfaceirrigation) (4)	211.7	420	631.7	78.36

*Including pre sowing irrigation (100 mm)

** Figures in parenthesis indicate the number of irrigations applied

Studies on irrigation scheduling for fodder oat through sprinkler:

The studies revealed that the maximum water use efficiency of 355.68 kg/ha mm was recorded with the treatment IW/CPE 0.5. The minimum water use efficiency was recorded with flood irrigation treatment. The green forage yield of oat was influenced by the level of irrigation significantly during both the years 2011-12 and 2012-13. The maximum green forage yield was recorded when irrigation was applied at IW/CPE 1.1. During 2012-13, the maximum plant height, dry fodder yield and oven dry fodder yield was also recorded with irrigation at IW/CPE 1.1.

Table 2.14.4: Effect of different irrigation treatments on water use and expense efficiency (2012-13)

Treatments	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm) *	WUE (kg/ha mm)
IW/CPE 0.5(1)** 09.11.12	10.8	60	170.8	355.68
IW/CPE 0.7(2) 08.11.12, 29.12.12	10.8	120	230.8	288.13
IW/CPE 0.9 (2) 07.11.12, 11.12.12	10.8	120	230.8	306.54
IW/CPE 1.1 (3) 06.11.12, 05.12.12 & 17.01.13	10.8	180	290.8	276.82
Control (Flood) (3) 12.11.12, 19.12.12 & 21.01.13	10.8	225	335.8	202.50

Studies on irrigation scheduling in winter planted chilli under low tunnels in cotton based drip irrigation system:

The studies revealed that the water expense efficiency was higher in the drip-irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 45.21 kg/ha mm was recorded under I_1 (0.6 Etc by drip system), followed by 39.43 kg/ha mm under I_2 (0.8 Etc by drip system) treatment. It may be concluded that, the fruit yield of chilli significantly increased with increase in the level of applied water up to 1.0 ETc. When the water level further increased (1.2 ETc) over 1.0 ETc, the difference in the fruit yield was non significant. The fruit yield of chilli (327.04q/ha) was recorded with drip irrigation at 1.0 ETc (LT) was statistically at par with that of 1.2Etc (LT) (324.88q/ha) and significantly higher than other treatments tested in the study. Thus drip irrigation at 1.0 ETc with low tunnel was found optimum irrigation schedule for chilli. It gave 47.38 % higher fruit yield of chilli and saved 9.55 % irrigation water over conventional surface irrigation and 83.58 % higher fruit yield of chilli and saved 3.23 % irrigation water over 1.0 ETc without low tunnel.

Table 2.14.5: Effect of different irrigation treatments on water use and expense efficiency

Irrigation schedule	**Effective rainfall (mm)**	**Irrigation water a pplied (mm)**	**Total water use (mm)**	**WEE (kg/ha mm)**
I1 = 0.6 ETc through drip (LT)	124.1	484.3	608.4	45.21
I2 = 0.8 ETc through drip (LT)	124.1	629.6	753.7	39.43
I3 = 1.0 ETc through drip (LT)	124.1	775.1	899.2	36.37
I4 = 1.2 ETc through drip (LT)	124.1	920.5	1044.6	31.10
I5 = 1.0 ETc through drip (WLT)	124.1	805.1	929.2	19.17
I6 = Control (Surface irrigation at IW/CPE 1.0)	124.1	870	994.1	22.32

Studies on response of chilli to fertigation

The studies revealed that the water expense efficiency was higher in the drip-irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 42.84 kg/ha mm was recorded under 100% RD in 9 splits closely followed by 120% RD treatment. Different fertilizer treatments significantly influenced chilli yield. The maximum chilli yield was recorded with 100 % RD and it was at par with 120% and 80 % RD treatments. The minimum chilli yield was recorded under flood irrigation treatment. Thus, 80 per cent recommended dose of fertilizer in 9 equal splits each at an interval of 13 days was found optimum dose for fertigation in chilli.

Table 2.14.6: Effect of different irrigation treatments on water use and expense efficiency

Irrigation schedule	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm)	WEE (kg/ha mm)
120 % RD	123.9	691.6	815.5	42.73
100 % RD	123.9	691.6	815.5	42.84
80 % RD	123.9	691.6	815.5	39.94
60 % RD	123.9	691.6	815.5	36.02
Flood	123.9	925.0	1048.9	21.02

Table 2.14.7: Effect of different fertigation treatments on yield and yield attributes of chilli

Treatments	Plant population (per plot)	Yield (kg/plant)	Yield (q/ha)	Fertilizer use efficiency (kg/kg NPK)
120% of RD	114.00	1.65	348.47	92.33
100% of RD	114.00	1.66	349.34	111.08
80% of RD	114.67	1.54	325.72	129.46
60% of RD	114.33	1.39	293.78	155.69
Control (RP)	108.33	1.10	220.46	70.10
S Ed	3.24	0.10	23.07	--
CD at 5%	NS	0.24	53.21	--

Studies on optimum irrigation schedule for Bt cotton through drip under plastic mulch

The results revealed that the maximum seed cotton yield was recorded when drip irrigation scheduled at 1.0 ETc (control). The mulching treatment has no any significant effect on the seed cotton yield; however, it saved the irrigation water. The yield recorded at 1.0 ETc without plastic mulch was statistically at par with seed cotton yield obtained at 0.8 Etc with plastic mulch. Increasing levels in irrigation water increased the seed cotton yield significantly up to 0.8 ETc with plastic mulch and 1.0 ETc without mulch.Thus, drip irrigation to Bt cotton at 0.8 ETc was found optimum. This treatment saves 14.86 % of irrigation water even over drip irrigation scheduled at 1.0 ETc without plastic mulch.

Table 2.14.8: Response of different treatments on Yield attributes and seed cotton yield

Treatments	Plant population 000/ha	No. of ball /Plant	Ball weight (gram)	Ball weight/ Plant(gram)	Seed cotton yield(q/ha)	WEE (kg/ha/ mm)
Mulch						
M_1-Raised bed PM	16.19	64.15	3.26	211.46	24.78	4.03
M_2-Raised bed WPM	16.79	59.32	3.86	226.69	23.55	3.65
M_3-Flat bed PM	16.45	60.10	3.82	227.24	25.80	4.24
Control	17.96	72.27	3.23	232.94	30.86	4.02
SEm$\pm$	0.27	1.68	0.13	6.86	0.54	
CD 5%	NS	NS	0.39	NS	1.59	
CD (Control/Mulch)	NS	7.91	0.62	NS	2.51	
Irrigation Levels						
I_1-0.4 ETc	16.48	53.24	3.49	184.25	19.07	3.88
I_2-0.6 ETc	16.30	60.02	3.65	220.19	22.65	3.92
I_3-0.8 ETc	16.52	65.56	3.62	233.35	27.43	4.14
I_4-1.0 ETc	16.61	65.93	3.82	249.30	29.69	3.96
SEm$\pm$	0.31	1.94	0.15	7.92	0.62	
CD5%	NS	5.77	NS	23.52	1.84	

Studies on response of tomato to fertigation under low tunnel

The water expense efficiency was increased with increasing levels of fertilizer application up to 120% RD of nutrient. The maximum water expense efficiency of 12.99 kg/ha mm was recorded under application of 120%RD of nutrient, followed by 12.06 kg/ha mm under application of 100%RD of nutrient. The fruit yield of tomato significantly increased with every increase in fertilizer level with drip irrigation up to the application of 80 % RD of nutrient. After that, the increase in yield was not significant. The maximum fruit yield of tomato (80.43 q/ha) was recorded with conventional surface irrigation with the application of recommended dose of nutrients which was significantly higher as compared with the application of 60 percent of recommended doses of nutrients and at par with 80, 100 and 120 percent of nutrient application with drip irrigation under low tunnel. The low yield in tomato was mainly due to poor bearing of fruits during the season mainly as a result of viral infection.

Table 2.14.9: Effect of different irrigation treatments on water use and expense efficiency

Irrigation schedule	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm)	WEE (kg/ha mm)
60%RD	96.1	523.3	619.4	7.37
80%RD	96.1	523.3	619.4	11.17
100%RD	96.1	523.3	619.4	12.06
120%RD	96.1	523.3	619.4	12.99
Flood	96.1	730.0	826.1*	9.22

*Including 100 mm pre-sowing irrigation in flood irrigation

Theme III

Management of rain and other natural sources of water

3.1 Almora

Water storage dynamics revealed that the lowest volume water reached in Julian day 153 and it started filling 154 Julian days onwards and reached maximum depth i.e. 135 cm at 188 Julian days. The runoff started flowing in tank during June 2013; from Julian day 154 days onwards and it became full by Julian day 188and later on water ranged 1it maintained up to 266 and later on it start declining. The runoff water was harvested from upper catchment (1200 m^2) in LDPE lined tank for providing supplementary irrigation to wheat crop. There was 45.9 per cent higher wheat yield obtained with supplementary irrigation in comparison to rain fed (18.9 q/ha) (Table 3.1.1). The highest grain yield was with the application of FYM @ 10 t/ha + recommended NPK both seasons followed by application of FYM @ 10 t/ha +50 % recommended NPK in both seasons. Similar trend was observed with regard to WEE, WUE, gross returns and gross returns per mm water use

Table 3.1.1 Grain yield and water use of wheat under supplementary irrigation and nutrients

Treatments	Grain yield (q/ha)	PMC (±)	Irrig. (mm)	WE (mm)	WEE (kg/ha/mm)	WUE (kg/ha/ mm	Gross returns (000 Rs/ha)	Gross returns (per mm water use in Rs/ha)
Irrigation								
Rain fed	18.9	-35.6	0.0	287.3	6.6	8.5	39.1	136.2
Supplementary irrigation	27.5	-32.5	100.0	384.2	7.2	8.6	53.3	138.8
CD (P = 0.05)	2.53				NS	NS	4.24	NS
Fertilizer treatments								
Control	9.3	35.5	50.0	337.2	2.6	3.2	16.8	48.0
FYM	20.8	33.2	50.0	334.9	6.3	7.9	41.6	126.1
Application of FYM 10t/ha + NPK in both seasons	33.4	32.8	50.0	334.5	10.0	12.5	67.3	202.8
Application of FYM 10t/ha + 50 % NPK in both seasons	27.2	-36.0	50.0	337.7	8.0	9.9	55.8	164.7
NPK in both seasons	22.6	37.1	50.0	338.8	6.7	8.3	43.8	129.5
10t FYM in Kharif + NPK in Rabi	25.8	29.8	50.0	331.5	7.6	9.5	51.9	154.0
CD (P = 0.05)	4.38				1.37	1.73	7.34	22.79

Total rainfall= 251.7 mm, Effective rainfall = 187.3 mm

There was significantly mean higher yield of soybean obtained in plots those received supplementary irrigation in wheat in comparison to rain fed plots. However, irrigation was not applied in *kharif* season. The yield enhancement might be due to improvement in nutrient and water reserve of the soil due to supplementary irrigation in wheat crop. The significantly higher yield was obtained with the application of FYM @ 10 t/ha +recommended NPK followed by application of FYM applied @ 10 t/ha + 50 % recommended NPK. The yield obtained by the application of FYM applied @ 10 t/ha and FYM applied @ 10 t/ha + 50 % NPK were at par with each other. Similar trend was observed with regard to WEE, WUE, gross returns and gross returns per mm applied water (Table- 3.1.2)

Table 3.1.2: Grain yield and water use of soybean under irrigation and nutrients

Treatments	Grain yield (q/ha)	PMC (±)	WE (mm)	WEE (kg/ha/mm)	WUE (kg/ha/mm	Gross returns (000 Rs/ha)	Gross returns (per mm water use in Rs/ha)
Irrigation							
Rain fed	16.0	522.4	522.4	3.1	4.1	51.9	99.5
Supplementary irrigation	19.2	524.1	524.1	3.7	4.9	61.0	116.8
CD (P = 0.05)	2.38			0.46	0.62	6.33	12.13
Fertilizer treatments							
Control	8.2	526.8	526.8	1.6	2.1	24.5	46.5
FYM 10t/ha in both season	21.7	520.9	520.9	4.2	5.6	70.0	134.5
Application of FYM 10t/ha + NPK in both season	27.0	521.7	521.7	5.2	7.0	87.1	167.0
Application of FYM 10t/ha + 50 % NPK in both season	22.8	522.2	522.2	4.4	5.9	74.9	143.5
NPK in both season	8.7	526.6	526.6	1.7	2.2	26.6	50.4
10t FYM in Kharif + NPK in Rabi	17.2	521.4	521.4	3.3	4.4	55.7	106.9
CD (P = 0.05)	4.12			0.79	1.07	11.0	21.0

In artificial-recharging techniques for hill springs, One of the springs located at VPKAS Hawalbagh farm was selected to revive because its discharge was greatly reduced due to heavy construction on its catchments. Therefore, recharging of ground water became zero. The roof water as well as surface water was harvested in trenches along with plantation on trenches to avoid evaporation and enhance time of concentration of water to increase the water concentration in aquifer recharging zone. The comparative study revealed that the five year mean annual discharge of the spring was higher 73.2, 100.7,114.2,and 135.9 per cent during 2006-2010, 2007-2011, 2008-2012 and 2009-2013, respectively in comparison to annual discharge recorded during 2000 before the inception of the treatments. Although five yearly mean annual rainfall was below by -19.4, 13.5, -15.5, and -13.6 percent in 2006-2010, 2007-2011, 2008-2012 and 2009-2013, respectively in comparison to year 2000.The annual discharge was 181.2 percent higher during 2013 in comparison to discharge recorded before treatment inception in 2000. The discharge and rainfall relationship was worked out including the data before the treatment inception and after the treatment inception excluding the before treatment inception. There was strong correlation between discharge and rainfall after treatment inception in comparison to before treatment inception. It showed that the treatments enhanced water percolation in soil. Therefore the correlation between discharge and rainfall increased. The discharge of spring greatly increased during lean period in comparison to discharge recorded in 2000.

Studies on the suitability of locally available covering material to protect pond lining Material from UV radiation and physical damages

The preliminary observation revealed that the LDPE/ silpaulin film alone lined tank (without any covering) damaged due to high temperature variation and also physical damage caused by a wild animal**.** The polythene covered with 40 % soil + 60 % stone filled plastic bags, or LDPE film covered with Agave leaf filled bags+ Soil or LDPE film covered with pine needles + soil, filled plastic bags got damage. There is a need to analyze water quality in the case of agave and pine needles tank.The LDPE / silpaulin film covered with round boulders bricks, and cement and stone/gravel blocks (Made locally) are working properly. There was no damage recorded in these tanks. The cement and stone/gravel blocks (Made locally) are very economical. The cement and concrete blocks do not required more technical knowledge and these can be made by farmers easily.The Preliminary study indicates that four treatments were found suitable to protect LDPE film from damage.LDPE film covered with cement and stone/gravel blocks (Made locally) +soil found very economical and suitable. The LDPE film also can be covered with round stone, bricks + soil, LDPE covered with a soil is also found suitable. The survey will also be under taken with structured questionnaire in order to know farmers point of view about the treatments simplicity, applicability, durability and economical feasibility. Further study will be taken with respect to percolation of water in these lined ponds/tanks and physical state of material over the time. The cost of tanks constructed with different methods and using different material is given in Table3.1.3.

Table3.1.3: Cost of tanks constructed with the help of different method and materials

	Cost (Rs)						Expected Life
Items	Cleaning	Excavation	Poly lining	Covering	Ball valve	Total cost	Years
LDPE	403	2485	2355	0	600	5843	2.0
LDPE+Tarfelt	403	2485	2355	2138	600	7981	3.0-5.0
LDPE + Block	403	2485	2355	2315	600	8158	>40.0
LDPE +Stone	403	2485	2355	2721	600	8564	>40.0
LDPE + Soil	403	3314	3720	664	600	8700	>15.0
Double LDPE+ Soil	403	2485	4710	664	600	8862	2.0
LDPE + Pine needle and soil filled bag on step	403	3314	3720	905	600	8941	2.0
LDPE + Ram bas and soil filled bag on step	403	3314	3720	905	600	8941	2.0
LDPE + Stone and soil filled bag on step	403	3314	3720	905	600	8941	2.0
Silpaulin alone	403	2485	5652	0	600	9140	2.0-5.0
Silpaulin + stone	403	2485	5652	2721	600	11861	>40
LDPE + Bricks	403	2485	2355	6222	600	12065	>40

Note: Above cost was estimated for Trapezoidal Tank Dimension (Top length=5.4 m, Top Width =4.0 m and depth 1.5 m)

Demonstration of LDPE film lined tank and MIS system at farmer's field

The micro- water recourses (capacity 300 m^3 in 2013-2014) and total water capacity 2277 m^3 under AICRP on water management project was developed in a farmer's field in previous years in three villages of Almora district by harvesting surface and runoff water. The drip system installed around 500 m^2 area in 2013-2014 on selected farmers to enhance water productivity. The MIS system has been installed at five farmer's field around 3921.0 m^2 in last year. The main line was laid out in last year as well as this year in some farmer's field. This area is extra area and not reported here. The area will be reported with farmers wise after laying lateral in the fields as per the water availability and farmers requirement. The practical know how knowledge was given to farmers and also how to maintain drip system.

3.2 Chalkudi

In-situ rainwater harvesting through micro catchments and its effect on coconut yield

The experiment aimed in studying the effect of micro-catchment water harvesting on growth and yield of coconut in comparison with drip irrigation and rainfed control. The experiment was started in 2006 and concluded in 2012. The data on nut yield and soil moisture status are given below. During 2010 nut yield could not be recorded as the area was affected by fire in summer.

Table3.2.1: Pooled data on yield and other growth parameters

Treatment	Yield (nuts/plant/ year)	Number of bunches/ year	Number of leaves/ year	B:C ratio
T_1 – Micro catchment water harvesting	**47.33**	8.17	12.71	**1.42**
T_2 – Drip irrigation at 75% pan evaporation	**41.25**	7.78	14.10	1.13
T_3 – Rain fed (control)	35.91	7.93	12.69	1.10
CD (5%)	9.773	NS	0.9568	0.2829

The treatment with micro catchment recorded the highest yield which was on par with drip irrigation at 75% PE and significantly superior to rainfed control. The micro catchment water harvesting plots recorded the highest B:C ratio also. Soil moisture studies at different depths showed that moisture content was higher at greater depths compared to rainfed and comparable with irrigation at 75 % PE. This technology involves less expenditure compared to drip irrigation. The bund needs to be raised in the initial stages only and from subsequent years only maintenance is required

3.3 Jammu

Techno-economic feasibility of surface/sub-surface pipe irrgation system within the canal command area of Jammu region

In view of the substantial conveyance losses in terms of seepage occurred in canal command system, the water productivity is quite less in general and *kharif* season in particular. To overcome the same, the surface/sub-surface pipe irrigation system may be explored in the Ranbir/Tawi-lift canal system. In this count, a case study was undertaken at Chakroi Farm of the University (falling under the tail end of the Ranbir canal).

Table 3.3.1: Salient features of sub-surface irrigation system

S. No.	Particulars	Specifications
1.	Area covered under irrigation system	50 Acres
2.	Source of water	Ground Water of 100 to 150 mm dia outlet
3.	Total length of the system	2,300 mt
4.	Depth of system	0.75 to 1 meter
5.	No. of hydrants installed of 100 mm Dia	36 numbers
6.	Tentative cost as on date per unit length (subject to variation from site to site)	Rs.550/- per meter (Approx.)
7.	Cropping pattern	Rice-Wheat rotation
	Constraints	Susceptible to breakage by unscrupulous elements

Modeling for planning the conjunctive use of water at basin level within the canal commands of Jammu.

For enhancing the water productivity across the Ranbir canal, it is imperative to assess the supply and demand gap of canal water supply. To that end, only D-3 data are available and other data of distributaries are in progress. The designed irrigation distribution system of D-3 command comprises of 6 km long lined water course of main distributary with 51 outlets and two minors each with 2 km long water courses (Rt. Minor with 21 outlets branching from main RD 150 m and Lt. minor with 18 outlets branching from main at RD 1400 m). Irrigation water is being drawn through these 90 outlets, although the number of originally designed outlets was only 59. The designed discharge capacity through the head of distributary is 35 cusecs and that through each of the two minors is 5 cusecs. This designed discharge capacity stands altered drastically due to poor maintenance of the canal system, interference by way of illegal drawals through cuts affected on water courses. Thus, the level of discharge rates at major sections of water courses and through outlets as well as drawl and spread of water into the fields varies drastically with seasonal demands.

The observations are underway for Baspur Minor, Samka Minor, Khanachak Minor, and Katyal Minor (under D-10A) regarding fortnightly discharge measurements at head-reach, mid-section and tail-ends of water courses with the corresponding tube-well density along with their discharges for groundwater supply. Relevant data will be collected with regard to design of canal system, operation schedule, and comprehensive information about the command with respect to topography, cropping pattern, crop productivity, socio-economic constraints, physical constraints, groundwater potential, and meteorological data have been planned. The stage-wise crop water demand will be assessed by deploying the CROPWAT software. As such, the suitable interventions will be made for enhancing water productivity of particular minors through a suitable conjunctive use of water resources. Further research work is in progress.

3.4 Jorhat

Effect of surface drainage on *kharif* sesamum:

The results on seed yield of sesamum indicated that the provision of surface drains at 6 m spacing greatly helped in increasing the yield of sesamum. The crops with drains produced mean seed yield of 6.55 q/ha against 4.82 q/ha under farmers' practice. Thus it is evident that the provision of surface drainage in sesamum is very much essential for crop establishment and subsequent crop growth which led to increase the yield by 35.89 per cent over the conventional farmers' practice of no drains.

Table 3.4.1: Effect of surface drainage on *kharif* sesamum

Seed yield (q/ha)		% increase
Farmers' practice (without surface drain)	With surface drain at 6 m interval	
5.68	7.45	31.72
4.30	5.85	36.04
3.80	5.83	53.42
5.25	6.33	20.57
5.06	7.31	44.47
4.82	6.55	35.89

Effect of tillage and legume mulching on seed and stover yield and water use of rapeseed

Different legume mulching practices followed in baby corn had no significant influence on the seed and stover yield of rapeseed. However, seed and stover yield were significantly influenced by tillage practices. Conventional tillage with irrigation at flowering increased seed and stover yield of rapeseed significantly followed by one cross ploughing + rice straw mulching. Conventional tillage + irrigation at flowering also recorded the highest water use. The highest WUE was recorded by one cross ploughing + rice straw mulching (94.8 kg/ha-cm) followed by conventional tillage + irrigation at flowering (88.1 kg/ha-cm). Rapeseed equivalent yield of the system was not significantly influenced by different mulching treatments. Among the tillage practices, conventional tillage with irrigation at flowering being at par with one cross plouging by power tiller (reduced tillage) + rice straw mulching recorded significantly higher rapeseed equivalent yield than one cross ploughing by power tiller and conventional tillage. The highest WUE of the system was recorded by one cross ploughing + rice straw mulching (229.86 kg/ha-cm) as shown in the Table3.4.2.

Table 3.4.2: Effect of tillage and legume mulching on seed and stover yield and water

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Water used (cm)	WUE (kg/ha-cm)	Rapeseed eq. yield (kg/ha)	Water used by the system (cm)	WUE of the system (kg/ha-cm)
Legume mulch							
M_1	690.3	1131.3	11.12	62.1	5047.86	25.97	194.37
M_2	720.9	1179.2	11.42	63.1	5241.99	26.63	196.85
M_3	707.0	1159.7	11.19	63.2	5173.84	26.29	196.80
SEm ±	9.9	16.0	-	-	125.9	-	
CD (0.05)	NS	NS	-	-	NS	-	
Tillage							
T_1	579.7	951.9	7.31	79.3	4960.8	22.32	222.26
T_2	551.1	900.9	7.80	70.7	4995.7	22.83	218.82
T_3	754.6	1235.2	7.96	94.8	5307.5	23.09	229.86
T_4	938.9	1538.9	10.66	88.1	5354.3	25.70	208.34
SEm ±	24.5	40.5	-	-	94.2	-	-
CD (0.05)	72.9	120.4	-	-	279.9	-	-
Interaction	NS	NS	-	-	NS	-	-

Legume mulch (in baby corn) :M_1 = No mulch; M_2 = Cowpea; M_3 = Dhaincha

Tillage (in *rabi* crops)

T_1 = Conventional tillage

T_2 = One cross plouging by power tiller (reduced tillage)

T_3 = One cross plouging by power tiller (reduced tillage) + Rice straw mulching

T_4 = One irrigation at flowering (30-35 DAS) + conventional tillage

3.5 Navasari

3.5.1 Cluster based MIS demonstration in tribal area

Navsari centre has developed large number of technologies related to MIS, mulching and fertigation in different crops of Gujarat. In order to promote MIS in tribal areas, Govt. of Gujarat has enhanced the subsidy up to 75 per cent as against 50 per cent in plain and coastal areas of the state. For popularizing MIS in tribal areas, Navsari centre has arranged 4 MIS demonstrations on farmers' fields in vegetable crops during *rabi* and summer seasons of 2011-12 and during 2012-13 another 12 demonstration were taken up.

Location:

The village Vanarashi is situated in Vansda taluka of Navsari district representing the eastern hilly areas of South Gujarat. In Vanarashi village majority of the farmers are having less than 2 acre land holding with fragmented units of less than one acre. The water resources are seasonal streams and low yielding dug-wells and bore wells having less than 10000 l/hr discharge capacity. In this village, not a single farmer has adopted MIS yet due to very small, fragmented land holding and poor economic conditions as well as less confidence in MIS technology. They are not ready to adopt MIS at their own cost. During our meeting with villagers, four farmers have shown interest for installing drip irrigation system in *rabi* season vegetable crops. Another 12 demonstrations were arranged in different vegetable crops in tribal areas of Vansada taluka at Vanarasi village and the crop condition is excellent. The results of the four demonstrations are given in table 3.7.1.

Results and interpretation

During the year under report, out of four farmers two grown bitter gourd and one each grown smooth gourd and water melon crop. Among the crops, higher net income of Rs. 26000/0.2 ha was realized with bitter gourd crop and the lowest net income of Rs. 16100/0.25 ha area was realized with water melon (Table 3.7.1). For increasing area under MIS in tribal area, another 12 demonstrations have been arranged and presently, the crop condition is good.

Table 3.5.1: The details regarding MIS demonstration (2013)

Name of farmer	Crop	Area (ha)	Yield (kg)	Crop duration (months)	Net profit (Rs)
Rajubhai Chhanabhai	Bitter gourds	0.20	3200	6	20600
Navanitbhai Bhagubhai	Bitter gourds	0.20	3900	6	26000
Nareshbhai Ramanbhai	Smooth gourds	0.25	2100	8	19500
Saileshbhai Vasantbhai	Watermelon	0.25	3350	4	16100

Selling price: *Bitter gourd @ 8 Rs/kg, Smooth gourd @ 15 Rs/kg and water melon @ 6 Rs/kg*

Rain water harvesting by adopting dam (Rubber Dam) technology and MIS for efficient utilization of harvested rain water in tribal area

A reconnaissance survey for selecting suitable site for installation of rubber dam in Gujarat at *Ranifalia / Vanarashi* village of *Vansda Taluka* of Navsari district was carried out by the scientists from DWM, Bhubaneswar in collaboration with the scientists from AICRP on Water Management, NAU, Navsari. Accordingly, necessary civil work for the installation of rubber dam at selected site has been completed and the installation of rubber will be completed by the end of March 2014. Further, for efficient utilization of rain water stored in rubber dam, we are planning to put MIS demonstrations in dam site areas. After group meeting with the farmers of the surrounding areas of the rubber dam site, we have selected **10** farmers for MIS demonstrations on different vegetable crops. The Micro Irrigation System (MIS) demonstration will be laid during ensuring *rabi* season on 2014-15. Further, the base structure for installation of rubber dam construction at three more sites is under progress and on completion of dam work, the *Schedule Tribe* (ST) beneficiaries will be selected and appropriate demonstrations will laid during *rabi* 2014-15 season.

3.6. Shillong

Zero energy based water harvesting (*Jalkund*) and its recycling for high value crop under hilly condition.

The demonstration on low cost micro rain water harvesting structure and their efficient utilization undertaken at different farmer's field viz; Nongsder village , Mawkhap and Sohpdok at Ri-Bhoi District. The harvested water is being used for growing vegetable crops; rearing livestock & poultry etc. the technology is getting immense popularity in different states of N.E. hill region.

Demonstration of in-situ soil moisture conservation in maize-toria cropping system in farmers' field

Demonstrations on in-situ soil moisture conservation in maize-toria cropping system were conducted in farmers' field at Mawlasnai village in Ri-bhoi District, Meghalaya. The result showed higher Maize equivalent yield under Maize + Groundnut intercropping system compare to farmer's practices of growing sole maize.The seed yield of mustard was higher under the treatment were Ambrosia @ 10t/ha was given which was followed by the treatment were Ambrosia @ 5t/ha was done compared to farmers' practice.

Basic study on soil-water-plant-atmospheric-environment relationship

4.1 Bilaspur

4.1.1 Lysimetric studies on consumptive use of rabi crop – lentil

Lysimetric studies on consumptive use of lentil revealed that the total crop evapotranspiration (ET_c) of the variety-K-75 is measured to be 15.05 cm. The crop coefficient (K_c) ranges 0.33-0.96 with average value of 0.70 for cropping period of 105 days (emergence to maturity). The total potential evapotranspiration (ET_o, estimated) is estimated 20.62 cm. The total pan evaporation (EVP) is calculated 30.54 cm.

Table 4.1.2: Evapotranspiration (mm/day) and Crop coefficient of Lentil in 2012-13

DAS	ETo	ETc	Kc
10	1.32	0.44	0.33
20	1.49	0.72	0.48
30	1.27	0.70	0.55
40	1.61	1.14	0.71
50	1.68	1.38	0.82
60	1.83	1.63	0.89
70	1.76	1.69	0.96
80	2.21	2.08	0.94
90	3.08	2.53	0.82
100	3.04	2.07	0.68
105	2.66	1.41	0.53

DAS: Days after sowing, ET_o: Potential Evapotranspiration, ET_c: Crop Evapotranspiration,

4.2 Chalakudi

Evaluation of surface and ground water quality across the state of Kerala and its effect on vegetation

As suggested by the expert committee relevant information about Chalakudy river,had to be collected before going for the detailed study. Hence, a pilot study was carried out about the Chalakudy river and the details are furnished below. Chalakudy river is indeed one of the heavily utilized rivers in Kerala. Six dams have been constructed across Chalakudy river starting from the late 1940s. The Chalakudy river diversion scheme (CRDS), a major irrigation scheme, has a weir of 3.96m height at Thumboormuzhi, 15kms east of Chalakudy town. The canal systems have a total length of 100kms for main canals and about 300kms for branch canals. The system caters to the irrigation needs of about 14000 ha. The scheme envisaged diversion through gravity of the natural flows in the river to adjacent water scarce areas for irrigation purpose. Apart from the above schemes there is another diversion, the Idamalayar diversion scheme which diverts a portion of monsoon inflow into the Peringalkuthu reservoir and empties into the Idamalayar reservoir in Periyar basin.

4.3 Dharwad

4.3.1 Sustenance of soil health and productivity of Maize – Chickpea cropping sequence in *vertisols* of Malaprabha command through integrated nutrient management.

The pooled results found that, significantly higher grain yield (76.78 q ha^{-1}) and fodder yield (125.5q ha^{-1}) was observed in RDF plus biofertilizer (*Azospirillum+PSB* @ 350 g/ha) with one row of sunhemp between two rows of maize compared with rest of the treatments.100% RDF grain yield (63.78 q ha^{-1}-fifth year and 64.3 q ha^{-1}-sixth year) was on par with 75% RDF plus biofertilizer (*Azospirillum+PSB* @ 350 g/ha) with one row of sunhemp between two rows of maize and maize stalk incorporation with cellulolytic culture (61.43 q ha^{-1}-fifth year and 63.9 q ha^{-1}-sixth year). This clearly indicates that, INM practices can save 25% chemical fertilizer and increase the availability and uptake of nutrients. Moisture regimes significantly influenced higher grain yield and water use efficiency (WUE) of maize. A higher grain yield of 69.73 q ha^{-1}was realized at I_1 moisture regime (IW/CPE = 0.8). However, water use efficiency was significantly influenced with respect to integrated nutrient levels. The significantly higher water use efficiency of 20.94 kg ha^{-1}-mm was found in RDF plus biofertilizer (*Azospirillum+PSB* @ 350 g ha^{-1}) with one row of sunhemp between two rows of maize as compared with rest of the treatments (Table 18).The uptake of NPK in maize were significantly superior at F3 (N ; 219.3 kg ha^{-1}, P ; 42.64 kg ha^{-1}and K ; 240.71 kg ha^{-1}).Higher nutrient availability in soil have supported maize crop for higher uptake of nutrients and production of grain and fodder yield of maize.

Table 4.3. 1: Effect of INM treatments and irrigation levels on WUE (kg/ha-mm) by maize:

Treatments	2007	2008	2009	2010	2011	2013	Pooled
Main-Irrigation levels							
I1 (0.8 IW/CPE)	13.00	20.75	19.13	14.60	19.28	15.79	17.10
I2 (0.6 IW/CPE)	15.09	23.78	18.50	14.43	20.18	16.89	18.08
I3 (0.4 IW/CPE)	14.72	22.35	18.11	14.52	22.92	19.39	18.60
SEm±	0.927	0.570	0.417	0.485	0.562	0.231	0.475
CD (0.05)	NS	2.240	NS	NS	2.206	0.905	1.495
Sub- INM Treatments							
F1= RDF	15.79	23.05	19.45	14.67	20.26	16.67	17.96
F2= RDF + BF (*Azospirillum* + PSB)	14.29	24.58	19.63	15.08	21.80	18.23	19.07
F3= RDF + BF + GM (one row of sunhemp between two rows of maize)	17.70	26.95	21.27	15.85	23.81	20.09	20.94
F4= 75% RDF + Maize stalk incorporation with cellulolytic culture +BF+ GM	13.15	20.96	18.36	13.88	19.43	16.60	17.06
F5 = 50% RDF + Maize stalk incorporation with cellulolytic culture+ BF+GM	10.42	15.91	14.25	13.14	18.66	15.20	14.59
SEm±	0.392	0.747	0.350	0.357	0.359	0.185	0.327
CD (0.05)	1.145	2.179	1.022	1.042	1.049	0.541	0.924
Interaction effect - Irrigation levels X INM Treatments							
SEm±	1.108	1.290	0.684	0.736	0.791	0.368	0.694
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

4.3.2 Effect of irrigation levels and land configurations for sustainable yield of maize-chickpea in in Malaprabha command

It was observed that a higher maize grain yield of 57.99 q/ha, gross income of Rs. 43459/ ha, net income of Rs. 26459/ ha and B:C ratio of 2.55 were obtained in irrigation level 0.4 IW/CPE. But all these are on par yield obtained in irrigation level 0.8 IW/CPE and 0.6 IW/CPE. A higher water use efficiency of 17 kg/ ha.mm was recorded with irrigation level 0.4 IW/CPE treatments. (Table 27). In land configuration treatments with 120 cm raised bed of Maize performed significantly superior in obtaining grain yield of 57.30 q/ha, gross income of Rs. 42,973 / ha, net income of Rs. 25,973 /ha and B:C ratio of 2.52 over the results obtained in maize planting on normal sowing with 60 cm raised bed. The interaction effect between irrigation and land configuration revealed that significantly higher grain yield of 63.57 q/ha, gross income of Rs. 47686/ ha, net income of Rs. 30686/ ha were obtained in irrigation level 0.8 IW/CPE with 120 cm raised bed planting. Land configuration with 120cm bed and Irrigation treatment with 0.6 IW/CPE yield on par with the other maximum yields. The water saving in irrigation level 0.6 IW/CPE was 25.36 and 20.36 per cent over 0.8 IW/CPE and 0.4 IW/CPE treatments respectively.

Table 4.3.2 : Effect of irrigation levels and land configurations on maize grain yield, economics and WUE during *Kharif*-2013.

Treatments	Maize Yield (q/ha)	WUE (Kg/ha-mm)	Gross income (Rs)	Net income (Rs)	B:C Ratio
Irrigation levels					
I_1 = 0.8 IW/CPE	52.04	11.73	39067	22036	2.30
I_2 = 0.6 IW/CPE	54.85	12.67	41136	24135	2.41
I_3 = 0.4 IW/CPE	57.99	17.00	43459	26459	2.55
SEm±	08.41	02.04	6300	6300	0.37
CD(0.05)	12.74	03.09	9542	9542	0.56
Land configurations					
L_1 = Normal	55.52	13.16	41650	24650	2.46
L_2 = 60cm raised bed	52.00	13.39	39007	22007	2.29
L_3 = 120 cm raised bed	57.30	14.85	42973	25973	2.52
SEm±	1.82	1.35	7068	7068	0.24
CD(0.01)	5.43	1.86	9684	9684	0.33
Interaction effect (I XL)					
I_1L_1	53.90	11.21	40442	23441	2.43
I_1L_2	51.65	12.12	38747	21747	2.28
$I_1 L_3$	50.57	11.85	37920	20920	2.23
I_2L_1	56.22	12.30	42157	25157	2.47
I_2L_2	50.57	12.00	37935	20935	2.30
$I_2 L_3$	57.75	13.72	43314	26314	2.55
I_3L_1	56.45	15.97	42352	25352	2.50
I_3L_2	53.77	16.05	40339	23339	2.37
$I_3 L_3$	63.57	18.97	47686	30686	2.80
SEm ±	3.16	1.35	7068	7068	0.42
CD (0.05)	9.40	1.86	9684	9684	0.57
SEm ±	03.55	2.35	7907	7907	0.47
CD(0.01)	10.54	2.60	10835	10835	0.64

4.3.3. Studies on site-specific nutrient management(SSNM) approach for irrigated maize under varied levels of irrigation under malaprabha command area:

Water Supply and nutrient demand in malrapha command is becoming an important issue. The site specific nutrient management (SSNM) is cost effective and plant need based approaches. It approach provide principle and tools for supply crop nutrients as and when needed to achieve higher yield. The SSNM approaches not specifically aim to either reduce or increase fertilizer use. Instead, they aim to supply nutrients at optimal rates and time to achieve higher yield and higher efficiency of nutrient use by the crop, leading to more net return per unit of fertilizer invested in malaprba command area.Among the irrigation levels, the crop receiving the irrigation level at 0.8 IW/CPE (I_1) recorded significantly higher maize grain yield (8.46 t/ha),gross income (Rs.103383/ha) and WUE over the other and also on par with the net income and B:C ratio of 0.6 IW/CPE. Nutrient management through fertilizer approach (SSNM), recoded significantly higher maize grain yield (8.89 t/ha), gross income (Rs.1,09,944 /ha), net income (Rs.77,570 / ha),B:C (3.54) and WUE (22.98 kg/ha-mm) were recorded in SSNM through fertilizer for targeted yield o f 14 t ha^{-1} over other target yields and also on par with net income and B:C ratio with application SSNM through fertilizer for targeted yield of 12 t ha^{-1} . Due to higher dose of nutrients, especially nitrogen, since doses of SSNM of treatments are set based on level of soil nutrient status such as low, medium and high. Interaction effects of irrigation s and SSNM through fertilizer for target yields levels were no significant for maize grain yield, economics and WUE except B: C ratio (Table 4.3.3).

Table 4.3.3 : Effect of irrigation levels and SSNM approach on B:C ratio and WUE (kg/ha-mm) of maize in maize –chick pea sequence during 2013

Treatments	B:C ratio			WUE		
	I1	I2	Mean	I1	I2	Mean
T1: SSNM through fertilizer for targeted yield of 8 t/ha	3.48	3.32	3.40	18.47	21.38	19.92
T2: SSNM through fertilizer for targeted yield of 10t/ha	3.51	3.34	3.43	19.12	22.43	20.77
T3: SSNM through fertilizer for targeted yield of 12 t/ha	3.54	3.37	3.46	20.10	23.69	21.89
T4: SSNM through fertilizer for targeted yield of 14 t/ha	3.65	3.43	3.54	21.05	24.92	22.98
Mean	3.55	3.37	3.46	19.69	23.11	21.39
	Sem±	CD at 5%	-	Sem±	CD at 5%	-
Irrigation(I)	0.05	0.20	-	0.37	1.46	-
Targeted Yields (T)	0.04	0.10	-	0.26	0.77	-
I X T	0.07	0.14	-	0.45	NS	-

4.4 Gayashpur

4.4.1 Study in water-nutrient dynamics in wheat in Gangetic alluvial plains of West Bengal

The crop evapotranspiration demand (Fig4.4. 1) at various crop growth stages showed maximum ETc demand in reproductive stage, followed by vegetative stage, moderate in seedling stage and least in ripening stage. This indicates that vegetative and in reproductive stages were more critical for higher water demand and needs optimum water supply. The water balance components and water use efficiency of wheat grown under three levels of NPK fertilizer doses, but same level of irrigation and rainfall situation is presented in following Table.

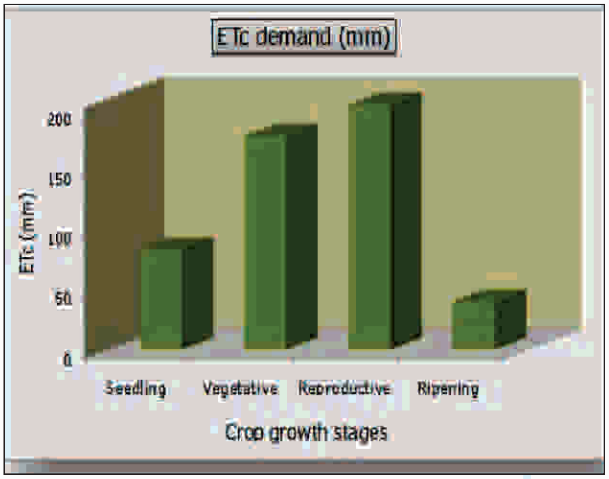

Fig.4.4.1 ET demand of crops

Table 4.4.1: Stage wise ET demand of the crop

Treatment	Rainfall (mm)	Irrigation (mm)	Soil water storage change (mm)	Seasonal ET (mm)	Grain yield (kg/ha)	WUE (kg/ha-mm)
F_1	99.0	173.53	79.77	192.76	1100	5.71
F_2	99.0	173.53	79.77	192.76	1220	6.33
F_3	99.0	173.53	79.77	192.76	1380	7.16

The above results indicated that the contribution of irrigation in water balance equation was 173.53 mm; while it was 99.0 mm for rainfall, a part of which was used for crop water requirement and a major part was likely stored in soil profile. The profile contribution in crop water requirement, as a whole, appeared to be nil. Seasonal evapotranspiration of wheat, regardless of different NPK fertilizers levels, was 192.76 mm. Fertilizer nutrient management was found to influence the WUE of wheat. Application of incremental doses of nutrients increased the water use efficiency of crop concomitantly. The conspicuous difference was mainly due to the improvement in the grain yield. This may be explained to the fact that increase in WUE of wheat with the application of fertilizers might have stimulated more rapid crop growth with lower vapour pressure deficit which resulted in decrease in evaporation/transpiration ratio and corresponding improvement in the transpiration efficiency.

4.5 Faizabad

4.5.1 Evaluation of drip irrigation with surface irrigation system in Sugarcane

The studies showed that the total water applied under different levels of drip and surface irrigation in sugarcane ratoon crop and water saving in drip irrigation. The amount of water applied in sugarcane crop was about 738 mm in case of surface irrigation and 498, 374 and 250mm in case of 80%, 60% and 40% of P.E. under drip irrigation system respectively. This showed that there was about 32-66% saving in irrigation water under drip irrigation system in comparison to surface irrigation in sugarcane cultivation.The yield data of sugarcane crop raised under different systems of irrigation are presented in Table 2.2.2. The drip irrigation @ 80% of PE with 100% N (I_3) gave the highest crop yield of 1015.00 q/ha followed by I_4 I_5 I_6 I_7 I_1 and I_2 in which it was 997.00, 903.00, 864.00, 706.00, 692.00 and 554.00 q/ha respectively. This indicates that the yield obtained under the treatment with 100% N was at par with that of 75% N treatments. The yield of sugarcane under drip irrigation @ 80%, 60% and 40% of P.E. were varied significantly with each other. The drip irrigation system gave in general significantly higher sugarcane crop yield in comparison to surface irrigation system.

Table 4.4.1: Yield of sugarcane crop under different levels of drip and surface irrigation system.

Treatments	Yield of sugarcane (q/ha)
I_1- Surface Irrigation (6cm at 0.8 IW/CPE) ratio with 100% N	625.00
I_2- Surface Irrigation (6cm at 0.8 IW/CPE) ratio with 75%	554.00
I_3- Drip Irrigation @ 80% PE with 100% N	1015.00
I_4- Drip Irrigation @ 80% PE with 75% N	997.00
I_5- Drip Irrigation @ 60% PE with 100% N	903.00
I_6- Drip Irrigation @ 60% PE with 75% N	864.00
I_7- Drip Irrigation @ 40% PE with 100% N	706.00
I_8- Drip Irrigation @ 40% PE with 75% N	692.00
CD at 5%	67.52

4.5.2 Evaluation of drip irrigation with surface irrigation system in Marigold

The results clearly indicated that there was about 26.02 to 63.01% water saving in case of drip irrigation in comparison to surface irrigation system in marigold crop. Treatment I_3 (Irrigation @ 80% of PE with 100% N fertilizer) gave the significantly higher yield (218.60 q/ha) of flower in comparison to surface irrigation and I_6, I_7 and I_8 treatments of drip irrigation and at par with I_4 and I_5. The surface irrigation (6cm at 0.8 IW/CPE) gave the lowest yield of flower (156.40 and 160.80 q/ha under 75% and 100% N application, respectively).

Table 4.5.2: Flower yield under different treatments of marigold

S.N.	Treatments	Flower yield (q/ha)
1.	I_1- Surface Irrigation (6cm at 0.8 IW/CPE) ratio with 100% N	160.80
2.	I_2- Surface Irrigation (6cm at 0.8 IW/CPE) ratio with 75% N	156.40
3.	I_3- Drip Irrigation @ 80% PE with 100% N	218.60
4.	I_4- Drip Irrigation @ 80% PE with 75% N	212.50
5.	I_5- Drip Irrigation @ 60% PE with 100% N	205.80
6.	I_6- Drip Irrigation @ 60% PE with 75% N	199.60
7.	I_7- Drip Irrigation @ 40% PE with 100% N	175.40
8.	I_8- Drip Irrigation @ 40% PE with 75% N	162.60
	C.D. at 5%	13.40

4.6 Jorhat

4.6.1 Integrated approach using Remote Sensing and GIS techniques for mapping of ground water prospects in Jorhat district, Assam

Out of the 84 geo-referenced observations recorded from 14 villages of Titabar & NW Jorhat Dev. Blocks, the ground water table depths range from 2.43 to 10.41 m bgl. Out of the 84 geo-referenced observations recorded from 14 villages of Kaliapani and C.J.D.B, the ground water table depths ranged from 2.19 to 17.82 m bgl.

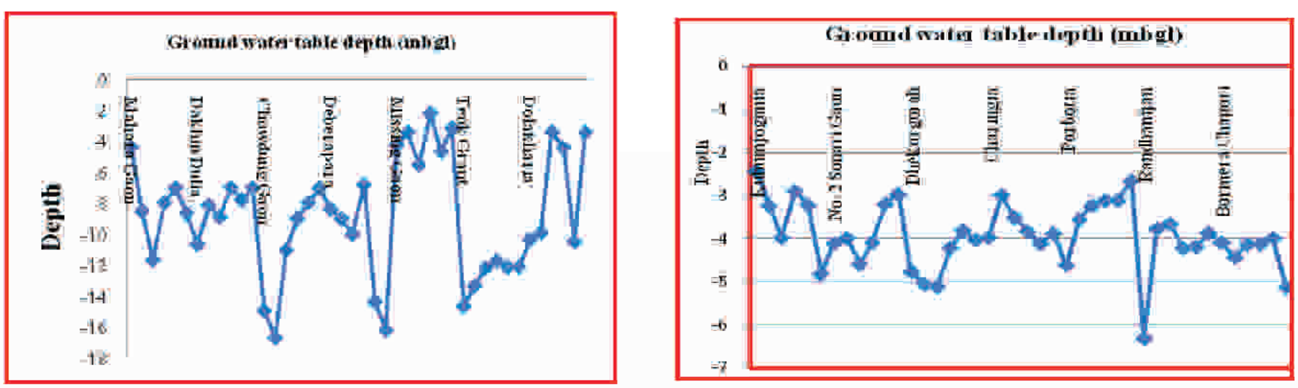

Fig.4.6.1 Ground water table depth at Titabor

Fig.4.6.2 Ground water table depth at Teok

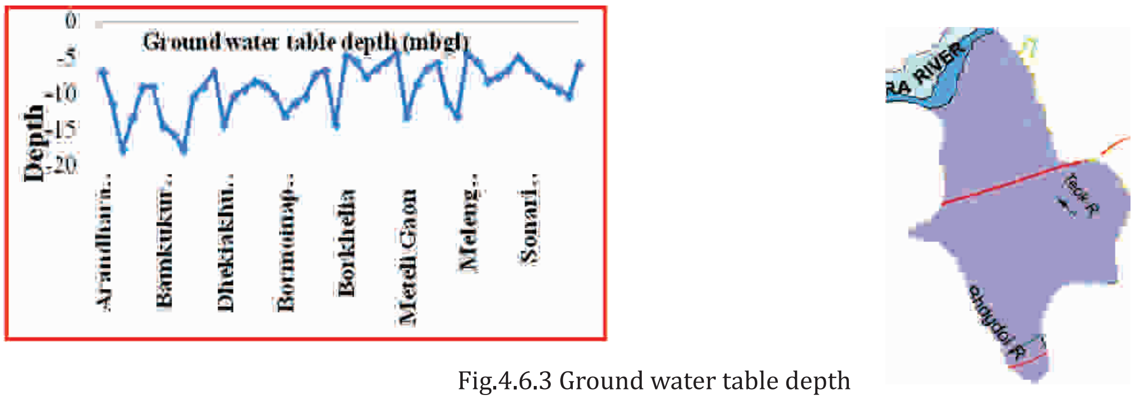

Fig.4.6.3 Ground water table depth

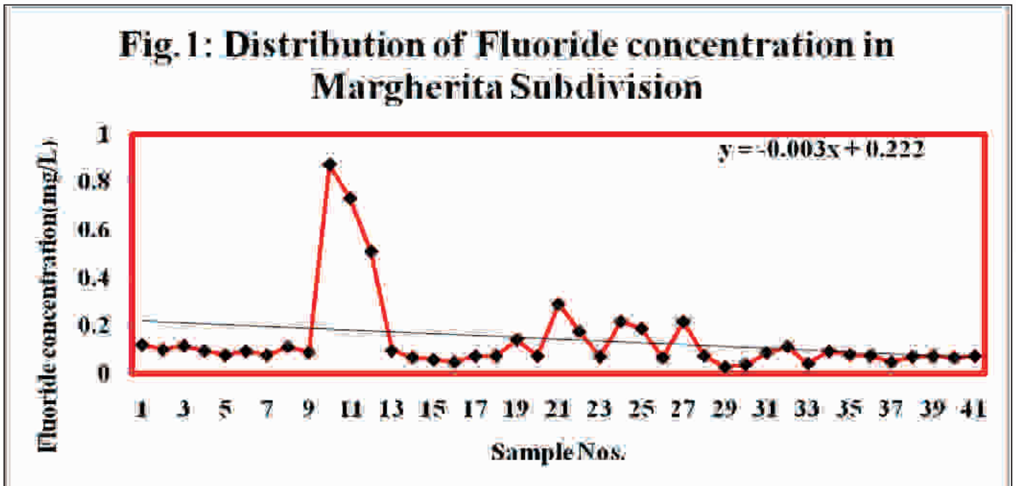

Fig.4.6.3 Ground water table depth

4.6.2 Study on Arsenic level in ground water, paddy soil and rice plant – a micro level study from Titabar area of Jorhat district, Assam

Studies showed Arsenic contamination in 67% samples based on the bench mark value of National Drinking Water Standard. The remaining had only 50% samples contaminated with Arsenic in Titabar area of Jorhat district, Assam.

4.6.3 Assessment of fluoride content in soil and irrigation water of Margherita subdivision, Tinsukia district, Assam Background

Results showed that nearly 80% samples had fluoride concentration less than 0.15 mg/L while 7% had more than 0.2 mg/L. Highest fluoride concentration was noticed in sample number 10 (0.872 mg/L) and lowest in sample number 29 (0.029 mg/L). It was observed that 7.3% samples had more than 0.5 mg/L fluoride concentration which showed comparatively higher value in respect to the rest of the samples. Fluoride contents below the guideline values of WHO have been reported in large number of samples. Because of low level of fluoride in ground water there may be a possibility of occurring dental caries among the children.

4.7. Jammu

4.7.1 Studies on soil-water-plant relationships for efficient irrigation management of field crops under Jammu conditions

The result revealed that the water content at field capacity (at 10 kPa tension) ranged from 0.13 to 0.24 $cm^3\ cm^{-3}$; and that of at PWP ranged from 0.05 to 0.11 $cm^3\ cm^{-3}$, having profile water storage of 9.2 to 10.2 cm m^{-1} depth. Since the profile water storage capacity of 5, 5-10, 10-15, 15-20, and 20 cm m^{-1} soil depth may categorized as very low, low, medium, high and very high, respectively; the present soil water status was rated as low in terms of profile water storage capacity under Ranbir canal command area.

4.8 Madurai

4.8.1 Studies on alternate wetting and drying irrigation regimes management through field water tube device in rice

The studies showed that maximum number of productive tillers of 357 per square meter and 246 grains per panicles were recorded with the irrigation adopted after 15 cm drop below ground in the water level of the field tube upto panicle initiation (50 DAT) and 10 cm drop prior to harvest. (T6). Higher grain yield of 7716 kg /ha and 10317 kg / ha straw yield were also recorded with irrigation T6 treatment. Similarly, the net returns and the BC ratio were higher with the treatment T6 –Rs.57,482; 1.89.The higher water use efficiency of 7.97 kg/ha/mm and water productivity of 111.58 Rs/ha/mm was recorded with the irrigation adopted after 15 cm drop below ground in the water level of the field water tube upto 10 days prior to harvest (T2).

Table4. 8. 1: Effect of irrigation regimes on Water use efficiency and water productivity

Treatments	Irrigation water applied in mm	Effective rainfall in mm	Total water use in mm	Grain yield (kg/ha)	WUE kg/ha/ mm	Water productivity Rs/ha/mm
T_1 Water level 10cm below ground upto 10 days prior to harvest	927	115.92	1042.92	6900	6.62	92.62
T_2 Water level 15cm below ground upto 10 days prior to harvest	800	115.92	915.92	7300	7.97	111.58
T_3 Water level 20cm below ground upto 10 days prior to harvest	764	115.92	879.92	6722	7.64	106.95
T_4Water level 15cm below ground upto AT stage (30 - 35DAT) and at 10cm below ground upto 10 days prior to harvest.	908	115.92	1023.92	7107	6.94	97.17
T_5 Water level 15cm below ground upto AT stage (30 -35 DAT) and continuous submergence upto 10 days prior to harvest.	1038	115.92	1153.92	6559	5.68	79.58
T_6 Water level 15cm below ground upto PI stage (45DAT – 50 DAT) and at 10cm below ground upto 10 days prior to harvest.	902	115.92	1017.92	7716	7.58	106.12
T_7Water level 15cm below ground upto PI stage (45 DAT - 50 DAT) and continuous submergence upto 10 days prior to harvest.	982	115.92	1097.92	7063	6.43	90.06
T_8Farmer's Practice	1067	115.92	1182.92	6187	5.23	72.22

4.9 Pantnagar

4.9.1 Development of water production function for different crops under *Tarai* conditions of Uttarakhand

The maximum seed yield of Mustard (1379 kg /ha) was obtained in lysimeters at IW/CPE ratio 0.50 irrigation treatment associated with 30 cm water table where 3 irrigations were given following the sprinkler method of irrigation, and the minimum seed yield of 538 kg /ha was obtained under flood irrigation treatment with 90 cm water table where only one irrigation was given (Table 4.9..1). In general, seed yields were more in 30 cm water table and decreased as the water table depth increased. The maximum water use efficiency of 3.74 kg/ha-mm was obtained at IW: CPE as 0.75 in with 60 cm water table when irrigation was given by sprinkler method receiving four irrigations, and the lowest water use efficiency of 1.28 kg/ha-mm was obtained under flood irrigation treatment where one irrigation was scheduled at IW: CPE as 0.5 under 90 cm water table.

Table 4.9.1: Water use, seed yield and water use efficiency of yellow Mustard through Lysimeters during *Rabi* season of 2012-13

Irrigation Treatment & Water Table depth	Ground water contribution (mm)	Total water applied (mm)	Total water use (mm)	Seed yield (Kg/ha)	WUE (kg/ ha - mm)
IW: CPE 0.5, Flood, 30 cm	553	144.5	697	1002	1.44
60 cm	99	144.5	544	1004	1.84
90 cm	276	144.5	420	538	1.28
IW: CPE 0.5, Sprin., 30 cm	360	184.5	545	1379	2.53
60 cm	283	184.5	467	926	1.98
90 cm	198	184.5	383	1213	3.17
IW: CPE 0.75, Flood, 30 cm	268	194.5	463	897	1.94
60 cm	195	194.5	389	652	1.67
90 cm	129	194.5	324	616	1.90
IW: CPE 0.75, Sprin, 30 cm	194	214.5	408	1324	3.24
60 cm	129	214.5	343	1287	3.74
90 cm	150	214.5	365	972	2.67
IW: CPE 1.0, Flood, 30 cm	216	244.5	461	837	1.82
60 cm	124	244.5	369	778	2.11
90 cm	99	244.5	344	750	2.18
IW: CPE 1.0, Sprin., 30 cm	308	274.5	583	1285	2.20
60 cm	175	274.5	449	1194	2.66
90 cm	116	274.5	391	1120	2.86

The main effects of different variables indicate that the ground water contribution got decreased as the water table depth increased (Table 4.1.2). At 90 cm depth, it was only 51.1 % of the 30 cm water table depth (317 mm). In flood method the ground water contribution was higher by 19 mm than the sprinkler method of irrigation. Among irrigation schedules, as the frequency increased, the ground water contribution decreased. The total water use (ground water contribution + irrigation depth+rainfall) also followed the similar trend. The grain yield of mustard was the highest at 30 cm water table depth and decreased by 15.2 and 29.1% as the water table was increased to 60 and 90 cm, respectively. Flood method had comparatively lower grain yield than the sprinkler method by a margin of 13.3 per cent. Among irrigation schedules it did not vary much. The WUE increased as the water table depth increased. Since, to maintain shallow water table more water had to be added which consequently led to more total water use, thus had lower WUE. As interactive effect of different factors tested, the grain yield of mustard was invariably more with sprinkler method compared to flood method except IW:CPE 0.50 under 60 cm water table depth. Flood irrigation especially at higher frequency did not improve the grain yield of mustard, showing its sensitivity to excess moisture. Based on the results obtained during the year 2012-13, sprinkler irrigation to mustard is more suitable than flood. Further 3 irrigations through sprinkler method at IW:CPE ratio 0.50 were adequate to obtained the good yield of yellow mustard. Flood method beyond1 irrigation reduced the grain yield. The mustard yield showed linear increase as the water use was increased, but the extent of increase was not appreciable (Fig. 4.9.1).

Table 4.9.2: Water use parameters of yellow Mustard under different treatments

Treatments	Ground water contribution (mm)	Total water Use (mm)	Mustard Seed yield (Kg/ha)	Water use efficiency (kg/ ha-mm)
Water table depth (cm)				
30	317	526	1121	2.20
60	218	427	973	2.33
90	162	371	868	2.34
Irrigation method				
Flood	232	447	1049	2.48
Sprinkler	213	437	1189	2.78
Irrigation schedule				
IW:CPE 0.50	345	509	1010	2.04
IW:CPE 0.75	317	487	1001	2.16
IW:CPE 1.00	292	466	1061	2.45

Cowpea (*Vigna unguiculata*)

During the crop season 6 irrigations were applied at 100 mm CPE, 4 at 150 mm CPE and 3 at 200 mm CPE. The number of irrigations was same for both the methods barring the depth. The results pertaining to water use, grain yield and water use efficiency of cowpea during summer season of 2013 conducted in lysimeters are presented in Table 4.2.1 and depicted in Fig. 4.2.1. The ground water contribution towards total water use in general increased as the water table depth decreased. To maintain the shallow water table more water addition was required. In treatment combination 100 mm CPE sprinkler method with 30 cm water table depth had the highest ground water contribution, while the lowest was noted in 200 mm CPE flood method with 90 cm water table depth (750 mm). At all the levels of irrigation, 60 cm water table depth was more productive than both 30 and 90 cm. Sprinkler irrigation at 100 mm CPE with 60 cm water table produced the highest grain yield (1565 kg/ha). It was the minimum in treatment combination of sprinkler method, 200 mm CPE associated with 90 cm water table depth (920 kg/ha). The relationship between grain yield of cowpea and water use indicates that as the water use increased there was increase in the grain yield. The relationship shows a R^2 value of 0.496. The main effects of various factors tested shows that as the water table depth was decreased the ground water contribution was increased. To maintain 30 cm water table depth 1226 mm water was required (Table 4.2.2), while for 90 cm it was only 849 mm. In sprinkler method relatively more water was required towards ground water table maintenance than the flood method. Not much variation was observed among irrigation schedules; however it was more in case of 100 mm CPE criterion, in which more irrigations were applied. Total water use differed almost in the similar fashion. At 60 cm water table depth, the grain yield was maximum (1389 kg/ha), followed by 30 cm and then 90 cm. It suggests that for cowpea, shallow water table is less suitable than medium water table. Sprinkler method produced higher grain yield than flood method by a margin of 65 kg/ha. Irrigation application beyond 100 mm CPE showed drastic reduction in the grain yield. Both the irrigation methods showed better performance at 150 mm CPE schedule. Under similar number of irrigations, at 100 and 150 mm CPEs, sprinkler method recorded higher yield than flood method. At 200 mm CPE, both the methods were almost alike. Frequent irrigations yielded better than less frequent irrigations at 90 cm water table depth. From the results obtained it can be concluded that sprinkler method is better than flood. Medium water table depth (60 cm) is more suitable than shallow water table or further deep water table. For higher yield and WUE, the 150 mm CPE ratio was optimum. It required 4 irrigations during the crop season.

Table 4.9.3: Water use and grain yield of cow pea and water use efficiency through Lysimeters during summer season 2013

Irrigation Treatment & Water Table depth	Ground water contribution (mm)	Total water applied (irrigation+ rainfall) (mm)	Total Water use (mm)	Seed yield (Kg/ha)	WUE (kg/ ha-mm)
100 mm CPE, Flood, 30cm	1197	278.2	1475	1326	0.90
60 cm	1099	278.2	1377	1479	1.07
90 cm	928	278.2	1206	1288	1.07
100 mm CPE Spri. 30 cm	1290	218.2	1508	1457	0.97
60 cm	1110	218.2	1329	1565	1.18
90 cm	977	218.2	1195	1356	1.14
150 mm CPE, Flood, 30cm	1181	218.2	1399	1243	0.89
60 cm	1036	218.2	1254	1344	1.07
90 cm	798	218.2	1016	1200	1.18
150 mm CPE Spri. 30 cm	1252	178.2	1429	1432	1.00
60 cm	1129	178.2	1307	1538	1.18
90 cm	863	178.2	1041	1265	1.22
200 mm CPE, Flood, 30cm	1187	188.2	1375	1042	0.76
60 cm	1011	188.2	1199	1246	1.04
90 cm	750	188.2	938	988	1.05
200 mm CPE Spri. 30 cm	1249	158.2	1408	1049	0.74
60 cm	1039	158.2	1198	1165	0.97
90 cm	779	158.2	937	920	0.98

Table 4.9.4:Water use parameters of cowpea under different treatments

Treatment	Ground water contribution (mm)	Total water Use (mm)	Grain yield (Kg/ha)	WUE (kg/ ha-mm)
Water table depth (cm)				
30	1226	1433	1258	0.88
60	1071	1277	1389	1.09
90	849	1056	1170	1.11
Irrigation method				
Flood	1021	1249	1240	1.00
Sprinkler	1077	1261	1305	1.04
Irrigation schedule				
100 mm CPE	1100	1348	1412	1.06
150 mm CPE	1043	1241	1337	1.09
200 mm CPE	1003	1176	1069	0.93

Rice (*Oryza sativa* L.)

The results pertaining to water use, grain yield and water use efficiency of rice during *kharif* season 2013 are given in Table 4.3.1 and are depicted in Fig. 4.9.1. It is clear from the Fig. 4.9.1 that the mean yield of rice was obtained to be 43.7 q/ ha with an average water requirement of 766.4 mm and average water use efficiency (WUE) as 5.8 kg/ha-mm during the *kharif* season of 2013 in lysimeters. During the crop season under report a well distributed good amount of rainfall was received.

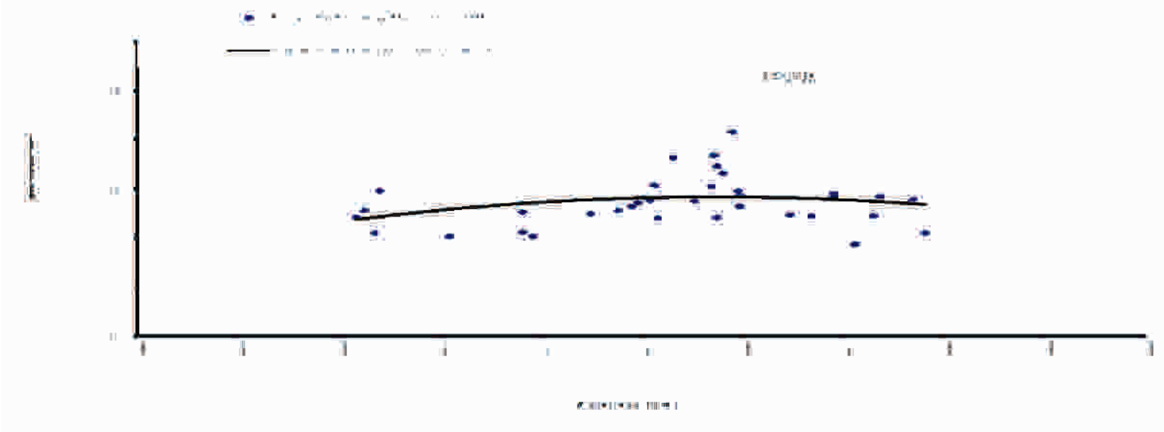

Fig. 4.9.1 Grain yield (q / ha) of rice as a function of water use (ET, mm)

In the month of June (603.4 mm), July (410.6 mm), August (438.6 mm), September (74.4 mm) and October (86.4 mm) rain fall occurred, which helped rice to grow well and an increase in Rice yield was observed during *kharif* season 2013.

Determination of crop coefficients

Values of crop coefficients for European dill computed based on ETp calculated and ET determined by Lysimeters are given in Table 4.4.1. The average Kc for European dill is 0.635 ranging from 0.221 (sowing time) to 1.421, a stage of maximum number of umbels formation at around 150 days after sowing. However, the average value of Kc for vegetable pea was 0.807 ranging from 0.125 (sowing time) to 1.519 at flowering & pod formation stage.

4.10 Parbani

4.10.1 Effect of canal irrigation on water table fluctuation and quality of underground water in Jayakwadi Command area

The results indicated that the water table of command area ranged from 2.66 m to 8.78 m in November-2013 while 4.8 m to 8.87 m in March 2014. The ground water table depth of uncommand area was higher than command area by 2.88 m in November-2013 and 2.03 m in March-2014. The rainfall received in the area during monsoon might have increased the ground water levels in November because farmers have not utilized well water in the observation period year 2013-14. Total rainfall received in the area was more than normal rainfall. The water was sufficient in Jayakwadi storage reservoir than last year hence it is released for irrigation. It was noticed that on an average ground water depth was more during March-14 both in command and uncommand area. Decrease in ground water level in both command and uncommand area in the month of March-14 is the result of utilization of well water for irrigation by farmers. The study area has many orchards of sweet orange. Most of the farmers are utilizing well water through drip for sweet orange in this year. Sugarcane was consistently cultivated in the area due to presence of co-operative sugar factory. The annual ground water table fluctuations during 1985 to 2014 are shown in table 2. The data indicate that during all these years the water table in command area is always increased due to recharge from canal water as compared to uncommand area (expect last year because water was not released to farmers). The progressive values also indicate that the water table depth in both command and uncommand area increased from 1992 to 2003. The water table levels from 2003 to 2011 increased by 5.86 m.The values of pH, Ec, CO_3, HCO_3, Cl , Ca + Mg, Na and SAR values of ground water from command area was higher than uncommand area. The quality of ground water based on Ec. and SAR in command area. can be categrised as C_4S_1 and C_3S_1 this indicate that the average ground water in command area has high (C_3) and very high (C_4) salinity. The high salinity water cannot be used on soils with restricted drainage where as very high salinity water is not suitable for irrigation under ordinary conditions. The ground water in uncommand area is also rated as high salinity.Based on SAR values the ground water in both command and uncommand areas are rated as no sodium hazards (S_1) and can be used for all types of soils with little danger of exchangeable sodium. The pH of ground water during the period of 1985 to 1998 was in very alkaline range where as 1999 to 2014 the pH was decreased. The Ec of ground water in command and uncommand area is increased in 2013 and 2014. In command area the ground water is in the range of very high to high salinity due to increased concentration of total soluble salt due to recharge where as Ec values of ground water in uncommand area are in medium salinity range to high salinity with some fluctuations in the values. The SAR values of command area were higher than uncommand area.

Table 4.10.1: Annual changes in pH , Ec & SAR of ground water in Jayakwadi command and uncommand March, 1985 to March, 2014

Year	pH		Ec (dsm^{-1})		SAR	
	Command	Uncommand	Command	Uncommand	Command	uncommand
1985	8.6	8.0	0.92	0.60	1.5	0.78
1986	8.9	8.1	0.82	0.8	0.7	0.50
1987	8.7	8.2	0.83	0.70	0.9	0.40
1988	8.5	8.0	0.92	0.60	1.5	0.98
1989	8.6	8.0	0.90	0.70	2.5	1.50
1990	8.6	8.0	1.8	0.70	3.5	2.10
1991	8.5	8.2	2.0	0.50	5.52	1.84
1992	9.0	8.4	1.8	1.0	0.91	0.77
1993	8.5	8.1	0.9	0.40	2.3	0.60
1994	8.34	8.0	0.8	0.30	0.9	0.50
1998	8.61	8.5	1.9	1.20	1.2	0.642
1999	7.65	7.59	1.2	0.56	0.76	0.70
2000	7.40	7.10	1.0	0.50	1.5	0.9
2001	7.81	7.65	1.13	0.52	2.8	1.20
2002	7.99	7.75	1.41	0.70	2.9	1.10
2003	7.98	7.91	1.40	1.10	1.53	0.164
2004	7.89	7.39	1.28	0.83	1.14	0.46
2005	8.0	7.58	1.02	0.82	1.52	1.17
2006	8.03	7.45	0.95	0.85	4.74	1.30
2007	7.63	7.53	1.01	0.95	2.88	2.70
2008	7.65	7.50	1.01	0.80	3.80	2.70
2009	7.66	7.60	1.3	0.70	4.10	3.70
2010	7.98	7.60	1.4	0.80	3.50	3.10
2011	7.83	7.57	1.59	0.67	5.95	3.61
2012	7.71	7.52	1.58	0.91	5.45	2.73
2013	7.72	7.37	2.31	1.91	3.82	1.84
2014	7.63	7.26	1.91	0.85	4.70	2.76

From this data it was concluded that in command and uncommand area, the ground water level was higher in the month of November due to recharge from rainfall. Ground water from Jayakwadi command area is categorized as C_4S_1 and C_3S_1 as high and very high indicating restrictions on its use. Scheduling of irrigation water through canal irrigation system largely depends on the availability of water storage in the Jayakwadi project.

4.11 Rahuri

4.11.1 Estimation of consumptive use of water by maize (sweet corn) and *rabi* onion through lysimetric technique

The onion bulb yield and stalk yield, CU, WUE, rainfall and number of irrigation applied to onion crop in lysimeter and field were studied. The onion bulb and stalk yield both from lysimeter and field were 2.589 kg, 0.195kg, 7790 kg, 584 kg respectively. The harvest index of lysimeter and field were 92 and 93 respectively.The moisture depletion was monitored daily and data in respect of ET, EP of crop were 578.10, 879.5 mm respectively. The irrigation water applied after considering moisture depletion at 50 mm CPE. The average ET was 4.65 and EP was 7.73. The average ET/EP ratio was 0.68. The maximum ET/EP ratio was 0.9 at transplanting to vegetative stage. There by slightly declining upto bulb enlargement stage. The lowest ET/EP was noticed at maturity stage 0.3.

The green cob and fodder yield, CU, WUE, rainfall numbers irrigation applied to sweet corn in lysimeter and field were presented in (Table4.11.1) . The green cob yield and fodder yield and harvest index both from lysimeter and field were 2.40 kg 1.90 kg and 0.55 and 12.10 t ha^{-1}, 10.60 t ha^{-1} and 0.53 respectively.The moisture depletion of lysimeter was monitored daily and data respect of total ET&EP of crop were 191.4 and 477.3 mm respectively. The irrigation water applied at 75 mm CPE. The average ET was 1.65 mm and EP was 4.33 mm respectively. The average ET/EP ratio was 0.38 minimum.It was noticed that at initial stage ET/EP ratio was minimum and with the advancement of growth there is dwindling of ET/EP ratio. Maximum ET/EP ratio was 0.5 at cob formation.The ET and EP during entire growth period of onion was 578.6 and 879.5 mm respectively. The ET/EP ratio was maximum 0.9 at transplanting to vegetative and lowest was at maturity stage 0.3. The ET and EP during entire growth period of sweet corn was 191.4 and 477.3 mm respectively. The total growth period for the crop was 109 days.

Table 4.11.1 : ET/ EP, at various growth stage of onion variety (N-2-4-1) *Rabi* 2012-2013

Physiological growth stage	Duration (days)	ET (mm)	EP (mm)	Average ET (mm)	Average EP (mm)	ET/ EP Ratio
Transplanting to vegetative	48	189.3	217.3	3.9	4.5	0.9
Bulb development	23	133.7	166.3	5.8	7.2	0.8
Bulb enlargement	34	196.4	293.6	5.8	8.6	0.7
Maturity	19	59.2	202.3	3.1	10.6	0.3
Total	124 days	578.6 (mm)	879.5 (mm)	4.65 (mm)	7.73 (mm)	0.68 (mm)

Table 4.11.2 : ET/ EP, at various growth stage of Sweet corn season Kharif – 2013

Physiological growth stage	Duration (days)	ET (mm)	EP (mm)	Average ET (mm)	Average EP (mm)	ET/ EP Ratio
Germination	24	26.9	113.4	1.1	4.7	0.2
Cob formation	36	92.2	172.6	2.6	4.8	0.5
Silking	27	41.1	107.6	1.5	4.0	0.4
Grain filling	22	31.2	83.7	1.4	3.8	0.4
Total	109 days	191.4	477.3	1.65	4.33	0.38

4.11.2 Development of Crop Coefficients for Soybean using lysimetric data

The crop coefficient curves were developed for two methods. These are Penman Monteith and Hargreaves-Samani. The results with Pan Evaporation method were not consistent due to the variation in pan evaporation data and hence this method was ignored. The polynomial equations of different orders with crop coefficient as a function of the ratio of days since sowing/planting to total crop growth period were fitted for all the years. It is seen that the polynomial equation of 5th order is the best fit as it gives the maximum value of regression coefficient for all the two methods of ETr. The average Kc values were obtained from the Kc polynomial equations of fifth order. These Kc curves for the polynomial equations of 5th order are presented in Figures 1 for Penman-Monteith method.

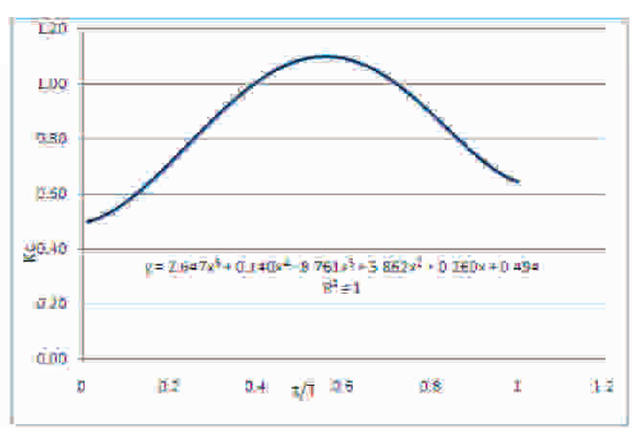

Fig 4.11.1 Kc curves for Soybean for ETr estimated by Penman Monteith method

Average weekly crop coefficient values for Soybean as estimated by the fifth order polynomial equations are presented in Table 1. The crop coefficients given in following table are recommended for the estimation of water requirement of Soybean. The crop coefficient curves for Soybean are represented by the polynomial functions of the fifth order as the function of the ratio of days since sowing/planting to total crop growth period.