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सिंचाई जल प्रबंधन पर
अखिल भारतीय समन्वित अनुसंधान परियोजना
All India Coordinated Research Project on Irrigation Water Management

भाकृअनुप-भारतीय जल प्रबंधन संस्थान
(भारतीय कृषि अनुसंधान परिषद)
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भाकृ अनुप
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Annual Report
2014-15

AICRP on IWM

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भारतीय जल प्रबंधन संस्थान
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Foreward.....

I am privileged to present the Annual Report of AICRP on Irrigation Water Management 20014-15, covering research findings of the All India Coordinated Research Projects spread across twenty six centres in the country. During the report period, network centers of AICRP on Irrigation Water Management (renamed after merger of AICRP on Water Management and AICRP on Groundwater Use) made considerable efforts to develop improved technologies through five well defined themes. Technical Programs were approved in the Chief Scientist's Meet of the project organized at CSK HPKV, Palmpur, Himanchal Pradesh.

I take this opportunity to express my sincere gratitude to Dr. S Ayyapan, Secretary (DARE, Govt. of India) and Director General (ICAR) for his constant support and encouragement. I also express my sincere gratitude to Dr. A. K. Sikka, Deputy Director General (NRM) of ICAR for his guidance, cooperation and keen interest in conducting network research. I sincerely acknowledge the timely cooperation received from Dr. S.K.Chaudhari, Assistant Director General (S&WM), NRM Division of ICAR during the report period. I also express my sincere thanks to all the Chief Scientists and scientists working in different centers for their hard work and timely cooperation to run the project smoothly. I place on record my sincere appreciation for the hard work done by Dr. Prabhakar Nanda, Principal Scientist at the PCU, Dr. M.Raychaudhari, Pr. Scientist, Er. Ranu Rani Sethi, Sr. Scientis and Dr. P.K.Panda, Sr. Scientist in compiling and editing the Annual Report. Through this Annual Report, the coordinating unit has made a sincere endeavour in presenting the salient findings of the research projects during 2014-15 executed by coordinating centres across the country. I hope that the report will prove worthy to agricultural planners, policy makers, researchers and other stake holders who are directly related with agricultural water management of the country.

Bhubaneswar

(S. K. Ambast)
Director

Preface

The irrigated agriculture in India has been ensuring about sixty percent of national food grain availability. The scientific water management has been a key factor in bringing about stupendous progress in agricultural production in scarcer areas. However, the areas which are profligate in water availability have lagged behind in its scientific management. 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. Thus, efficient use of irrigation water with higher productivity is crucial for the development of sustainable agriculture.

To address the issues of water management in irrigation commands, AICRP on Water Management was established during 1967 and to address the groundwater related problems, AICRP on Groundwater Utilization was established in 1971. The achievements of both the AICRPs are immense. The two schemes of AICRP on Water Management and AICRP on Groundwater Utilisation have been merged to be renamed as All India Coordinated Research Project on Irrigation Water Management during XII Plan which 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 six centers in the country. The coordinating centers have been representing diversified agro economic and geo hydrological situations. The AICRP on Irrigation Water Management (IWM) 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 the 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 Irrigation Water Management experiments, extension for the year 2014-2015 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. We place our gratefulness to the Deputy Director General (NRM) and Assistant Director General (S&WM), NRM Division of ICAR and the Director, ICAR-IIWM, Bhubaneswar who have been the mentors for the day to day management of the scheme.

Prabhakar Nanda
Mousumi Raychaudhari
Pramod Kumar Panda
Ranu Rani sethi

कार्यकारी सारांश

सिंचाई जल प्रबंधन पर अखिल भारतीय समन्वित अनुसंधान परियोजना जो जल प्रबंधन के क्षेत्र में अनुसंधान एवं विस्तार गतिविधियों के लिये अधिकृत है, के अंतर्गत विभिन्न महत्वपूर्ण विषयों जैसे कृषि उत्पादन पद्धति में आपूर्ति-मांग के अंतर को समान बनाये रखने के लिये क्षेत्रीय स्तर पर सतही जल, भूजल एवं अपशिष्ट जल की उपलब्धता तथा गुणवत्ता का आकलन, जल उपयोग दक्षता एवं जल उत्पादकता बढ़ाने के लिये दबाव सिंचाई पद्धति का डिजाइन एवं विकास, भूजल पुन:भरण पद्धतियों का विकास, मिट्टी-पानी-पौधे पर्यावरण के संबंध पर मूल अध्ययन तथा स्थायी फसल उत्पादन के लिये सतही, भूजल एवं अपशिष्ट जल संसाधनों के संयोजी उपयोग आदि विषयों पर कार्य किया गया।

(i) कृषि उत्पादन पद्धतियों में जल की आपूर्ति एवं मांग के मिलान के लिये निर्णय समर्थन पद्धति (डीएसएस) का उपयोग करके प्रबंधन उपायों का विकास तथा क्षेत्रीय स्तर पर सतही जल, भूजल एवं अपशिष्ट जल की उपलब्धता तथा गुणवत्ता का आकलन।

- अमरावती बेसिन का कुल जलग्रहण क्षेत्र 8280 वर्ग किलोमीटर है जो तमिलनाडु राज्य के चार जिलों कोयम्बटूर, डिंडीगुल, करूर एवं तिरुपूर में स्थित है। इस बेसिन के विषयगत मानचित्रों (मिट्टी, भूविज्ञान, लिनिमेंट घनत्व, जल निकासी घनत्व, भू भाग, ढ़लान, भूमि उपयोग एवं भूमि कवर मानचित्र) को तैयार किया गया। इन मानचित्रों का भूजल पुन:भरण एवं विकास के संभावित क्षेत्रों की पहचान का निर्णय लेने की प्रक्रिया के लिये इस्तेमाल किया जाएगा। इस बेसिन में 24 वर्षा गेज स्टेशन उपलब्ध थे इन स्टेशनों से प्राप्त चालीस वर्षों के वर्षा आंकड़ों का विश्लेषण किया गया। इस बेसिन की औसत वार्षिक वर्षा 1009.8 मिमी थी। बेसिन के ऊपरी छोर में सामान्य वर्षा के वर्षों की संख्या अधिक थी जबकि अंतिम छोर की तरफ सामान्य वर्षा में कमी के वर्षों की संख्या अधिक पायी गयी। इम्पीरिकल फार्मूले का उपयोग करके पुन:भरण की मात्रा का 17 से 30% तक अनुमान लगाया गया। इस बेसिन में कुल ब्लॉकों की संख्या 33 थी जिनमें से 16 अति शोषित, 2 संवेदनशील, 12- अर्द्ध संवेदनशील तथा शेष ब्लॉक सुरक्षित श्रेणी में आते हैं।

- जबलपुर केन्द्र द्वारा नरसिंहपुर जिले के विभिन्न संसाधनों की जल की उपलब्धता का क्षेत्र में उगाई जाने वाली विभिन्न फसलों की जल की मांग के अनुसार अध्ययन किया गया। वर्ष भर में नहरों के डिजाईड डिस्चार्ज एवं संचालित घंटों के आंकड़ों को एकत्रित करके सतही जल की उपलब्धता का मूल्यांकन किया गया। भूजल की उपलब्धता की स्थिति का भूजल विभाग से प्राप्त आंकड़ों का उपयोग कर अनुमान लगाया गया। खरीफ एवं रबी के मौसम के लिये अलग से वर्षा, इवेपोट्रान्स्पिरेसन तथा मिट्टी की नमी उपलब्धता का उपयोग कर मानक जल बजट के माध्यम से फसल जल मांग का अनुमान लगाया गया। मौजूदा उत्पादन पद्धति में सुधार करने के लिये मांग एवं आपूर्ति के परिणामों का विश्लेषण भी किया गया।

- उदयपुर जिले के जयसमंद जलग्रहण क्षेत्र में भूजल संभावित क्षेत्रों को चित्रित किया गया तथा साथ ही साथ विभिन्न भूजल संभावित क्षेत्रों एवं कृत्रिम पुन:भरण क्षेत्रों को भी वर्गीकृत किया गया। पेप्डोपुलस कूपर विधि का उपयोग करके पम्पिंग परीक्षण के आंकड़ों के विश्लेषण के आधार पर ट्रांसमीटिविटी एवं भंडारण गुणांक क्रमश: 123.82 से 386.94 वर्ग मीटर/ दिन एवं 0.000160 से 0.03047 तक पाये गये। यहाँ कुल 109 स्थानों पर जलस्तर में उतार-चढ़ाव विधि द्वारा भूजल पुन:भरण का अनुमान लगाया गया। इस अध्ययन क्षेत्र में औसत भूजल पुन:भरण 2.87 सेमी/वर्ष हो पाया। इस अध्ययन क्षेत्र को चार भूजल संभावित क्षेत्रों में बांटा गया जैसे अच्छा, थोड़ा अच्छा, खराब एवं बहुत खराब क्षेत्रों जो कि क्रमश: 12.82, 49.65, 33.21 एवं 4.32% क्षेत्र को दर्शाते हैं। बेसिन का लगभग 87.18 फीसदी क्षेत्र खराब/ मध्यम भूजल संभावित क्षेत्र के अंतर्गत आता है इसलिये, स्थायी भूजल प्रबंधन सुनिश्चित करने के लिये इस ओर तत्काल ध्यान देने की आवश्यकता है। कृत्रिम भूजल पुन:भरण के लिये कुल उपयुक्त क्षेत्र केवल 279 वर्ग किमी ही है जो अध्ययन क्षेत्र में केवल 15.02% का ही योगदान देता है।

• रायपुर केन्द्र द्वारा खारुन वाटरशेड में भूजल की उपलब्धता पर जलभृत मापदंडों एवं जलवायु परिवर्तन के प्रभाव का अध्ययन किया गया। इस संदर्भ में एआईसीआरपी के वैज्ञानिकों के सहयोग से वर्ष 1991-2013 की अवधि में वर्षा एवं तापमान परिवर्तनशीलता का विश्लेषण 1961-90 की अवधि के आधार की तुलना में किया गया। यह पाया गया कि यहाँ वर्षा एवं तापमान में महत्वपूर्ण परिवर्तन हो रहा है। खारुन वाटरशेड के एक छोटे से भाग छोकरनाला भू-जल बेसिन में पंप परीक्षण द्वारा जलभृत के व्यवहार का पता लगाया गया। डलडल सियोनी (RGI EW-IV एवं RGI OW-I) के लिये जलभृत गुण जैसे ट्रांसमीटिविटी (T) 2.93 से 3.16 वर्ग मीटर/ दिन तथा स्टोरेटिविटी (S) 3.17 x 10^5 से 3.46 x 10^5 के बीच थे जबकि FAE कुंआ, IGKV, रायपुर के लिये ट्रांसमीटिविटी 9.37 से 9.51 वर्ग मीटर/दिन के बीच पायी गयी।

• राहुरी केन्द्र द्वारा हार्ड रॉक क्षेत्र में भूजल पूर्वेक्षण की विद्युत प्रतिरोधकता विधि की विश्वसनीयता का परीक्षण एक प्रयोग आयोजित करके किया गया। विद्युत प्रतिरोधकता विधि को श्लमबरजर सारणी के साथ 26 विभिन्न स्थानों पर भू भौतिकीय जांच के लिये इस्तेमाल किया गया। हार्ड रॉक क्षेत्र के लिये विद्युत प्रतिरोधकता विधि की विश्वसनीयता किसानों द्वारा उपयोग में लिये गये वास्तविक कुओं के साथ कर्व ब्रेक तकनीक से प्राप्त विद्युत प्रतिरोधकता परिणामों की तुलना द्वारा स्थापित की गयी। यह तकनीक हार्ड रॉक क्षेत्र में कुंए की स्थिति का पता लगाने में 88.46% तक विश्वसनीय पायी गयी। इस पद्धति से प्राप्त जल सहित संरचना की गहराई के मूल्यों की तुलना गहराई के वास्तविक मूल्यों के साथ की गयी। पानी की गहराई के अनुमानित एवं वास्तविक मूल्यों के बीच लगभग 6 प्रतिशत विचलन पाया गया। इस प्रकार, यह विधि जल सहित संरचना की गहराई जानने में 93.44% तक सही साबित हुई।

• जूनागढ़ केंद्र ने ऊर्ध्वाधर बिजली लग प्रतिरोधकता तकनीक द्वारा उबेन नदी बेसिन की जलभृत के मानचित्रण का आयोजन किया। उबेन नदी में सर्वेक्षण को नौ अलग अलग स्थानों पर जैसे चोकी, माखीयाला, पाटला, वाडल, चोबारी, गोलाधार, रवनी रूपावती, फारेनी एवं सतलपुर में आयोजित किया गया। विभिन्न परतों के विद्युत प्रतिरोधकता मूल्य के आधार पर भूगर्भीय संरचनाओं को निर्धारित किया गया।

• रायपुर केंद्र द्वारा धनगाँव वाटरशेड में जल संसाधनों के प्रभावी प्रबंधन के लिये भू-कर स्तर भूमि उपयोग योजना शुरू की गयी। इस वाटरशेड में धनाली, धनगाँव, लावतरा, चमारी, खंडसरा, अटारिया,घानाडीह कलाँ, करचुआ, केवांछी, बनासपुर, रामपुर, खुर्सबोड़, समेरिया एवं मारतरा सहित 15 गांव शामिल हैं। धनगाँव वाटरशेड 77.19 वर्ग किलोमीटर क्षेत्र के साथ एक 5 वां ऑर्डर वाटरशेड है। वाटरशेड, उप वाटरशेड, जल निकासी, DEM, मिट्टी एवं भूमि उपयोग मानचित्रों को जीआईएस तकनीक का उपयोग कर तैयार किया गया। भू-कर नक्शे के डिजिटलीकरण का काम जियोरेफ्रेंसिंग के कार्य के साथ प्रगति पर है। स्वाट विश्लेषण के आधार पर नौ उप वाटरशेडों में से SW7 उप वाटरशेड की संवेदनशील उप वाटरशेड के रूप में पहचान की गयी।

• लुधियाना केन्द्र द्वारा 'पीएचपी' सर्वर के तहत निर्णय समर्थन पद्धति (DSS) को पटकथा भाषा में विकसित किया गया। यह पद्धति समय एवं स्थान के अनुसार सूक्ष्म स्तर पर पम्पिंग सेट के उचित चयन के लिये ऊर्जा की आवश्यकता की जानकारी प्रदान करती है। इसके लिये पिछले 16 वर्षों (1998-2013) के मानसून पूर्व के आँकड़ों से भूजल मानचित्रों को तैयार किया गया एवं जीआईएस तकनीक की मदद से विश्लेषण किया गया। इसके अलावा पंजाब के प्रत्येक गांव की औसत वृद्धि/कमी का जीआईएस का उपयोग करके मूल्यांकन किया गया। जीआईएस, विभिन्न स्रोतों या विषयों से स्थानिक जानकारी का एकीकरण एवं विश्लेषण करने के लिये महत्वपूर्ण उपकरणों में से एक है। यह निर्णय समर्थन पद्धति (DSS) भूमि उपयोग, स्थान एवं कार्य के घंटों के आधार पर पंप की ऊर्जा की आवश्यकता चयन में सहायता करेगी।

• लुधियाना केंद्र ने जियोइन्फोर्मेटिक्स का उपयोग कर मध्य पंजाब में भूजल पंपों से कार्बन उत्सर्जन का अनुमान लगाया। संख्या एवं पंप (बिजली या डीजल) के स्रोत पर चौदह वर्षों (1998 2012) के आंकड़ों को पंजाब कृषि विभाग से प्राप्त किया गया। मध्य पंजाब के लिये जल के स्तर में परिवर्तन संबंधी मानचित्र भी तैयार किये गये। पिछले 14 वर्षों के दौरान जल के स्तरों का क्षेत्र 3-10 मीटर था जो 53 से 21.9 प्रतिशत तक कम हो गया है जबकि 20 मीटर से अधिक गहराई के तहत जल स्तरों का क्षेत्र 0 से

24.6 प्रतिशत तक बढ़ गया है। यह स्थिति मध्य पंजाब में भू जल स्तर में गिरावट की गंभीर समस्या को दर्शाती है। अलग-अलग वर्षों के लिये डीजल एवं बिजली संचालित ट्यूबवेल दोनों के लिये पंप घनत्व मानचित्र (पंपों की संख्या प्रति 1000 हैक्टेयर) तैयार किये गये। SC-III क्षेत्र में बिजली पंप सेटों में तेजी से वृद्धि हुई एवं वर्ष 2000-2011 के दौरान SC-III में एक सटीक रैखिक प्रवृत्ति का प्राप्त हुई। अध्ययन की अवधि के दौरान SC-III एवं बीएम-III में विद्युत पंप सेट घनत्व में क्रमशः 67% तथा 42% की बढ़ोतरी हुई। जबकि अध्ययन की अवधि के दौरान डीजल पंप सेट के मामले में UB-III और SC-III में घनत्व में क्रमशः 11% एवं 7% की कमी पायी गयी। BD-III एवं BM-III में 49% एवं 46% की वृद्धि देखी गई।

(ii) अपशिष्ट जल सिंचाई सहित सिंचाई जल प्रबंधन के बदलते परिदृश्यों के तहत मिट्टी-पानी-पौधा पर्यावरण के संबंध पर आधारभूत अध्ययन।

- लुधियाना जिले में स्थानीय स्तर पर सिंचाई पानी की आवश्यकता एवं कृषि उत्पादन पर जलवायु परिवर्तन के प्रभाव को समझने के लिये एक अध्ययन आयोजित किया गया। फसल उपज, फसल की अवधि एवं सिंचाई की आवश्यकताओं पर जलवायु परिवर्तन के प्रभाव का आकलन करने के लिये क्रॉप सिस्ट मॉडल (CROPSYST) का उपयोग किया गया। लुधियाना जिले के लिये यह अनुमान लगाया कि खरीफ मौसम के दौरान एमसी (MC) एवं इसी (EC) मिट्टी श्रेणियों में पर्याप्त रूप से सिंचित एवं उर्वरित धान की औसत उपज में 30.4% से 14.8% तक कमी हो सकती है। हालांकि, रबी में एमसी मिट्टी श्रेणी के तहत गेहूँ की फसल उपज में मामूली सी 0.2% की वृद्धि हो सकती है तथा इसी मिट्टी श्रेणी में 12.5% तक कमी हो सकती है। एमसी एवं इसी मिट्टी श्रेणियों में धान की फसल की अवधि को 17 दिन (16.3%) एवं 24 दिन (23.1%) कम किया जा सकता है। तथा गेहूँ की फसल की अवधि को 8 दिन (5%) एवं 22 दिन (13.4%) कम किया जा सकता है। एमसी एवं इसी मिट्टी श्रेणियों में धान की पैदावार में सभी वर्षों में लगभग 48.7% की कमी होगी। एमसी एवं इसी मिट्टी श्रेणियों में खरीफ मौसम के दौरान सिंचाई आवश्यकता में क्रमशः 48.7% एवं 51.0% की कमी होगी जबकि रबी मौसम के दौरान 25.3% एवं 41.7% की कमी होगी।

- जबलपुर केंद्र द्वारा गेहूँ की फसल में ड्रिप्पर एवं लेटरल के विभिन्न लेआउट के तहत मिट्टी के नमी क्षेत्र पर मूल अध्ययन आयोजित किया गया। सिंचाई के बाद अलग-अलग अंतराल पर नमी प्रोफाइल भी तैयार की गयी एवं ड्रिप्पर तथा लेआउट की उपयुक्तता के लिये सहसंबंध स्थापित किया गया। नमी वितरण पर काम भी प्रयोगशाला परिस्थितियों में किया गया। क्रॉपवाट (CROPWAT) मॉडल में जलवायु आंकड़ों की जानकारी पर विचार करके इस मौसम एवं लंबी अवधि के वार्षिक बदलाव के साथ इवेपोट्रान्स्पिरेसन में बदलाव निर्दिष्ट करने के लिये अध्ययन किया गया।

- तमिलनाडु में करूर टाउन में अमरावती नदी बेसिन, नीचे के बहाव की ओर कपड़ा विरंजन एवं रंगाई ओद्योगिक इकाइयों द्वारा आंशिक रूप से उपचारित अपशिष्ट प्रवाह के निर्वहन के कारण बहुत ही प्रदूषित है। विभिन्न मौसम के दौरान विद्युत चालकता मूल्यों में बढ़ती हुई प्रवृत्ति देखी गयी जो 0.29 से 2.46 डेसी साइमन्स/मीटर थी। विभिन्न मौसमों से एकत्रित भूजल के नमूनों में सोडियम आयनों की मात्रा 1.58 से 9.22 मिली इक्वीवेलेंट/लीटर के बीच पायी गयी। अमरावती नदी बेसिन के अंतिम छोर की ओर अरायाकुरिची, नागमपल्ली एवं करूर क्षेत्रों में 28.5 से 65.7% भूजल नमूने उच्च एवं मध्यम लवणता वर्ग में पाये गये जो भूजल प्रदूषण का संकेत देते हैं। सिंचाई उपयुक्तता के इसी (EC) एवं सोडियम अवशोषण अनुपात (SAR) मानकों के आधार पर बेसिन के अंतिम छोर में जब भूजल का सिंचाई के लिये उपयोग किया गया तो उच्च लवणता श्रेणी में प्राप्त हुआ। अतः करूर जिले के बड़े हिस्से में सिंचाई के लिये भूजल का उपयोग करते समय उचित मिट्टी प्रबंधन उपाय अपनाये जा रहे हैं।

- उदयपुर केन्द्र द्वारा राजस्थान के भीलवाड़ा जिले में भूजल गुणवत्ता का मूल्यांकन किया गया। जिले के विभिन्न ब्लाकों से कुल 110 भूजल के नमूने एकत्रित किये गये। परिणामों ने बताया कि भीलवाड़ा जिले में भूजल गुणवत्ता के लिये प्रमुख सीमित कारक लवणता (90.90% भूजल के नमूने उच्च से बहुत उच्च श्रेणियों सी$_3$ एवं सी$_4$ के अंतर्गत आते हैं) है। केवल 9.99% भूजल के नमूनों में सोडिक से उच्च सोडिक जल (S_3 और S_4 वर्ग) की समस्या है। इसी तरह, क्षारीयता की समस्या बहुत छोटे से क्षेत्र में (8.18% भूजल के नमूनों में सोडियम अवशोषण अनुपात अधिक से अधिक 2.5 मिली इकवीवेलेंट/लीटर पाया गया) ही पायी गयी। इसलिये,

इस अध्ययन क्षेत्र में उच्च लवणता की समस्या को देखते हुये अत्यंत सावधानी से भूजल की खारेपन की समस्याओं का प्रबंधन किया जाना चाहिये।

• उदयपुर केन्द्र द्वारा हाड़ोती क्षेत्र में सब्जी उत्पादन के लिये अपशिष्ट जल के उपयोग के लिये जिलेवार गुणवत्ता निर्धारित की गयी। अपशिष्ट जल के नमक लोड, पीएच एवं धातु संदूषण में बहुत परिवर्तन पाया गया। आवश्यक सूक्ष्म पोषक तत्वों में से केवल जिंक (Zn) अधिकतम अनुमेय सीमा के बाहर पाया गया, लेकिन बूंदी एवं कोटा में अपशिष्ट जल में अनुपयोगी भारी धातु (केडमियम, सीसा, क्रोमियम एवं नीकिल) सुरक्षित सीमा से अधिक पाये गये जबकि अंता (बाराँ) एवं झालावाड़ जिलों में इन अवांछनीय भारी धातुओं का न्यूनतम संदूषण पाया गया। अपशिष्ट जल सिंचित सब्जियों की फसलों में भारी धातुओं के संचय को ध्यान में रखते हुये कोटा एवं बूंदी जिलों में पालक, पत्ता गोभी, फूलगोभी तथा लहसुन की फसलों में अनुपयोगी भारी धातु संचय विशेष रूप से अपशिष्ट जल सिंचाई के साथ एक प्रमुख समस्या पायी गयी। पालक एवं पत्ता गोभी की सब्जियों में फूलगोभी तथा लहसुन की तुलना में अधिक कैडमियम संचय हुआ।

• पंजाब के उत्तरी एवं मध्य हिस्सों में भूजल में आर्सेनिक की सांद्रता क्रमश 0.003 से 0.042 मिलीग्राम/लीटर एवं 0.009 से 0.042 मिलीग्राम/लीटर के बीच बदलती रहती है। लुधियाना केन्द्र द्वारा उपयुक्त नैनो फिल्टर को विकसित करने के लिये अध्ययन आयोजित किया गया ताकि भूजल से आर्सेनिक की सांद्रता को कम करके पीने के पानी की योग्यता में सुधार किया जा सके। चयनित रेत को ठीक से सल्फ्यूरिक अम्ल (H_2SO_4) से धोया गया। ऊर्जा फैलाने वाले एक्स-रे स्पेक्ट्रोस्कोपी (EDX) के विश्लेषण से स्पष्ट रूप से रेत के बुनियादी घटकों की उपस्थिति देखी गई अर्थात कार्बन, ऑक्सीजन, एल्यूमीनियम, सिलिका एवं पोटाश आदि की। धोयी हुई रेत को लोहे के आक्साइड के साथ लेपित करके EDX के माध्यम से विश्लेषण किया गया जिससे रेत के बुनियादी घटकों के साथ लोहे की उपस्थिति का पता चला। फूरियर परिवर्तन अवरक्त स्पेक्ट्रोस्कोपी (FTIR) से 525 सेमी$^{-1}$ एवं 464 सेमी$^{-1}$ बैंड पर लोहे के आक्साइड की कमजोर अवशोषण का पता चला।

• जूनागढ़ केंद्र द्वारा सौराष्ट्र क्षेत्र में ड्रिप सिंचाई के लिये भूजल की उपयुक्तता का मूल्यांकन किया गया। सौराष्ट्र क्षेत्र के 7 जिलों की 73 तहसीलों के 391 चयनित कुओं में से भू-जल के नमूने रबी सीजन 2012 एवं 2013 के दौरान मानक तरीकों से एकत्रित किये गये। भूजल के नमूनों की गुणवत्ता मानक विधियों से निर्धारित की गयी। कुंओ के स्थान का अच्छी तरह से पता लगाने के लिये जीपीएस का उपयोग किया गया। ड्रिप सिंचाई के लिये भूजल की उपयुक्तता के मूल्यांकन के लिये पीएच, इसी (EC), केल्सियम, मेग्नेसियम, सोडियम, आइरन एवं मेंगनीज तथा कार्बोनेट, बाइकार्बोनेट, क्लोराइड व सल्फेट और नाइट्रेट-नाइट्रोजन जैसे भूजल गुणवत्ता मापदंडों का आकलन किया गया। भूजल की गुणवत्ता के मानकों का उपयोग करके टीडीएस (TDS), अवशिष्ट सोडियम कार्बोनेट (RAC), कुल स्थायी कठोरता (TPH), सोडियम अवशोषण अनुपात (SAR), टीएसएस (TSS) आदि का निर्धारण किया गया। सौराष्ट्र क्षेत्र के लिये भूजल गुणवत्ता मानचित्र तैयार किये गये। भूजल में उपस्थित इसी (EC), SAR एवं RAC के आधार पर क्रमशः 56.24%, 18.4%, 6.64% एवं 18.68% नमूनों को अच्छा जल, खारा जल, उच्च SAR खारा जल एवं क्षारीय जल की श्रेणियों में पाया गया।

(iii) विभिन्न कृषि पारिस्थितिकी प्रणाली के लिये जल उपयोग दक्षता एवं जल उत्पादकता बढ़ाने के लिये छोटे भूमि धारकों के सिस्टम सहित सतही तथा दबाव सिंचाई पद्धतियों का डिजाइन, विकास एवं परिशोधन

• जबलपुर केन्द्र ने एक्वाक्रॉप मॉडल का उपयोग कर गेहूं की लक्षित उपज के लिये सिंचाई के समय के निर्धारण पर एक अध्ययन किया। यह अध्ययन जलवायु परिवर्तन के साथ सिंचाई का समय निर्धारण करने में सहायक होगा ताकि जल की कमी हो तो भी जल उपयोग क्षमता बढ़ाई जा सके। गेहूँ की फसल में ड्रिप सिंचाई के उपयोग पर क्षेत्र अध्ययन आयोजित किये गये जिससे पता चला कि गेहूँ की उपज में ड्रिप सिंचाई के साथ वृद्धि हुई। 60 सेमी लेटरल दूरी के साथ 40 सेमी दूरी पर ड्रीप्पर लगाना उपज के मामले में काफी बेहतर पाया गया।

•	तमिलनाडु के पश्चिमी क्षेत्र में एकीकृत कृषि पद्धति में जल उत्पादकता के परिणामों ने बताया कि अन्य वार्षिक फसलों के बीच Co_4 -CN संकर घास में उच्च जल उपयोग दक्षता (WUE) 179.4 किलोग्राम/हेक्टेयर-मिमी थी। भिंडी की फसल ने अन्य मौसमी फसलों के बीच उच्च जल उपयोग दक्षता (45.4 किलोग्राम/हेक्टेयर-मिमी) दर्शायी।

•	धान में सुरक्षित वैकल्पिक गीला एवं सुखाने (SAWD) की सिंचाई विधि से फसल कटाई के 7 से 10 दिन पहले 15 सेमी जल निकास के बाद सिंचाई करने पर उच्च जल उपयोग दक्षता (5.77 किलोग्राम/हेक्टेयर-मिमी) प्राप्त हुई जबकि पारंपरिक सिंचाई विधि से 5.17 किलोग्राम/हेक्टेयर-मिमी ही प्राप्त हुई। पारंपरिक सिंचाई, अधिकतम टिल्लरिंग वृद्धि अवस्था पर 15 सेमी जल निकास के बाद सिंचाई एवं फसल कटाई के 10 दिन पहले तक सतत सिंचाई से शुद्ध लाभ तथा लाभः लागत अनुपात (2.62) अधिक प्राप्त हुआ।

(iv) कुशल उपयोग हेतु वर्षा जल प्रबंधन तथा विभिन्न भूजल गर्भीक स्थितियों के तहत भूजल की उपलब्धता बढ़ाने के लिये भूजल पुन:भरण तकनीकियों का विकास एवं मूल्यांकन

•	लुधियाना केंद्र द्वारा तीन स्थानों पर स्थगित कुओं को संशोधित करके कृषि क्षेत्रों के माध्यम से वर्षा जल संचयन की व्यवहार्यता का पता लगाया जा रहा है। यहाँ जल स्तर के गिरावट की दर में वृद्धि, जल स्तर में वृद्धि की दर से अधिक देखी गयी। पुन:भरण की दर को भी देखा गया जो समय के साथ परिवर्तित होती पायी गयी। औसत हैड अंतर के साथ सभी तीन स्थलों पर उच्चतम पुन:भरण की दर 121.9 लीटर/मिनट से 1.91 लीटर/मिनट के बीच प्राप्त हुई। सभी तीन स्थलों पर तीन मौसमों के लिये यानी मानसून पूर्व, मानसून एवं मानसून के बाद इसी (EC) एवं अवशिष्ट सोडियम कार्बोनेट (RAC) का भी पता लगाया गया। साइट 1, साइट 2 एवं साइट 3 पर इसी (EC) की मात्रा को 0.60-1.273, 0.50-1.400 एवं 0.54-1.015 डेसी साइमंस/ मीटर के बीच पाया गया जबकि स्थल 1 एवं स्थल 2 पर प्रचुर मात्रा में सूखे कुओं में मिट्टी के नमूनों में इसी (EC) क्रमशः 0.278 to 0.875 एवं 0.188-0.920 डेसी साइमंस/ मीटर के बीच पायी गयी। इसलिए सभी तीन सत्रों में लवणता स्वीकार्य सीमा के भीतर ही रहती है। सूक्ष्मजीवाणु/कीटनाशक/ कीटनाशक संदूषण के लिये भूजल की गुणवत्ता का भी विश्लेषण किया गया एवं सीमित सीमा से कम ही पाया गया।

•	जबलपुर केन्द्र की अपर नर्मदा बेसिन में अलग-अलग भूजल गर्भीक परिस्थितियों में भूजल पुन:भरण का मूल्यांकन किया गया। केंद्रीय भूजल बोर्ड एवं केन्द्रीय जल आयोग से प्राप्त आंकड़ों के आधार पर सतही जल संसाधनों एवं भू-जल ड्राफ्ट के योगदान का अभिकलन किया गया। कम भूजल उपयोग एवं अधिक भूजल उपयोग क्षेत्रों को वर्गीकृत किया गया तथा भूजल के उपयोग को बढ़ावा देने के लिये भूजल संरचनाओं के निर्माण की सिफारिश भी दी गयी। इस बेसिन के संवेदनशील क्षेत्रों में भूजल पुन:भरण संरचनाओं को भी प्रस्तावित किया जा रहा है।

•	अमरावती नदी बेसिन के दक्षिण में अपर ओडाई वाटरशेड (4B2A7a2) के लिये संभावित पुन:भरण क्षेत्रों की पहचान की गई। रिमोट सैंसिंग एवं जीआईएस तकनीक का उपयोग कर भूविज्ञान, भू-आकृति विज्ञान, भूमि उपयोग/भूमि कवर, मिट्टी तथा ढलान आदि के विषयगत मानचित्र तैयार किये गये। प्रत्येक विषय की विशेषताओं का कृत्रिम पुन:भरण की प्रक्रिया की द्रष्टि से उनकी प्रतिक्रिया के अनुसार विस्तार से अध्ययन किया गया। विस्तृत अध्ययन के बाद कृत्रिम पुन:भरण के लिये उपयुक्त स्थल का चयन करने के लिये रैंकिंग तथा वेटेज दिया गया एवं वेटेज के बाद ओवरले विश्लेषण किया गया। पुन:भरण मानचित्र की सहायता से पांच अलग अलग पुन:भरित क्षेत्रों की पहचान की गई, अर्थात्, 'बहुत अच्छा' 'अच्छा' 'मोडरेट', 'खराब' एवं 'बहुत खराब'।

•	उदयपुर केन्द्र द्वारा राजस्थान के हाड़ोती क्षेत्र में खुदे हुए तालाबों के माध्यम से भूजल संसाधनों के संवर्धन में इन तालाबों की व्यवहार्यता का पता लगाने के लिये प्रयोग आयोजित किया गया। तालाबों की समग्र क्षमता का पता लगाने के लिये दो खेत तालाबों अर्थात् भावपुरा तथा मोतीपुरा की गहराई क्षमता वक्र का अभिकलन किया गया। जलग्रहण के आकार एवं खेत तालाब की क्षमता के बीच संबंध स्थापित करने के लिये इन दो तालाबों के जलग्रहण क्षेत्र से वर्षा अपवाह की उपलब्धता की भी गणना की गयी।

भावपुरा एवं मोतीपुरा तालाबों की भंडारण की क्षमता (2896.5 एवं 1803.2 घन मीटर), वर्षा अपवाह उपलब्धता (7093 एवं 9718 घन मीटर) की तुलना में काफी कम थी।

- जूनागढ़ केंद्र द्वारा तीन भूजल पुन:भरण तकनीकियों अर्थात् चेक बाँध, रिचार्ज बेसिन एवं छत जल संचयन से भूजल पुन:भरण का पिछले मानसून के मौसम के दौरान मूल्यांकन किया गया। वर्ष 2014 में दैनिक पानी के संतुलन के आधार पर पाया गया कि कुल रिचार्ज 14,420 घन मीटर तथा चैक डैम से 12,582 घन मीटर वर्षा अपवाह को बचाया गया एवं जलग्रहण क्षेत्र से कुल वर्षा अपवाह 19,997 घन मीटर था। इस हाइड्रोलॉजिकल इकाई (चेक बाँध जलग्रहण) में वर्षा से उपलब्ध कुल जल संसाधन का 88,017 घन मीटर के रूप में अनुमान लगाया गया। वर्तमान दर के आधार पर संरचना का खर्च 95,000 रुपए होने का पता चला इसलिये सरंचना के 20 वर्ष के प्रभावी कार्य के लिये लागत रुपए 0.33/घन मीटर कुल पुन:भरण आयतन तक पहुँच गयी। धारा की बहाव अवधि को छोड़कर वाष्पीकरण नुकसान 834 घन मीटर पाया गया जबकि धारा बहाव अवधि के दौरान यह 3123 घन मीटर था मानसून के मौसम के दौरान पुन:भरण बेसिन के जलग्रहण क्षेत्र से कुल वर्षा अपवाह की मात्रा 33,381 घन मीटर प्राप्त हुई जिसमें से 15,510 घन मीटर अपवाह को बेसिन में एकत्रित किया गया तथा 17,870 घन मीटर अपवाह बेसिन के बाहर चला गया। पुन:भरण बेसिन के जल भंडारण से कुल वाष्पीकरण नुकसान 657 घन मीटर तक हुआ। इसलिये शुद्ध पुन:भरण 14,853 घन मीटर प्राप्त हुआ (पानी एकत्रित-वाष्पीकरण हानि)। छत के प्रति वर्ग मीटर क्षेत्र से कुल अपवाह 0.87 घन मीटर प्राप्त हुआ जिसमें से केवल 0.26 घन मीटर अपवाह ने भूजल पुन:भरण के रूप में योगदान दिया तथा छत के प्रति वर्ग मीटर से 0.61 घन मीटर अपवाह को सम्प में एकत्रित किया गया। इस पद्धति की लागत रुपए 172 प्रति वर्ग मीटर निर्धारित की गयी।

- रायपुर केन्द्र द्वारा रिमोट सेंसिंग एवं जीआईएस तकनीक का उपयोग कर बिलासपुर जिले के लिये भूजल पुन:भरण योजना को आयोजित किया गया। राज्य के कुल 146 ब्लॉकों में से 15 ब्लॉकों को अर्द्ध संवेदनशील श्रेणी में वर्गीकृत किया गया जहाँ भूजल विकास की अवस्था 70% से अधिक है। उपलब्ध आंकड़ों का उपयोग कर जल निकासी, ढ़लान, जिला एवं ब्लॉक सीमा मानचित्र, मिट्टी की बनावट तथा लिनीमेंट मानचित्र आदि तैयार किये गये। उपग्रह इमेजरी के पिक्सेल पर आधारित वर्गीकरण का कृत्रिम भूजल पुन:भरण योजना बनाने के लिये इस्तेमाल किया जाएगा।

राहुरी केन्द्र द्वारा भूजल स्तर में गिरावट की समस्या से निपटने के लिये बोर वेल के अच्छी तरह से पुन:भरण के लिये कृत्रिम भूजल पुन:भरण तकनीक विकसित की गयी। यह प्रयोग अनुसंधान फार्म में आयोजित किया गया तथा जुलाई, 2014 से अक्टूबर 2014 तक विभिन्न परीक्षण किये गये। स्थानीय स्तर पर उपलब्ध सामग्री से बने फिल्टर का सस्पेंडेड लोड सांद्रता के लिये परीक्षण किया गया। इस फिल्टर को एक परत, दो परत, तीन परत एवं चार परत की फिल्टर सामग्री के संयोजन के साथ विकसित किया गया। अर्थात रेत-I (0.6-0.2 मिमी), कोणीय ग्रेवला- I (9.5-15.5 मिमी), कोणीय ग्रेवल- II (15.5-21.5 मिमी), मटर आकार बजरी –I (20-24 मिमी), मटर आकार बजरी -I (24-28 मिमी) एवं ईंट फ्लेक्स (24-28 मिमी) आदि के साथ। एक परत में परत मोटाई 100 सेमी थी, दो परत 25 सेमी एवं 75 सेमी, तीन परत में 25 सेमी, 37.5 सेमी, 37.5 सेमी तथा चार परतों में 25 सेमी, 25 सेमी, 25 सेमी एवं 25 सेमी थी। चार परतीय फिल्टर ने अन्य सभी फिल्टर की तुलना में निस्पंदन क्षमता (92.3%) तथा डिसचार्ज (1.156 लीटर/सेकंड) के मामले में बेहतर प्रदर्शन दिखाया।

(v) स्थायी फसल उत्पादन के लिये सतही जल, भूजल एवं अपशिष्ट जल संसाधनों के संयोजी उपयोग हेतु प्रबंधन उपाय विकसित करना।

- कोयंबटूर केंद्र द्वारा लोअर भवानी परियोजना कमांड क्षेत्र में भूजल एवं नहरी जल के संयोजी उपयोग का अध्ययन किया गया। चयनित कुगलूर जल वितरणिका में 47 प्रत्यक्ष स्लूइस (Sluices) लगाये गये हैं। वितरणिका के प्रत्येक हेड, मध्य एवं अंतिम छोर में तीन कुंओं का I-टर्न एवं II-टर्न स्लूइस कमांड के तहत चयन किया गया। कुल 18 कुओं (I-टर्न में 9 कुंओ एवं II-टर्न 9 कुंओ) का अध्ययन के उद्देश्य के लिये चयन किया गया। चयनित कुंओं के कमांड क्षेत्र में उगाई गयी फसलें, नहर के माध्यम से फसलों की सिंचाई तथा भूजल स्तर में उतार-चढ़ाव आंकड़ों को दर्ज किया गया। अगस्त 2014 एवं दिसंबर 2014 के बीच II टर्न कमांड में

फसल सिंचाई के लिये जलाशय के जल का उपयोग किया गया तथा अप्रैल 2014 में भूजल के पुन:भरण एवं पीने के पानी की समस्या को हल करने के लिये जल छोड़ा गया। स्लूइस के ऊपरी भाग की ओर किसान ज्यादा नहरी जल उपयोग करते हैं जबकि अंतिम भाग की ओर वहाँ भूजल उपलब्धता कम है फिर भी किसान भूजल का अधिक उपयोग करते हैं। ड्रिप सिंचाई पद्धति को लगाने वाले किसानों ने केवल भूजल का इस्तेमाल किया।

- मनधार शाखा नहर में जल के संयोजी उपयोग की तकनीक का मूल्यांकन किया गया तथा प्रभावी जल प्रबंधन योजना का विकास किया गया। मौजूदा संयोजी जल उपयोग की तकनीकों ने उपलब्ध, उपयोगित एवं उपयोग में लिये जाने वाले सतही जल की क्रमशः 5.35, 4.81 एवं 3.07 घन मीटर मात्रा को बताया। भूजल की कुल उपलब्धता 2.55 घन मीटर थी जिसमें से 1.62 घन मीटर मात्रा उपयोग करने योग्य है तथा वर्तमान में 0.31 घन मीटर भूजल का उपयोग किया जाता है। उपलब्ध पानी की कमी को पूरा करने के लिये खरीफ में धान एवं सब्जियों को उगाने के लिये इष्टतम फसल योजना को 631.7 एवं 33.2 हेक्टेयर क्षेत्र में लागू किया गया तथा रबी में गेंहू, चना एवं लेथाइरस की फसलों के लिये क्रमशः 22.2 हेक्टेयर, 15.6 हेक्टेयर एवं 4.44 हेक्टेयर क्षेत्र आवंटित किया गया।

- मूला सिंचाई परियोजना के तहत मूसलवाड़ी माइनर सिंचाई परियोजना में सतही एवं भूजल के संयोजी उपयोग की योजना को राहुरी केंद्र द्वारा शुरू किया गया। इस लघु सिंचाई परियोजना (मूसलवाड़ी सिंचाई परियोजना, जिलाः अहमदनगर) की क्षमता 5.36 मिलियन घन मीटर है तथा कृषि योग्य कमांड क्षेत्र 762 हेक्टेयर है को अध्ययन के लिये चुना गया। इस परियोजना के अंतर्गत 6.70 किमी का नहरी नेटवर्क है। इस नहर की क्षमता 18 क्यूसेक है तथा इस नहरी नेटवर्क मे कुल 12 आउटलेट हैं जो कुल 762 हेक्टेयर कमांड क्षेत्र को शामिल करते हैं। जलाशय, जलाशय के अंदर बहाव, फसल पैटर्न, जलवायु, नहरी नेटवर्क, इकाई आंकड़े, आउटलेट निकास, आउटलेट निस्पंदन क्षमता एवं मृदा से संबन्धित आंकड़ों को एकत्रित किया गया तथा स्वाट मॉडल का उपयोग करके इन आंकड़ों के विश्लेषण का काम प्रगति पर है।

जन जातीय उप परियोजना (टीएसपी)

रायपुर केन्द्र द्वारा जल उपयोग दक्षता में वृद्धि के माध्यम से इस क्षेत्र के आदिवासी किसानों के उत्थान संबंधित गतिविधियों को लागू किया गया ताकि उनको अधिक आय मिल सके। इस संबंध में राजनांदगांव जिले के आदिवासी ब्लॉक अंबागढ़ चोकी के गांवों मुरेठीटोला, कोडी, वरचाकुटुंब एवं बेलारगोड़ी आदि को सिंचाई जल उपयोग में सुधार के लिये तकनीकियों के प्रदर्शन के लिये चुना गया। ड्रिप सिंचाई पद्धति के लिये 0.18 हेक्टेयर (2 नग) एवं 0.30 हेक्टेयर (5 नग) क्षेत्र डिजाइन किया गया है जिनको जल के कुशल उपयोग के लिये खेतों में स्थापित किया गया। फव्वारा सिंचाई पद्धति के 2 सेट भी कम से कम नुकसान के साथ सिंचाई जल उपलब्ध कराने के लिये किसानों के बीच वितरित किये गये।

इस टीएसपी के तहत कृषि विज्ञान केन्द्र, नंदुरबार द्वारा भूजल अनुसंधान परियोजना, MPKV, राहुरी के सहयोग से सब्जियों की फसलों के लिये ड्रिप एवं फव्वारा सिंचाई पद्धति पर एक कार्यशाला को आयोजित किया गया। इस कार्यशाला के दौरान कृषि विज्ञान केन्द्र, नंदुरबार के सहयोग से नंदुरबार जिले के चयनित 53 आदिवासी किसानों (18 आदिवासी किसानों को ड्रिप सिंचाई सामग्री सेट एवं 35 आदिवासी किसानों को फव्वारा सिंचाई सामग्री सेट) को ड्रिप एवं स्प्रिंकलर सिंचाई प्रणाली सामग्री निंबोनी गाँव में 8 दिसम्बर 2014 को वितरित की गयी।

- सतपुड़ा की पहाड़ियों के कुंडम ब्लॉक तथा किमोर पठारी क्षेत्र में जल उपयोग दक्षता (WUE) एवं जल उत्पादकता (WP) को बढ़ाने के लिये किसानों को प्रशिक्षित किया गया तथा लाइन बुवाई एवं गेहूं के लिये फव्वारा सिंचाई विधि को अपनाने के लिये सक्षम बनाया गया। यह क्षेत्र सिंचाई सुविधा से वंचित है तथा साथ ही यहाँ भूजल उपलब्धता भी बहुत कम है। अतः फव्वारा सिंचाई पद्धति को यहाँ उपस्थित उचित मिट्टी एवं फसल की स्थिति के लिये डिजाइन किया गया। यह काम 18 लाभार्थी किसानों की संख्या के साथ बिचुआ एवं संजारी गाँवों में किया गया। फसल प्रबंधन एवं सिंचाई पर नजर रखी गयी तथा फव्वारा सिंचाई एवं पारंपरिक बाढ़ सिंचाई विधि से सिंचित फसलों में प्राप्त पानी की आपूर्ति, फसल विकास एवं उपज संबंधी आंकड़े दर्ज किये गये।

EXECUTIVE SUMMARY

Salient Achievements of AICRP on Irrigation Water Management during 2014-2015

During the year 2014-2015, 26 centers carried out research and extension work in the field of assessment of water availability, groundwater recharge, groundwater use at regional level, evaluation of pressurized irrigation system, groundwater assessment and recharge, water management in 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 2014-2015 are given below:

Brief Technical Achievements (2014-15)

Assessment of irrigation water demand and system supply and Groundwater use

At Jammu, the maximum deficit of irrigation in the Rainbir canal system is found to be from 9th to 30th September during pinnacle initiation to flowering stage of Rice crop to the quantum of 4568.8 ha-m. This indicates that either frequency of rotation of irrigation supply should be reduced from present 7 days to alternate day or sub-surface irrigation potential to the tune of 4568, 8 ha-m be developed at disaggregated level of said command by stakeholders and supplied in the shape of conjunctive water use in space, time and augmentation by stake-holders for improving water productivity of Rice crop in the study area i.e basmati bowl R.S. Pura and similar approach needs to be followed for entire command area.

At Bilaspur, Groundwater recharge planning for Bilaspur district using remote sensing and GIS has been conducted. Out of 146 blocks in the state, 15 have been categorized as semi-critical as the stage of groundwater development in these area is more than 70% but less than or equal to 90%. Various thematic maps including drainage map, slope map, district and block boundary maps, soil texture and lineament maps were generated using available data. The pixel based classification of the satellite imagery will be used for the planning of artificial groundwater recharge plan.

At Coimbatore, in Amaravathy basin, average annual rainfall was estimated 1009.8 mm and more number of normal years was observed at the head end of basin and number of deficit years was high in the tail end. The recharge was estimated using the empirical formulas range from 17 to 30 %. The number of blocks in the basin is 33, out of which 16 were over exploited, 2-critical, 12- semi critical and remaining blocks are safe.

At Junagarh, the groundwater quality maps for Saurashtra region were prepared. Based on the EC, SAR and RSC of the groundwater, 56.24%, 18.4%, 6.64% and 18.68% samples were found under categories of good water, saline water, high SAR saline water and alkali water class respectively.

At Junagarh, it is observed on the basis of daily water balance in year 2014, total recharge was 14420 cu.m, runoff escaped from check dam was 12582 cu.m, total runoff from catchment was 19997 cu.m. Total Water resource available from rainfall in hydrological unit (check dam catchment) was estimated 88017 cu.m. Structure cost on current rate basis was estimated Rs. 95000, so recharge cost goes to Rs. 0.33 per cu.m of recharge volume @ 20 years effective service of structure. Recharge per sq.m of catchment was observed 0.19 cu.m. Evaporation loss excluding stream flowing period was found 834 cu.m and during stream flowing period it was 3123 cu.m. During monsoon season total 33381 cu.m of runoff volume was generated from catchment area of recharge basin, out of that 15510 cu. m was trapped in to the basin and 17870 cu.m was escaped from the basin. Evaporation loss from the water storage of recharge basin was estimated as 657 cu.m. So, net recharge was 14853 cu.m. (water collected – evaporation loss). It was found that out of total runoff 0.87 cu.m per square meter of roof, 0.26 cu.m of runoff per square meter of roof was contributed as ground water recharge and 0.61 cu.m of runoff per square meter of roof was collected in to sump. Cost of system was determined Rs.172 per square meter.

At Ludhiana, during the last 14 years, the area under different under water table 3-10 m has reduced from 53.0 to 21.9 per cent, whereas the area with water table depth greater than 20 m depths has rose from 0.0 to 24.6 per cent indicating that central Punjab is under severe declining water table problem. The pump density maps (no of pumps per 1000 ha) were prepared for both diesel and electric operated tubewells for the individual years. The electric pumpset in SC-III had sharply increased and followed an exact linear trend from 2000-2011 SC-III and BM-III witnessed a 67% and 42% increase in electrical pumpset density respectively during the study period. In case of diesel pump sets, UB-III and SC-III witnessed a 11% and 7% decrease in the density respectively whereas BD-III and BM-III showed an increase of 49% and 46% respectively during the study period

At Ludhiana, it was found that In the northern and central parts of Punjab, the concentration of arsenic in groundwater varied from 0.003 to 0.042 mg/l and 0.009 to 0.042 mg/l respectively. Study is being conducted by Ludhiana centre to develop suitable nano-filter which can reduce concentration of arsenic from groundwater to improve its potability. The selected fine sand was washed with H_2SO_4. Energy-dispersive X-ray spectroscopy (EDX) analysis clearly showed the presence of basic components of sand viz. carbon, oxygen, aluminium, silica and potash. The washed fine sand then coated with iron oxide and analysed through EDX which shows the presence of iron along with basic components of sand. Fourier transformation infrared spectroscopy (FTIR) shows the weak absorption of iron oxide at the 525 cm^{-1} and a medium band at 464 cm^{-1}.

At Ludhiana, It was predicted that the average yield of adequately irrigated and fertilized rice for Ludhiana district may reduce by 14.8% in MC and by 30.4% in EC during *kharif* season. However, in *rabi,* wheat may marginally increase by 0.2% in MC and reduced by 12.5% in EC. In MC and EC (averaged over soil series), crop duration would be shortened by 17 days (16.3%) and 24 days (23.1%) in rice; and 8 days (5%) and 22 days (13.4%) in wheat, respectively. Rice yield in MC and EC would decrease almost in all the years compared to that of the PTS.The irrigation requirement in MC and EC would decrease by 48.7% and by 51.0% during the *kharif* season; and 25.3% and 41.7% in *rabi* season, respectively.

At Rahuri, artificial groundwater recharge technique for recharge of bore well is developed by Rahuri centre to tackle the problem of declining groundwater table. The experiment was conducted at the Instructional Farm and the tests were conducted during the period from July, 2014 to October 2014. The filters made from various locally available materials were tested for the constant suspended load concentration of 200 NTU. The filter developed in single layer, two layer, three layer and four layer with combination of filter material viz. sand- I (0.6-0.2mm), angular gravel-I (9.5-15.5mm), angular gravel- II (15.5-21.5), pea gravel –I (20-24mm), pea gravel –I (24-28), brick flacks (24-28mm). The layer thickness in single layer was 100 cm, in two layer was 25cm, 75cm, in three layer was 25cm, 37.5cm, 37.5cm and in four layers 25cm, 25cm, 25cm and 25cm. The four layer filter has performed better in terms of filtration efficiency (92.3%) and discharge (1.156 lps) amongst all other filters.

At Raipur in Chakranal watershed, the aquifer properties were found for Daldal Seoni (RGI EW-IV and RGI OW-I) ranges from, transmissivity (T) 2.93 to 3.16 m²/day and storativity (S) 3.17 x 10^{-5} to 3.46 x 10^{-5} and for FAE well, IGKV Raipur ranges from, transmissivity 9.37 to 9.51 m²/day.

At Udaipur, the results revealed that the major limiting factor in groundwater quality of Bhilwara district is salinity (90.90 % water samples falls under high to very high salinity classes, $_{C3}$ and $_{C4}$). Only 9.99 % groundwater samples have the problem of high to very high sodic water ($_{S3}$ and $_{S4}$ classes). Similarly, the alkalinity problem encountered only in very small area (8.18 % groundwater samples reported to have more than 2.5 me^{L-1} of RSC). Therefore, looking to the problem of high salinity, utmost care should be taken towards the management of salinity problems of groundwater in the study area.

At Udaipur, the study indicated that about 87.18 per cent of the basin falls under poor/ moderate groundwater potential zones and therefore, immediate attention is required for ensuring sustainable groundwater management in the basin. The area suitable for artificial recharge is 279 km^2, which contributes only 15.02 per cent of the total study area.

Evaluation of conjunctive water use techniques in the Mandhar branch canal and development of effective management plan. Existing Conjunctive water use practices shows available, utilizable and utilized surface water as 5.35 Mm^3, 4.81 Mm^3 and 3.07 Mm^3 respectively where as groundwater availability is 2.55 Mm^3 in which 1.62 Mm^3 is utilizable and currently 0.31 Mm^3 is utilized. To meet the deficit of available water optimal crop plan has assigned 631.7 ha and 33.2 ha area in kharif to paddy and vegetables where as in rabi

22.2 ha, 15.6 ha, 4.44 ha area has been assigned to wheat, gram and lathyrus respectively. Results on Irrigation scheduling and water use efficiency.

At Bhavanisagar,In the safe alternate wetting and drying (SAWD) irrigation method in rice, higher WUEof 5.77 kg/ha/mm was noticed under irrigation after 15 cm DPW from 7 DAT to 10 daysprior to harvest while lower WUE of 5.17 kg/ ha/mm was observed under the conventional irrigation practice. The net return and B: C ratio (2.62) also was higher with conventional rrigation practice and irrigaion after 15 cm DPW upto maximum tillering and continuous submergence up to 10 days prior to harvest.

At Bilaspur, it was revealed that delaying irrigation upto 3-5 days after subsidence of ponded water can be considered to be the best water regime for paddy in clay-loam to clay as about 40-60% of irrigation water can be saved without yield loss in comparison to continuous shallow submergence (+/- 5 cm ponded water) At Faizabad, the improved water management practice (6cm water per irrigation through checks of 10x10m) gave higher grain yield of 41.77, 41.40 and 40.50 q/ ha at head, middle and tail end of Chandpur distributory in comparison to farmers practice in which these were 31.50, 31.42 and 29.89 q/ha, respectively. Thus, about 31.76–35.50% higher grain yield was obtained under improved water management practice over farmer's practice of wheat crop. The water expense efficiency (WEE) was found to be highest (149.87 kg/ha.cm) at head followed by middle and tail end at which it was 148.55 kg/ha.cm and 145.32 kg/ha.cm under improved irrigation practices, respectively. The water expense efficiency was quite low in case of farmers practice which were 85.44, 84.21 and 81.07 kg/ha.cm at head, middle and tail end of the distributory respectively. At Faizabad, Maximum pigeon pea equivalent yield (22.14 q/ ha) was recorded when pigeon pea was grown on raised bed in paired row intercropping with rice at farmer fields under poor availability of canal water at tail end of distributory. The above intercropping system which was based on rainfed cultivation was most economical by giving maximum net return of Rs. 67988.00 per hectare. At Faizabad, Integrated farming system including pisi culture and duckery was found more productive and remunerative than conventional cropping system (rice-wheat) giving highest net return of Rs. 129471.00/ha/yr. with B:C ratio 2.67 against conventional system (Rs. 73625.00/ha/ yr and 1.62).

At Faizabad, Transplanting rice has recorded the highest yield of 43.39 q/ha which was significantly higher over rest of the planting method of rice. Drum seeding of rice gave the second highest yield of 37.52 q/ha which was also significantly higher over planting with zero tillage machine and seeding under dry condition but at par with that of broadcasting of sprouted seeds under puddled condition. Irrigation schedule has significant effect on rice crop yield and I1 irrigation schedule (7cm irrigation at 1-DADPW) recorded the significantly higher yield of rice 46.11 q/ha over other irrigation schedules in which 7cm irrigation was applied at 4 (I2), 7(I3) and 10 (I4) days after disappearance of ponded water (DADPW). The rice yield under I2, I3 and I4 irrigation schedule was 41.12, 32.54 and 26.14 q/ha respectively.

At Faizabad, Improved irrigation practice of 6cm water at critical stages (CRI, late jointing and milking, two irrigation from canal and one from tube-well water) by check basin (100m2) produced significantly higher grain yield (4217.14 kg ha-1) of wheat as compared to farmers practices (3087.86kg ha-1) in which two irrigations from canal with 8-10cm of water by flooding field to field method were given. The increase in yield was 36.97% in case of improved irrigation practice over farmers practice. WEE was also found significantly higher (54.48%) with improved irrigation practice over farmers practices.

At Gayeshpur, the analysis of data showed that the grain yield of wheat was maximum (3340 kg/ ha) with highest frequency of irrigation at 20% MAD of ASM, however, was at par with moderate frequency of irrigation at 40% MAD of ASM (3187 kg /ha). Similarly, the highest grain yield was obtained with 160:80:80 kg/ha N: P_2O_5: K_2O fertilizer level, but yield was statistically at par with 120:60:60 kg/ha N: P_2O_5: K_2O. The nutrients (NPK) uptake was maximum with irrigation at 20% MAD of ASM (84.6, 22.7 and 71.9 kg/ha of NPK, respectively) and also with highest level of 160:80:80 kg/ha N: P_2O_5: K_2O fertilizers (99.0, 26.9, 84.6 kg/ha of NPK, respectively), but were on par with 40% MAD of ASM and 120:60:60 kg/ ha N: P_2O_5: K_2O fertilizers, respectively. The interaction between irrigation and fertilizer levels showed that maximum yield (4153 kg/ha) and water use efficiency of 13.8 kg/ha-mm was recorded with irrigation at 20 and 60% MAD of ASM, respectively both supplemented with 160:80:80 kg/ha N:P_2O_5:K_2O fertilization.

At Hissar Planting of wheat cv. WH 711 under FIRBS resulted in higher irrigation and total water productivity (5.20 and 1.41 kg/m^3) as compared to conventional sowing (3.70 and 1.25 kg/m3), however, the yield did not differ significantly in both the systems of sowing.

At Hissar Wheat succeeding mungbean produced significantly higher grain yield (4781 kg/ha), irrigation (4.64 kg/m^3) and total water productivity (1.36 kg/m^3) than sorghum (4465 kg/ha, 4.21 kg/m^3, 1.22 kg/m^3).

At Hissar, Conventional tillage resulted in significantly higher grain yield (4826 kg/ha) than complete zero (4327 kg/ha) but it was at par with zero-tillage in rabi (4717 kg/ha). The water productivity of irrigation water under zero tillage in rabi was higher (4.81 kg/m^3) than conventional (4.39 kg/m^3) and complete zero (4.08 kg/m^3).

At Hissar, The grain yield of wheat was highest with irrigation at IW/CPE of 0.9 whereas irrigation water productivity was highest under irrigation at IW/CPE of 0.60.

At Hissar, Application of irrigation at IW/CPE = 1.0 resulted in significantly higher yield over irrigation at IW/CPE=0.8 and 0.6. Intercropping of maize:soybean in 1:1 planting geometry produced substantially higher maize grain yield.

At Jammu research findings reveal that there is dire need of critical irrigation during CRI stage-November and booting stage-March of wheat to meet up minimum (1) irrigation of 60 mm in view of canal closure during the period. The quantum of this additional irrigation potential is 1798.5 ha-m at disaggregated level of study area. It needs to be supplied to the farmers through shallow tube-wells. This shall upscale water productivity of rice-wheat sequence.

At Jorhat, Pooled yield of three years revealed that two irrigations, one each at flowering and siliqua development stage recorded significantly higher seed yield of yellow sarson than one irrigation either at flowering or siliqua formation stage and rainfed crop. Pooled yield data also revealed that application of 90-60-60 N-P_2O_5-K_2O kg/ha being at par with 75-50-50 N-P_2O_5-K_2O kg/ha recorded significantly higher seed yield than 60-40-40 N-P_2O_5-K_2O kg/ha. At Jorhat, drainage coefficient for Assam lemon revealed that highest value of drainage coefficient (4.28 cm/h) was obtained for PVC pipe with mineral envelope followed by PVC pipe with organic envelope. Bamboo pipe with organic envelop resulted in the lowest drainage coefficient of 0.669. The plastic pipe irrespective of envelope material lowered the water table better than other treatments during the rainy season. The same pipes are being used in Rabi season for providing irrigation water to root zone and observation on yield and plant attributes are being taken.

At Navsari, it is concluded that for achieving higher yield and net profit from pigeon pea (rabi), the crop is to be irrigated through drip at 0.6 PEF with laying of 50μ black plastic as mulch (BPM) with 56 per cent coverage area.

At Navsari, Based on the yield and economics, it is concluded that for getting higher yield and net profit from rabi castor, crop should be sown at 2.4 m x 0.6 m spacing. Further, it should be fertilized with 160:40 kg N and P/ha. The 10 per cent dose of N and whole quantity of P should be given as basal and remained 90 per cent N is to be given through fertigation in 10 equal splits at an interval of 8-10 days starting from 15 DAS.

At Shillong, Zero tillage for both kharif and rabi crops resulted in higher grain yield as compared to conventional tillage. Grain yield of rice was 15% higher under zero tillage. Zero tillage also had a significant influenced on the yield of succeeding rabi crops: pea (2108.4 kg ha^{-1}), mustard (943.1 kg ha^{-1}) and buckwheat (723.6 kg ha^{-1}) as well as the water use efficiency as compared to conventional tillage.

Pressurised irrigation system and Fertigation

At Faizabad, Drip irrigation @ 80% of PE with 100% N (I3) gave the highest crop yield of 1000.50 to 1050.60 q/ha followed by I4 I5 I6 I7, I8, I1 and I2 in which it was 980.40 to 1035.40, 892.20 to 952.20, 850.50 to 901.60, 688.10 to 750.80, 680.40 to 730.80, 615.00 to 635.40 and 529.50 to 554.00 q/ha respectively. The yield obtained under the treatment with 100% N fertigation was at par with that of 75% N fertigation 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 yield in comparison to surface irrigation system. Drip irrigation treatment (Irrigation @ 80% PE with 100% N) was found most economical with B:C ratio of 4.03, 7.74 and 7.62 during three consecutive years (2012-2014) followed by I4 I5 I6 I1, I7, I2 and I8 treatments of irrigation. Drip irrigation saved about 59.46, 69.53 and 79.67% irrigation water under 80%, 60% and 40% of PE irrigation levels in comparison to surface irrigation in sugarcane cultivation respectively.

At Hissar, Irrigation applied at 0.8 PE through drip resulted in highest seed cotton yield and water productivity. Among the surface methods irrigation at IW/CPE=0.75 by furrow method higher seed cotton yield as well as water productivity. Mulching with wheat straw @ 4 or 6 t/ha produced similar yield and water productivity but was considerably superior to no mulch.

At Hissar, Irrigation with mini-sprinklers of wetting diameter of 6 m in wheat saved 40 mm water with an additional grain yield of 231 kg ha^{-1} as compared to surface irrigation. After 5 years of operation of mini-sprinklers (6 m dia), a net profit of Rs. 28427/ha was achieved over surface irrigation. The productivity of irrigation and total water use was also higher under mini-sprinkler as compared to surface irrigation.

At Bhavanisagar, The results of water productivity in integrated farming system in western zone of TamilNadu revealed that the water use efficiency (WUE) was higher in CO4 CN hybrid grassof about 179.4 kg/ ha/mm and among the other annual crops, Bhendi resulted in higher WUE (45.4 kg/ ha/mm).

At Bhavanisagar, the study on optimization on irrigation and Fertigation schedule revealed that in the treatments receiving less of irrigation water and higher fertigation level, the potassium content near to the lateral seems to be higher compared to places far off laterals. Irrespective of irrigation levels and fertigation levels available potassium was found to be higher in the 15-30 cm depth compared to 0-15 cm depth and this may be due leaching of nutrients during the water movements. Water use efficiency was maximum in the treatment drip irrigation at 40% of PE and 60% of PE with lateral spacing of 90 cm.

At Bhavanisagar, Sub surface drip irrigation to SSI cane at 1.0 PEF with an interval of 2 days recorded the maximum cane (146t/ha) yield and sugar yield (17.91 t/ha). Fertigation of 75% RDF :50% P & K as basal, balance through drip as WSF (Ultrasol- 9:5:33, Urea & SOP) registered the highest cane (133.41 t/ha) and sugar yield (15.54 t/ha). The maximum WUE and water productivity of SSI cane were registered with sub surface drip fertigation of 75% RDF: 50% P & K as basal, balance through drip as WSF (Ultrasol- 9:5:33, Urea & SOP). With regard to irrigation levels, the highest WUE and water productivity were observed under irrigation at 0.6 PEF.

At Chalakudy, drip Irrigation @ 2 ltr./plant on alternate days using inline drippers along with mulching can be recommended for salad cucumber. Full dose of N and K as drip fertigation with conventional fertilizers (Urea and MOP) at weekly intervals (8 times) and full P as basal could increase the yield of salad cucumber. The two different fertilizer sources tested did not have any significant influence on the yield of salad cucumber. The soluble fertilizer (Krista K) was more costly and conventional fertilizers were more economical and registered significantly higher B : C ratios compared to soluble fertilizers. Soluble fertilizers could register a B: C ratio of 1.89 whereas conventional fertilizers recorded a B:C ratio of 2.41.

At Gayeshpur, the 3-year pooled analysis showed that the gravity drip irrigation scheduling at 1.0 Eo (evaporation replenishment) coupled with the conjunctive use of 50% inorganic N plus 50% organic N through vermicompost produced significantly the highest number of spikes/plot (72.6), number of florets per spike (10.3), longer spike length (65.9 cm), higher weight of single spike (43.2 g) and spike yield (9886 kg/ha) of gladiolus, which was competitive with the gravity drip irrigation scheduling at 0.8 Eo supplemented with 50% inorganic N plus 50% organic N through vermicompost. The performances of conventional surface irrigation were found to be poor in exhibiting the quality parameters and flower yield of plant. The highest water use efficiency of 65.63 kg/ha-mm was obtained with gravity drip irrigation scheduling at 0.6 Eo and the lowest of 31.65 kg/ha-mm in conventional surface irrigation.

At Jammu, the pooled data for three years Rabi 2011-12 to 2013-'14 for yield and water-use forPotato (Solanum tuberosum) indicates that irrigation methods and irrigation schedules differed significantly. Sprinkler method recorded significantly higher yield over flooding but at par yield with skip furrow method. Irrigation schedule of 0.3 PE recorded significantly higher yield over 0.7PE but at par yield with 0.5 PE. Water use efficiency was recorded highest with sprinkler irrigation 42.74 kg /ha-mm followed by skip-furrow 40.89 kg/ ha-mm and flooding irrigation 30.47 kg/ ha-mm, respectively.

At Navbsari, based on the results of experiment on comparative performance of water soluble and routinely used fertilizer in banana (cv. Grand Naine) under drip irrigation, among the fertilizer levels, L_3 (80 % RD) recorded significantly higher values of all these attributes as compared to L_2 and L_1. As far as effect of frequency of fertilizer application is concerned it was found to be significant on all the attributes except no. of hands per bunch. In all the cases, F_2 (twice in a week) frequency of fertigation recorded significantly higher values. The fruit yield followed the significant descending trend on L levels i.e. $L_3 > L_2 > L_1$ between the two frequency of fertigation, level F_2 recorded significantly higher fruit yield as compared to F_1. In case of control v/s rest analysis, treatment mean was better than drip and drip better than surface control.

At Palampur, 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 fertigation with an interval of at least 11 days between two successive fertigation.

At Palampur, 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 fertigation with an interval of at least 11 days between two successive fertigation.

At Pantnagar, in Lysimeter the average rice yield of 46.47 q/ha was obtained with an average water requirement of 701.3 mm, having average WUE as 6.68 kg/ha-mm during the kharif season of 2014. The higher grain yield of mustard was obtained under shallow water table (30 cm) with sprinkler irrigation method than flood method. Even under deep water table situations, sprinkler method was better than flood method. Flood method was inferior to sprinkler as it produced lower mean grain yield by a margin of 217 kg/ha. The mean increase in WUE due to sprinkler method was 0.54 kg/ha-mm over the flood method (1.87 kg/ha-mm). The average crop coefficient (Kc) value for Mustard cv. Pant Peeli Serson-1 is 0.56 ranging from 0.17 (sowing time) to 1.02, a stage of flowering & pod formation stage. During summer months, cowpea needs to be irrigated at CPE loss of 150 mm with sprinkler and 200 mm CPE loss with flood method. Overall, sprinkler method of irrigation was superior to flood and had higher WUE. Both the methods performed better at 60 cmwater table depth.

At Pantnagar, In transplanted rice poor efficacy of PE herbicides in the want of proper moisture is a big issue to achieve satisfactory weed control. Based on the grain yield, it can be concluded that for higher efficacy of Pretilachlor (PE), irrigation must not be delayed from 1DADSW during initial crop phase (upto 15 DAT). In more stressed treatments Bispyribac-Na (PoE) performed better than Pretilachlor. With alone application of either herbicide, irrespective of moisture regimes, the weed control efficiency was better with Bispyribac than Pretilachlor. But under severe stress, both herbicides failed to control the weeds effectively. Based on interaction data it is noted that weeds dry matter < 2.0 g/m2 (transformed values) at 60 DAT is the critical value for obtaining good rice yield.

Rainwater harvesting and utilization

At Dapoli, from the three years study it is observed that, use of dry grass mating + 75% shading net retained more water in Jalkund as compared to other treatments followed by a cover of dry grass matting + polyethylene paper. Use of dry grass mating + 75% shading net retained (56.5%) more water as compared to control treatment.

At Dapoli, Irrigation up to 20 days from peanut stage of cashew nut could not increase yield, whereas, the yield was significantly increased and was highest (4.53 kg/plant) when irrigation was delivered up 40 days from peanut stage of cashew nut. Yield under treatment irrigation up to 80 days from peanut size of cashew nut was decreased, which indicated that cashew requires water up to 60 days from peanut size of cashew nut to increase the yield. The results indicated that application of total water of 6 ha-mm (60000 litres) up to 40 days after the peanut stage of cashew nut could increase the cashew yield of fully grown crop to 1.30 tonnes/ha with the WUE of 216.7 kg/ha-mm. Highest yield could be observed in treatment combination I_2T_2 i.e. irrigation application @ 50 litres/plant up to 40 days after peanut stage of fruit development.

At Shillong, turmeric grown under terrace condition with FYM + straw mulching significantly recorded higher yield (27740.6 kg ha^{-1}) as compared to other treatments. Weed population and density was also significantly influenced by different manures and mulching. The control plots recorded highest weed population.

At Shillong, zero tillage resulted in higher maize equivalent yield (5940.03 kg ha^{-1}) as compared to conventional tillage. Among the intercropping system/ residue management treatments, the maize equivalent yield (MEY) was higher under Maize + Groundnut Paired Row (residue retention) which was 57.87% more as compared to sole maize and the yield of succeeding toria was also found to be higher under Maize + Groundnut Paired Row (residue removal) which was 43.75% higher as compared to Sole Maize (residue retention).

At Palampur, under irrigation depth of 2 cm, application of plastic mulch in Brinjal resulted in significantly higher gross and net returns than under application of either organic mulch (21.12 & 25.69 %) or no mulch (38.41 & 41.44 %) and application of organic mulch after planting of crop resulted in significantly higher (14.27 %) gross returns than under application of no mulch. However, in case of net returns, application of organic mulch had no effect when compared with no mulch treatment. Similarly, B: C ratios were not influenced by source of mulch in comparison to no mulching under irrigation depth of 2 cm.

Basic Studies on Soil-water-plant relationship

At Ludhiana, It was predicted that the average yield of adequately irrigated and fertilized rice for Ludhiana district may reduce by 14.8% in MC and by 30.4% in EC during kharif season. However, in rabi, wheat may marginally increase by 0.2% in MC and reduced by 12.5% in EC. In MC and EC (averaged over soil series), crop duration would be shortened by 17 days (16.3%) and 24 days (23.1%) in rice; and 8 days (5%) and 22 days (13.4%) in wheat, respectively. Rice yield in MC and EC would decrease almost in all the years compared to that of the PTS.The irrigation requirement in MC and EC would decrease by 48.7% and by 51.0% during the kharif season; and 25.3% and 41.7% in rabi season, respectively.

INTRODUCTION

All Indian Coordinated Research Project on Water Management and All India Coordinated Research Project on Groundwater Utilisation were merged to be rechristened as All India Coordinated Research Project on Irrigation Water Management during the XII Plan and are operating in 26 centres. There are multiple locations under Tamil Nadu Agricultural University (Bhavanisagar, Madurai, Coimbatore), Jawaharlal Neheru Krishi Viswa Vidyalaya, Jabalpur (Powerkheda and Jabalpur), Panjab Agricultural University, Ludhiana (Bathinda and Ludhiana), Indira Gandhi Krishi Viswa Vidyalaya (Raipur and Bilaspur) centres. The mandates of the merged AICRP on Irrigation Water Management are as follows.

Revised Mandates of AICRP on Irrigation Water Management after merger of AICRP on WM and AICRP on GWU are

1. Assessment of surface and ground water availability and quality at regional level and to evolve management strategies using Decision Support Systems (DDS) for matching water supply and demand in agricultural production systems.
2. Design, development and refinement of surface and pressurized irrigation systems including small holders' systems for enhancing water use efficiency and water productivity for different agro-eco systems
3. Management of rain water for judicious use and to develop and evaluate groundwater recharge technologies for augmenting groundwater availability under different hydro-geological conditions.
4. Basic studies on soil-water-plant-environment relationship under changing scenarios of irrigation water management.
5. To evolve management strategies for conjunctive use of surface and ground water resources for sustainable crop production.

List of existing centres and their controlling institutions under AICRP on Irrigation Water Management

Table.1 Centres and their controlling Universities

S.No.	Location of the Centre	Controlling University/ICAR Institute
1.	Almora	VPKAS., Almora
2.	Bathinda, Ludhiana	PAU., Ludhiana
3.	Belvatagi	UAS.,Dharwad
4.	Bhavanisagar,Madurai, Coimbatore	TNAU., Coimbatore
5.	Bilaspur, Raipur	IGKVV., Raipur
6.	Chalakudy	KAU., Thrissur
7.	Chiplima	OUAT., Bhubaneswar
8.	Dapoli	KKV., Dapoli
9.	Faizabad	NDUAT., Faizabad
10.	Hisar	CCSHAU., Hisar
11.	Jammu	SKUAST., Jammu
12.	Jorhat	AAU., Jorhat
13	Junagarh	Junagarh Agricultural University
14	Gayeshpur	BCKVV, Kalyani
15.	Kota	Kota Agricultural University
16.	Morena	JNKVV, Jabalpur
17.	Navsari	NAU., Navsari
18.	Palampur	HPKVV, Palampur
19.	Pantnagar	GBPUAT, Pantnagar
20.	Parbhani	MAU, Parbhani
21.	Powarkheda, Jabalpur	JNKVV, Jabalpur
22.	Pusa	R.A.U., Pusa
23.	Rahuri	M.P.K.V., Rahuri
24.	Shillong	ICAR Res. Complex for NEH region
25.	Sriganganagar	R.A.U., Bikaner
26.	Udaipur	MPUAT, Udaipur

Irrigation Commands under AICRP on Irrigation Water Management

The locations of the centres of AICRP on Irrigation Water Management catering to different irrigation commands and agro ecological regions in the country are given in Table 2

Table 2. Agro ecological region-wise distribution and irrigation commands represented by the centres of AICRP on Water Management

Region No.	Agro-ecological region	State	Irrigation Region	Centre	Controlling command organization
1	Western Himalayas, cold arid ecoregion with shallow skeletal soils	J & K	Jammu Tawi		
2	Western Plain, Kachchh and part of kathiawar Peninsula, hot ecoregion, with desert and saline soils	Punjab Haryana Rajasthan Gujarat	Bhakra Bhakra IGNP	Bathinda Hisar Sriganga-nagar	PAU CCS HAU RAU-Bikaner
3	Deccan Plateau, hot arid ecoregion, with red & black soils	A.P. Karnataka			
4	Northern Plain and central Highlands including Aravalis, hot semi-arid ecoregion, with alluvium-derived soils	Punjab Haryana Gujarat Rajasthan U.P. M.P.			
5	Central (Malwa) Highlands, Gujarat Plains & Kathiawar Peninsula, hot semi-arid ecoregion, with medium & deep black soils	Rajasthan M.P. Gujarat	Chambal Chambal	Morena Kota	JNKVV MPUAT, Udaipur
6	Deccan Plateau, hot semi-arid ecoregion, with shallow and medium (with inclusion of deep black soils)	A.P. Maharashtra Karnataka	Mula Jayakwadi Malaprabha	Rahuri Parbhani Belvatagi	MPKV MKV UAS, Dharwad
7	Deccan (Telangana) Plateau and Eastern Ghats, hot semi-arid ecoregion, with red & black soils	A.P.			
8	Eastern Ghats, TN uplands and Deccan (Karnataka) Plateau, hot semi-arid ecoregion with red loamy soils.	A.P. Karnataka Tamil Nadu	Lower Bhavani Periyar Vaigai	Bhavani-sagar Madurai	TNAU
9	Northern Plain hot subhumid (dry) ecoregion, with alluvium derived soils	Bihar Punjab U.P.	Sharda Canal Sharda Sahayak	Pantnagar Faizabad	TNAU GBPUA&T NDUA&T
10	Central Highlands (Malwa, Bundelkhand & Eastern Satpura) hot humid ecoregion, with black and red soils	M.P. Maharashtra	Tawa	Powarkheda	JNKVV

Region No.	Agro-ecological region	State	Irrigation Region	Centre	Controlling command organization
11	Eastern Plateau (Chhatisgarh), hot subhumid ecoregion, with red & yellow soils	U.P. Bihar M.P.	Hasdeo Bango	Bilaspur	IGKVV
12	Eastern (Chhotanagpur) Plateau & Eastern Ghats, hot subhumid ecoregion, with red and lateritic soils	Bihar A.P. M.P. Orissa	Hirakud	Chiplima	OUA&T
13	Eastern Plain, hot subhumid (moist) ecoregion, with alluvium-derived soils.	U.P Bihar	Gandak	Pusa	RAU
14	Western Himalayas, warm sub-humid (to humid with inclusion of perhumid) ecoregion with brown forest & podzolic soils.	J & K H.P. U.P.	Ravi & Tawi	Jammu Palampur Almora	KSUAS&T HPKVV VPKAS
15	Bengal & Assam Plain, hot sub-humid (moist) to humid (inclusion of perhumid) ecoregion, with alluvium-derived soils.	Assam Meghalaya Manipur West Bengal	Jamuna DVC	Jorhat Gayeshpur	AAU BCKV
16	Eastern Himalayas, warm per-humid ecoregion, with brown & red hill soils.	Sikkim West Bengal Arunachal Pradesh			
17	North-eastern Hills (Purvachal) warm perhumid ecoregion with red & lateritic soils.	Arunachal Pradesh Nagaland Manipur Mizoram Tripura Meghalaya	Shillong		ICAR-Complex for NEH.
18	Eastern coastal plain, hot subhumid to semi-arid ecoregion with coastal alluvium-derived soils.	West Bengal Orissa A.P. Tamil Nadu Pondicherry			
19	Western Ghats & Coastal Plain, hot humid-perhumid ecoregion, with red, lateritic and alluvium-derived soil.	Gujarat Kerala Karnataka	Ukai-Kakrapar Chalakudy	Navsari Chalakudy	NAU KAU
20	Inlands of Andaman-Nicrobar and Lakshwadweep, hot, humid to per-humid island ecoregion, with red loamy and sandy soils.	Lakshadweep Andaman & Nicobar Island (UT)			

Locality characteristics of AICRP on Irrigation Water Management Centres

Locality characteristics in terms of soil, water table, annual rainfall, source of irrigation etc. in respect of each AICRP centres are given in Tables 2 and 3.

Table 3. Locality characteristics of AICRP centres in irrigation commands

Name of Centre	Soil type	Depth of water table (m)	Annual rainfall (mm)	Source of irrigation	Irriga-tion water quality
Belvatagi	Sandy loam to clay	Very deep	556	Canal	Good
Bhavanisagar	Red sandy loam to clay loam	3-10 m	702	Canal	Good
Bilaspur	Sandy loam to clay	> 2 m	1249	Canal	Good
Chalakudy	Loamy sand to sandy loam, slightly acidic	> 2 m	3146	Canal	Good
Chiplima	Sandy loam to sandy clay loam	0.2-5 m	1349	Canal	Good
Faizabad	Silty loam to silty clay loam	3-4 m	1163	Canal Tubewell	Good Good
Hisar	Loamy sand to sandy loam	0.4-1 m	430	Canal Tubewell	Good Good
Jammu	Sandy loam to silty loam	>4 m	1175	Canal	Good
Jorhat	Sandy loam to sandy clay loam, slightly acidic	0-15 m	1985	Canal Tubewell	Good Good
Bathinda	Loamy sand to sandy loam	1.0-4 m	400	Canal Tubewell	Good Good
Kota	Clay loam to clay	0.7-2 m	777	Canal	Good
Madurai	Sandy loam to clay loam	0.5-2 m	858	Canal	Good
Gayeshpur	Sandy loam to clay loam	0.2-2 m	1315	Canal Tubewell	Good Good
Morena	Sandy loam to sandy clay loam	5-15 m	875	Canal Tubewell	Good Good
Navsari	Clayey	1-5 m	1418	Canal	Good
Pantnagar	Sandy loam to clay loam	0.5-3 m	1370	Canal Tubewell	Good Good
Parbhani	Medium to deep black clayey	> 3 m	879	Canal	Good
Powarkheda	Clay loam to clayey	1-5 m	1285	Canal	Good
Pusa	Sandy loam	2-6 m	1200	Canal Tubewell	Good Good
Rahuri	Deep black clayey	2-5 m	523	Canal	Good
Sriganganagar	Loam to silty clay loam	> 10 m	276	Canal Tubewell	Good Good

Theme I

Assessment of surface water, groundwater and wastewater availability and quality at regional level and to evolve management strategies using Decision Support System (DSS) for matching water supply and demand in agricultural production systems.

The AICRP on Irrigation Water Management centres carried out location specific research on regional water availability from different sources and on farm demonstrations under above theme across the country during the reporting year. Under the theme, selected studies were conducted to determine the regional availability of water in command areas of distributaries of major, medium, minor irrigation projects and tubewell commands. The results of selected studies are presented below;

1.1 Pantnagar

Pantnagar centre carried out studies on groundwater availability and its dynamics in one districts of Uttarkhand and two district of Uttar Pradesh. The districts lie in the Baur -Behgul Inter basin. The basin is located between latitude of 28^0 29′ 56" and 29^0 06′ 56" N, and longitude of 79^0 06′ 43" and 79^0 36′ 33" E. It covers part of Udham Singh Nagar district of Uttarakhand and Bareilly and Rampur districts of Uttar Pradesh. The eastern boundary of the area is marked by Behgul river, west by Baur river. Total geographical area and perimeter under study were about 2,17,640 ha and 346 km, respectively, of which 73,084 ha fell in Udham Singh Nagar district, 84933 ha in Rampur district and rest (59,623 ha) in Bareilly district.

Study was conducted to assess groundwater behaviour and changes that took place during the period of 20 years i.e. from 1990 to 2010 in Bahur-Behgul inter basin of Uttarkhand state. The pre-monsoon and post-monsoon water table data were recorded in the study area. The depth of water table of the study area was analysed district wise as given below. The average water table depth for pre-monsoon period varied from 3.67 m to 4.04 m with the coefficient of variation as 37% and 22% during the years 1990 and 2010, respectively. For post-monsoon period, average

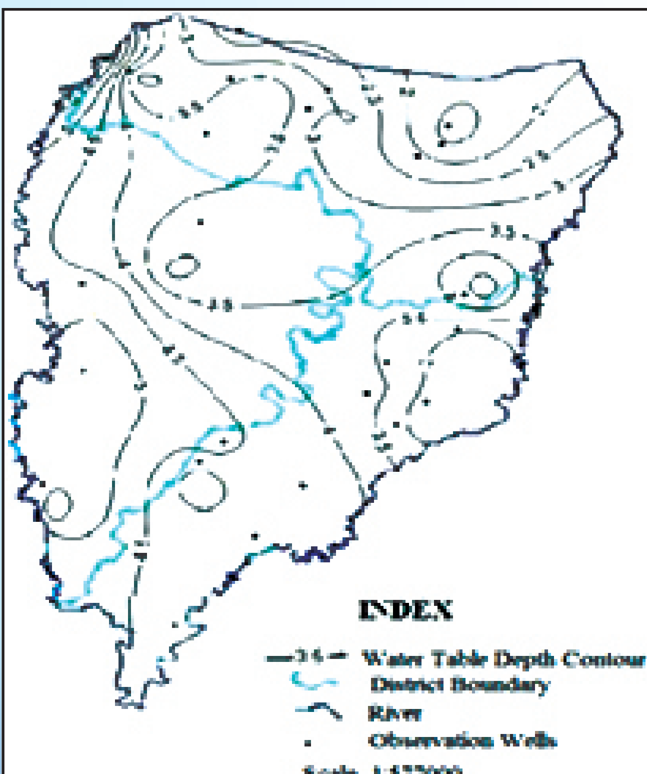


Fig. 1. Pre-monsoon depth to water table contour map (1990) of Baur- Behgul interbasin

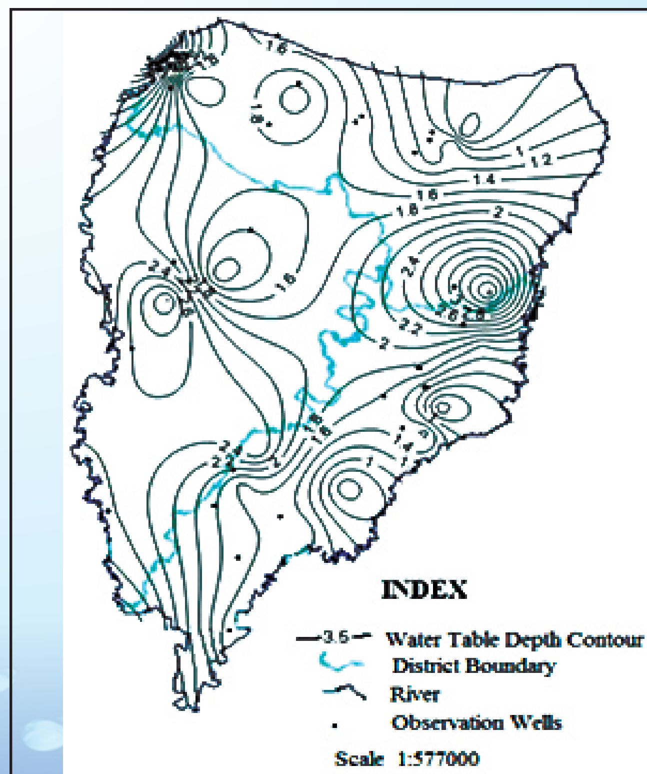


Fig. 2. Post-monsoon depth to water table contour map (1990) of Baur - Behgul inter basin

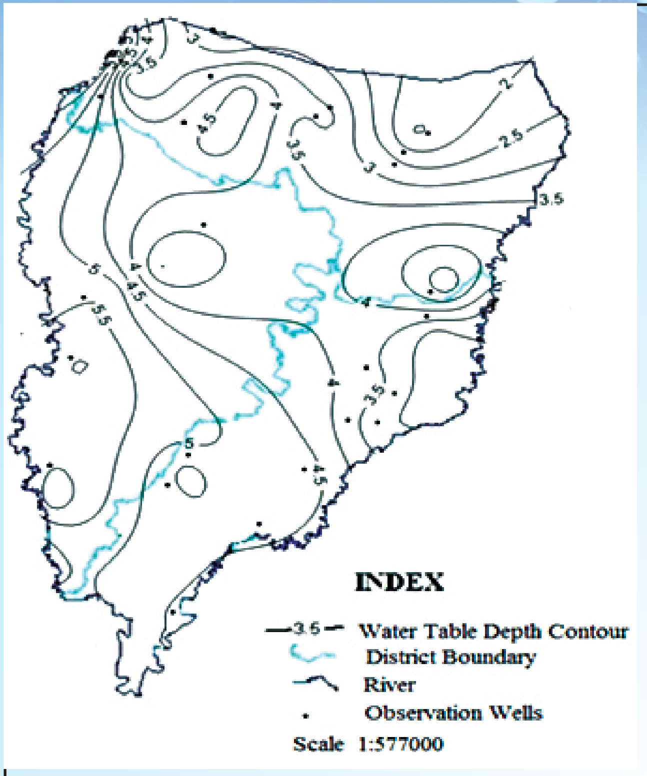


Fig. 3. Pre-monsoon depth to water table contour map (2010) of Baur-Behgul inter basin

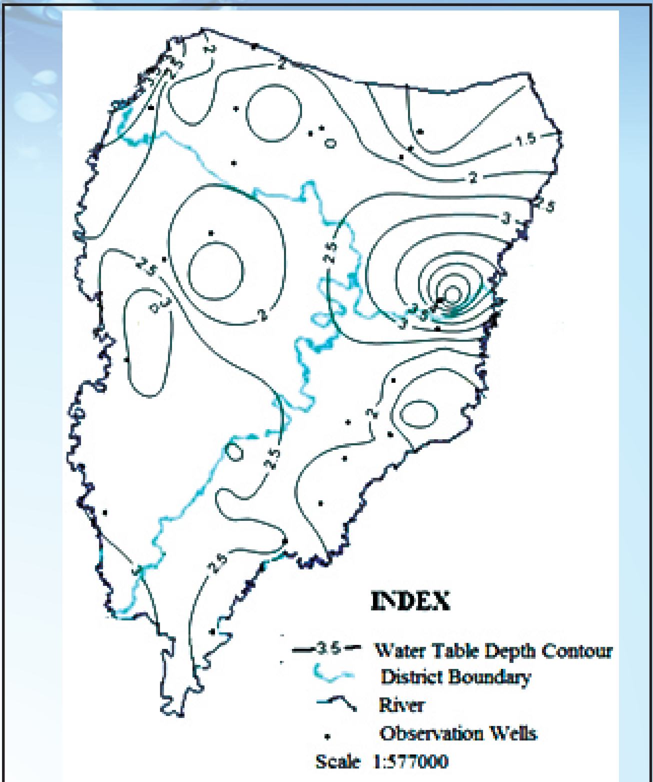


Fig. 4. Post-monsoon depth to water table contour map (2010) of Baur-Behgul inter basin

water table depth varied from 1.81 m to 2.35 m with the coefficient of variation as 55% and 34% during the years 1990 and 2010, respectively. Water table contour map for pre-monsoon and post-monsoon depths to water table, below ground level, for the years 1990 and 2010 are shown in Figs. 1 to 4.

The study revealed that there was decline in depth of pre-monsoon water table was found in Barua bagh, CRC Pantnagar, University Bhatta, Satuia, Semalpura, University Gymnasium, Gularbhoj, Jhagarpuri, Khanpur, Chhatarpur, Motipura, Bazpur and Kelakheda areas of Udham Singh Nagar district, where as Bilaspur, Swar and Milak blocks of Rampur district and Baheri, Shergarh and Meerganj blocks of Bareilly district there was decline in both pre- and post monsoon water table depths during 1990 - 2010. The decline in depth of post-monsoon water table was found at all the places of Gadarpur and Rudrapur blocks of Udham Singh Nagar district. The areas under Swar and Milak blocks of Rampur district, and Shergarh and Meerganj blocks of Bareilly district were identified as the main problematic areas where the condition of groundwater mining was prevailing and need immediate attention and suitable remedial measures to manage the problem well within time. The canal network may be extended to the problematic areas to supply water for irrigation and also to serve as a potential source for recharging underground aquifer. The problem of declining water table was experienced in the study area mainly because of lack of proper planning of a systematic groundwater extraction programme. The trend clearly showed the physical scope of recharging of groundwater in the area lying near the banks of the rivers. None of the study areas was, however, observed under waterlogged condition. This means that some part of the total area is drastically facing the problem of groundwater depletion.

1.2 Jabalpur

Jabalpur centre carried out studies on groundwater assessment in alluvial areas of Upper Narmada Basin. Narsinghpur district was selected to study the water availability through different sources and crop water demand considering different crops grown in the region. Surface water (SW) availability was assessed by collecting data regarding canals, designed discharge, operating hours throughout the year. Groundwater (GW) availability was estimated using the data from the State Groundwater Department. Crop water requirements were estimated using standard water budgeting using rainfall, evapo-transpiration and Soil moisture availability during Kharif and Rabi season separately. The demand and supply results were analyzed to improve the existing production system.

Simulation of groundwater using MODFLOW was carried out in alluvial region of Narsinghpur district during last year. Model studies were conducted in groundwater simulation in UNB to finalize the values of Hydraulic conductivity and specific yield in Narsinghpur district. Results of the calibrated flow model (steady and transient states) indicate that the hydraulic conductivity of the Upper Narmada basin ranges between 0.000257 and 0.000567 m/sec. The model was validated with 10 years data and applied to forecast the groundwater changes in 2025. After calibration and validation three different scenario were considered for future prediction, first is to continue with the present rate of abstraction with present recharge rate of 10% of rainfall, second, is increment of groundwater withdrawal by 12% till 2025 with present recharge rate and third one is to increase withdrawal by 20% up to 2025 (Fig 5 and 6).

While predicting the model for the year 2025 increased abstraction rates by 12% of current withdrawal rate were considered. It was observed during the prediction run that a maximum head range of 456 to 463 m and minimum head range 306 to 308 m which is 0.2% to 0.3% less than present head values. However decreasing water levels stressed the need of enhancing recharge, reducing irrigation demands, and use of efficient methods of irrigation as well as changing crops of low water requirements in the area.

Reducing the recharge rate by 9% of the average annual recharge rate and considering the withdrawal as 12% more of current withdrawal rate, the maximum head ranges from 456 to 460 m and minimum head range 339 to 346 m was observed. This has a deviation of 0.3% to 0.4% in observed head values. The extent of dry cell is more in comparison to scenario 1. This reflects that the recharge should not be lowered than the present situation. Comparison between observed and computed heads in year 2013 for both scenarios are presented in fig 7 and 8.

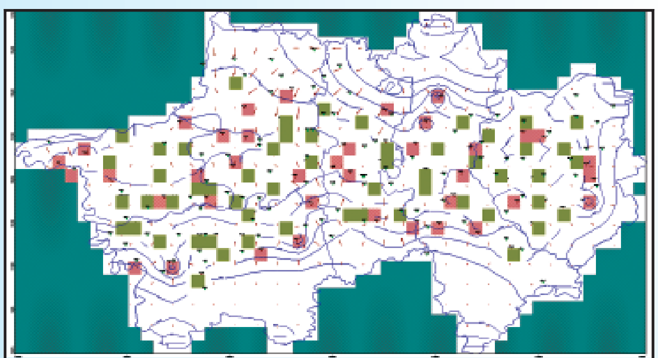


Fig 5. First scenario flow direction and water level contour map


Fig 6. Second scenario flow direction and water level contour map

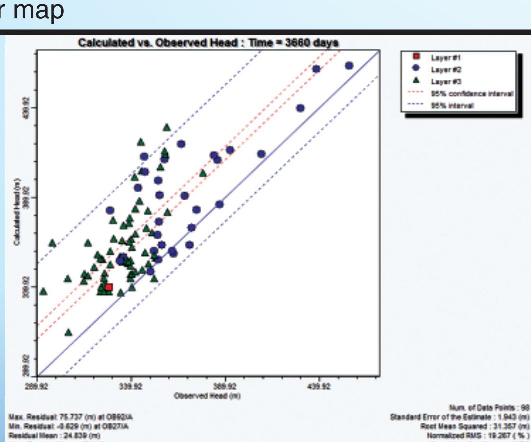


Fig. 7. Comparison between observed and computed heads in year 2013 (first scenario)

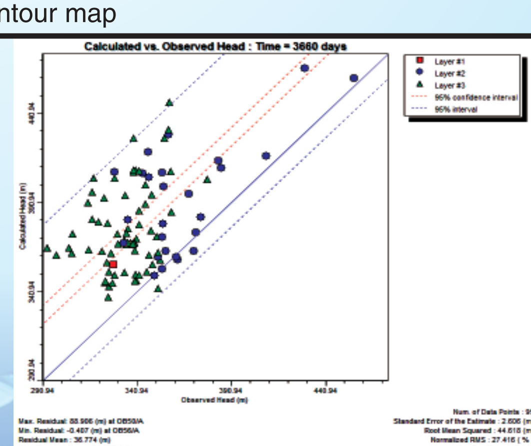


Fig. 8. Comparison between observed and computed heads in year 2013 (second scenario)

1.3 Udaipur

Udaipur centre carried out delineation of groundwater potential zones in Jaisamand basin of Udaipur district.The groundwater potential zones of Jaisamand catchment of Udaipur district was delineated and the various potential zones as well as artificial recharge zone were characterized. The gross catchment area of the Jaisamand basin is 1813 km^2 and the gross capacity of the lake is 568.18 M.Cum. In this study, the thematic layers on geomorphology, drainage, soil, land use, net recharge, etc. was used for the delineation of groundwater potential zones in the Jaisamand basin. To demarcate the potential zones, all the thematic layers have been assigned suitable relative weights and then integrated using ILWIS GIS software. The weights of the different themes were assigned on a scale of 1 to 5 based on their influence on the occurrence of groundwater potential. Furthermore, different features of each theme will be assigned weights on a scale of 1 to 9 according to their relative influence on groundwater potential. Based on this scale, the qualitative evaluation of different features of a given theme will be performed as: poor (weight = 1-1.5); moderate (weight = 2-3.5); good (weight = 4-5.5); very good (weight = 6-7.5); and excellent (weight = 8-9). The relative influence of the individual themes and features on groundwater potential was decided based on the experts' opinion, information and local knowledge. The net recharge for the basin has been estimated using water table fluctuation method with point recharge value.

To develop the thematic map of net recharge and also to find out specific yield as well as transmissivity, constant discharge transient pumping test in the basin were started in 2013-14 based on systematic square grid pattern. Entire Jaisamand basin was divided into 50 systematic square grids. The size of each square grid was 6 km × 6 km. The pre and post monsoon groundwater samples along with water tables were also collected in each grid. Based on pumping test data analysis using Papedopulos - Cooper method, transmissivity and storage coefficients ranged from 123.82 to 386.94 m^2/day and from 0.000160 to 0.03047 respectively. Groundwater recharge of 109 sites was estimated by using water table fluctuation method and the average groundwater recharge for the study area was found to be 2.87 cm/year. The study area were divided into four groundwater potential zones, viz., 'good', 'moderate', 'poor', and 'very poor', covering 12.82, 49.65, 33.21 and 4.32 per cent area respectively (Fig 9). About 87.18 per cent of the basin falls under poor/ moderate groundwater potential zones and therefore, immediate attention is required for ensuring sustainable groundwater management in the basin. The area suitable for artificial recharge is 279 km^2, which contributes only 15.02 per cent of the total study area (Fig 10).

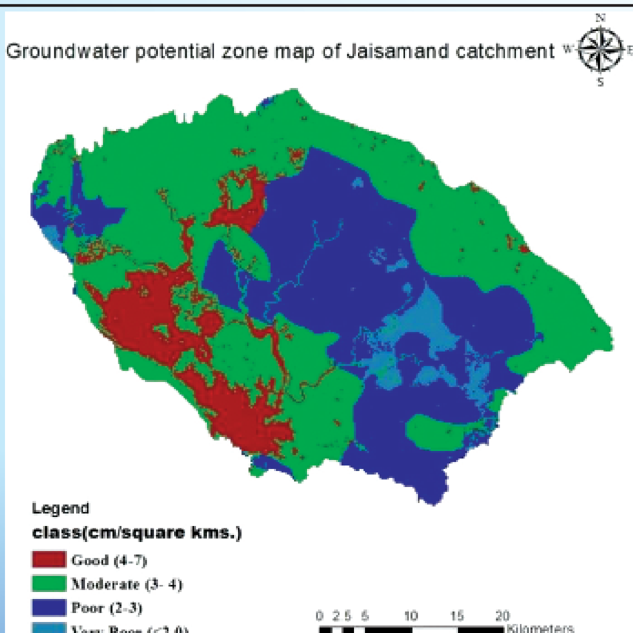


Fig. 9 Groundwater potential zones

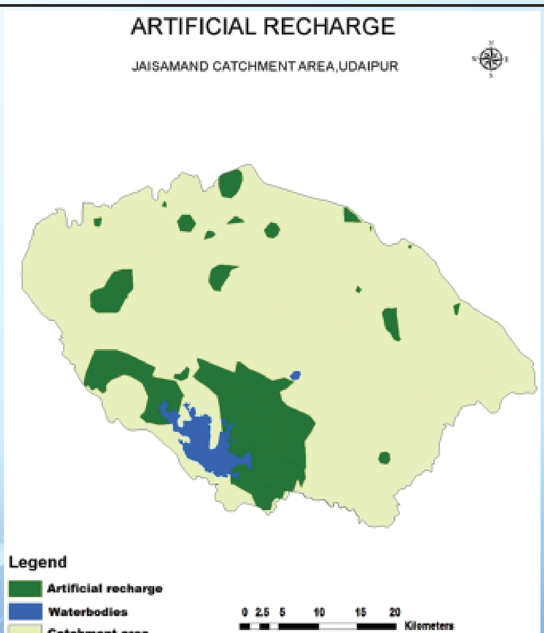


Fig. 10 Favorable artificial groundwater recharge zones

The different physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), calcium (Ca^+), magnesium (Mg^+), sodium (Na^+), potassium (K^+), bicarbonate (HCO_3), carbonate (CO_3), chloride (Cl^-), and sulphate (SO_4) present in pre and post monsoon samples of the study area were determined using standard methods. The variations in individual groundwater quality parameters map are prepared in GIS environments and shown in fig 11. The pH of groundwater varied from 6.80 to 7.90 with a mean of 7.35 in pre monsoon period and 7.20 to 8.50 with a mean of 7.77 in post monsoon period. About 46.48 per cent area of Jaisamand catchment has pH ranges between 7.10 to 7.35 during pre monsoon period and 55.38 per cent area ranges from 7.70 to 7.85 during post monsoon period. The electrical conductivity (EC) varies from 0.62 to 6.70 ds/m with an average of 1.596 ds/m during pre monsoon and 0.25 to 5.83 ds/m with an average of 1.14 dS/m during post monsoon period. The major ion chemistry data revealed that Mg and Ca are the most predominant cationic constituents followed by Na during pre monsoon period as well as post monsoon period. Most part of the study area was found negligible K and CO_3 during both pre and post monsoon period. The highest HCO_3 was found in the Bortalai, Karget, Sathpur meenan, Umedpura etc. villages in pre monsoon period and about 83.01 per cent area shows the HCO_3 greater than 2.62 meq/l during post monsoon period. The EC and TDS shows highly significant and good positive correlations with Ca, Mg, Na, K, Cl and SO_4 during both pre and post monsoon period. It is suggested that presence of calcium, magnesium, sodium, potassium, chloride and sulphate in the study area greatly influence the TDS and EC.

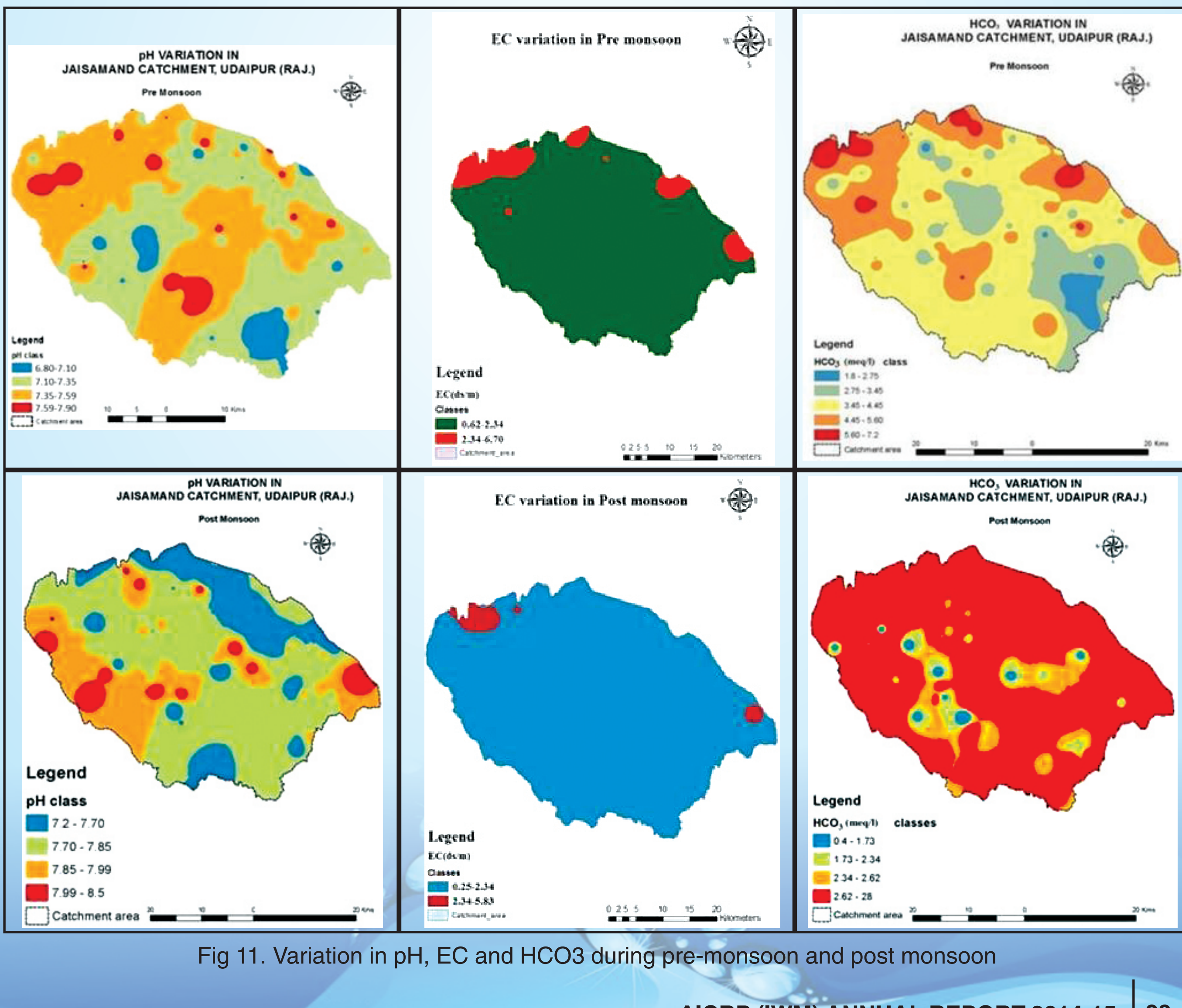


Fig 11. Variation in pH, EC and HCO3 during pre-monsoon and post monsoon

1.4 Rahuri

Rahuri centre carried out studies on reliability of electrical resistivity method of prospecting groundwater in hard rock region of Maharastra. The surface electrical resistivity method was used with Schlumberger array for geophysical investigations at 26 different locations. The data collected from the vertical electrical sounding is used for the calculation of apparent resistivity. The apparent resistivities are calculated by using standard formula proposed by Carrington and Watson. From resistivity data the minimum and maximum apparent resistivity of the different locations of study area are collected and presented in table 1.1.

The reliability of electrical resistivity method for hard rock region was established by comparing the results of electrical resistivity method using curve break technique with the actual bores or wells taken by the farmers. It was found that the instrument and the technique are 88.46 % reliable in hard rock region in locating the spot for well. The values of depth of water bearing formation estimated from the method of successful bores were compared with the actual values of depth of water bearing formation (Table 1.1). Around six per cent deviation was observed between estimated and actual values of depth of water bearing formation. Thus this method is 93.44 % accurate in finding out the depth of water bearing formation.

Table 1.1. Apparent resistivity and depth of water bearing formation of different locations

Yes No.	Minimum apparent resistivity, (ohm-m)	Maximum apparent resistivity, (ohm-m)	Depth of water bearing formation by using curve break method,m	Depth of water bearing formation actually locations	% Deviation
VES 1	2.685	452.208	50	51.82	+3.51
VES 2	10.400	85.915	80	90	+10.98
VES 3	2.637	41.165	72	54.87	-31.21
VES 4	2.437	74.606	93.33	90	-3.70
VES 5	7.046	126.605	96	90	-6.66
VES 6	36.298	148.714	59.5	Failed	0
VES 7	4.514	214.427	98.82	90	-9.80
VES 8	0.110	79.029	84.12	90	+6.53
VES 9	32.279	185.244	98.52	70.10	-40.54
VES 10	10.605	95.589	94.34	90	-4.82
VES 11	3.014	32.174	18.28	27.43	+33.35
VES 12	13.188	324.990	50.58	27.43	-84.39
VES 13	0.466	101.548	26.80	42.68	+37.21
VES 14	0.297	152.891	62.72	48.78	-28.57
VES 15	6.029	206.531	98.75	76.21	-29.57
VES 16	9.546	499.637	54	60.93	+11.37
VES 17	13.023	95.330	30	18.30	-63.93
VES 18	16.705	153.749	62.64	60.96	-2.75
VES 19	92.403	608.932	57.05	54.86	-3.99
VES 20	29.265	294.695	72.45	Failed	0
VES 21	24.092	868.147	74.34	79.24	+5.69
VES 22	12.686	84.074	48	48.78	+1.59
VES 23	11.681	204.037	104.70	54.87	-90.81
VES 24	37.806	394.199	42.35	45.73	+7.39
VES 25	30.860	228.680	83.33	Failed	+100
VES 26	6.029	638.959	48	54.87	+12.52

1.5 Junagarh

Junagarh centre carriedout studies on aquifer mapping of Uben river basin by vertical electrical sounding resistivity technique . Survey was conducted at nine different sites namely Choki, Makhiyala, Patala.Vadal, Chobari. Chobari. Goladhar. Ravani rupavati. Fareni. Satalpur in Uben river (Fig 12) and based on electrical resistivity values of different layers, geological formations were determined. The IGIS signal stacking Resistivity Meter Model SSR-MP-AT-DS was adopted for the study. The SSR-MP-AT-DS is programmable through user-friendly menu for its operation. the special feature in SSR-MP-AT-DS resistivity Meter is that it can store the data and directly down loads to the computer through RS232 port for further analysis. It has also a provision to display data through 16×2 alphanumeric liquid crystal display which can be recorded manually at the time of survey. Schlumberger Array method was adopted.

$$\tilde{N}_{as=} [ð (L^2 - l^2)/2l]R$$

where, $ñ_{as}$ = apparent resistivity (Ù-m) ,

l = distance from center line to inner probes (m)

L = distance from center line to outer probes (m)

R = measured resistance (Ù)

a = probe spacing (m)

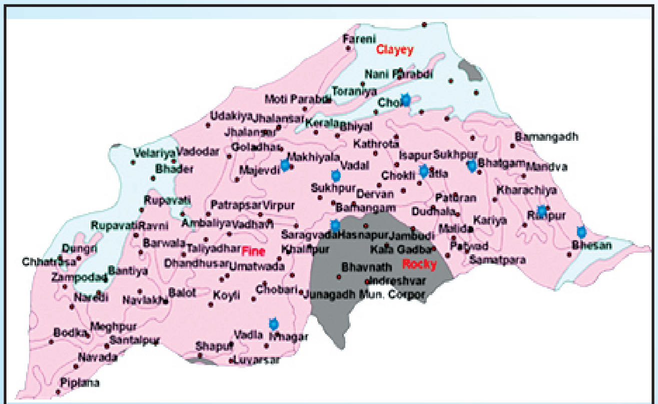


Fig. 12: Survey sites in Uben river basin

The resistivity values of different geological formations are collected from the literature and used in the study.

The following geological formations were found at different sites,

a) Choki Survey site : Up to 20 m from surface unconfined aquifer was found, first confined aquifer was at depth of 26.6m , second confined at depth of 133.3 m and third confined aquifer at depth of 160 m were appeared having possibility of water availability.

b) Makhiyala Survey site : At very shallow depth basaltic layer was found but seven confined aquifers were observed at depths of 13.3m, 33.3m, 46.6m, 86.6 m, 140m, 153.3m, 173.3m 1nd 180m. good water availability was observed at this location.

c) Patala Survey site: Very specific site was observed up to 6.7 m depth in un confined aquifer availability of water was determined. Also only one confined aquifer was observed at a depth of 153.3 m. remaining layers having no much possibility of water availability.

d) Vadal Survey site : Depth up to 46.6 m m possibility of water in unconfined aquifer was observed, In confined zone four aquifer were found at a depth of 86.6 m, 146.6m 160m and 186.6 m

e) Chobari : Up to 20 m from surface unconfined aquifer was found. Seven confined aquifers were observed at depth of 26.6m, 53.3m, 66.6m, 106.6m 146.6m, 160m, 186.6m having possibility of water availability. Poor quality water was observed at a depth of 120m.

f) Goladhar Survey site: Very deep at 106.6 first basaltic layer was found so up to 106.6m was fractured unconfined aquifer. After that only two confined aquifers were found at a depth of 120m and 166.6m having possibility of water availability.

g) Ravani rupavati Survey site : Hard Layer like basaltic was not found but hard sand stone apears at a depth of 40 m so above this the aquifer was consider unconfined. Below 60m and 126.6m aquifers of large thickness are observed having good possibility of water availibilty. But the both the aquifer may be in semi pervious nature.

h) Fareni Survey site : Unconfined aquifer was found up to the depth of 40 m. Between basaltic layers four confined aquifers were observed at a depth of 60 m, 100 m, 113.3m and 160 m. having possibility of water availability

i) Satalpur Survey site : At a depth of 140 m only one basaltic layers was found Unconfined aquifer was found up to the depth of 46.6 m .Between Hard sand stone two semi confined aquifers are observed at a depth of 53.3 m and 133.3 m deep. One confined aquifer was observed at a depth of 146.6m.

1.6 Raipur

Raipur centre carried out cadastral level land use plan for effective management of water resources of an agricultural watershed. Watershed comprises 15 village including Dhanali, Dhangaon, Lawatara, Chamari, Khandsara, Ataria, Ghanadih Kalan, Karchua, Kewanchhi, Banaspur, Rampur, Khursbod, Sameria and Martara. Dhangaon watershed is a 5th order watershed coverng 77.19 km^2 area. Most of the thematic maps like watershed, sub-watersheds, drainage, DEM, soil and land use have been prepared using GIS technique. Based on the analysis of SWAT, the critical sub watershed was identified as SW7. The main village in this micro watershed is administrative boundary of village Dhangaon. The digitization work of the acquired cadastral map was carried out along with its georeferencing (Fig13). Geodatabase of the cadasatral (patwari) records have been created with more than 660 land holdings by the tribal farmers. IRS-Resourcesat-2 LISS IV (5.8 m resolution), Path – 102, Row-057 satellite data of 10 October, 2014 date was procured from National Remote Sensing Center, Hyderabad for getting the cadastral level land use of the micro watershed. Pixel based classification technique has been applied for retrieving the micro level information. The soil map, slope and farming situation maps are also being prepared and based on the various dominating factors, land and water resource development plan will be developed at cadastral level. The field level information about the management plan can be readily transmitted to the farmers as there field number (khasra no.) along with name is stored in the geodatabase (Fig 14).

1.7 Ludhiana

Ludhiana centre carriedout studies on spatial decision support system for determining energy requirement for groundwater utilization. The increased demand of water resources has created problem of water table decline in most part of state. The decline in water table results in decreased water pumped and increase in energy requirement for lifting water, which ultimately leads to increasing the cost of cultivation. Especially during year 2012 the rainfall was deficient in the month of July and August and electricity demand shoot up and sufficient supply of electricity was not available. Information on groundwater fluctuation in space and time at micro level is limited for the selection of energy efficient agricultural pumping sets. Keeping this in view the groundwater behavior in the Punjab using GIS was studied and a spatial decision support system (DSS) was developed for determining energy requirement for groundwater utilization.

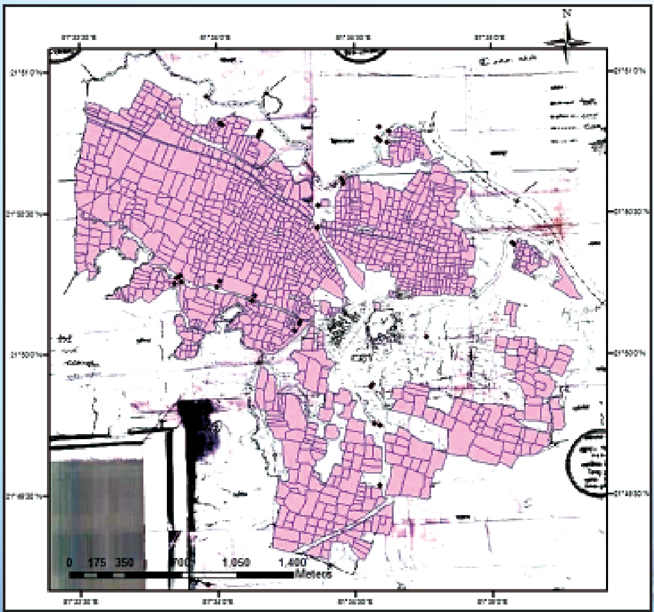


Fig. 13 – Cadastral map of Dhangaon micro Watershed

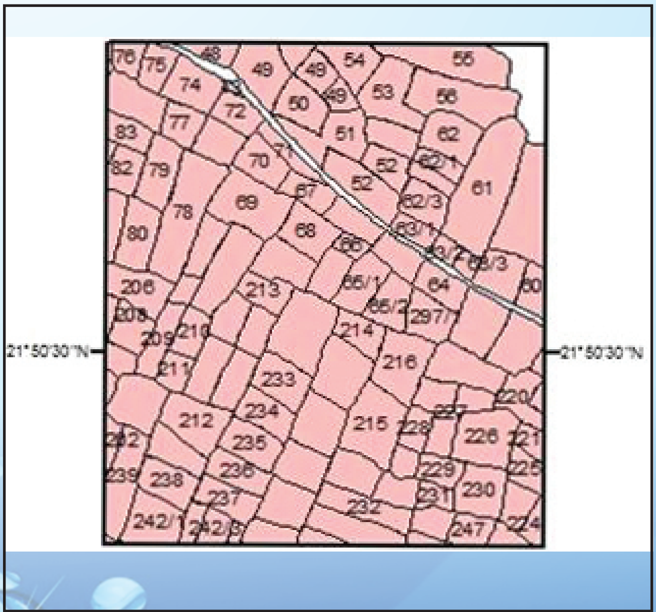
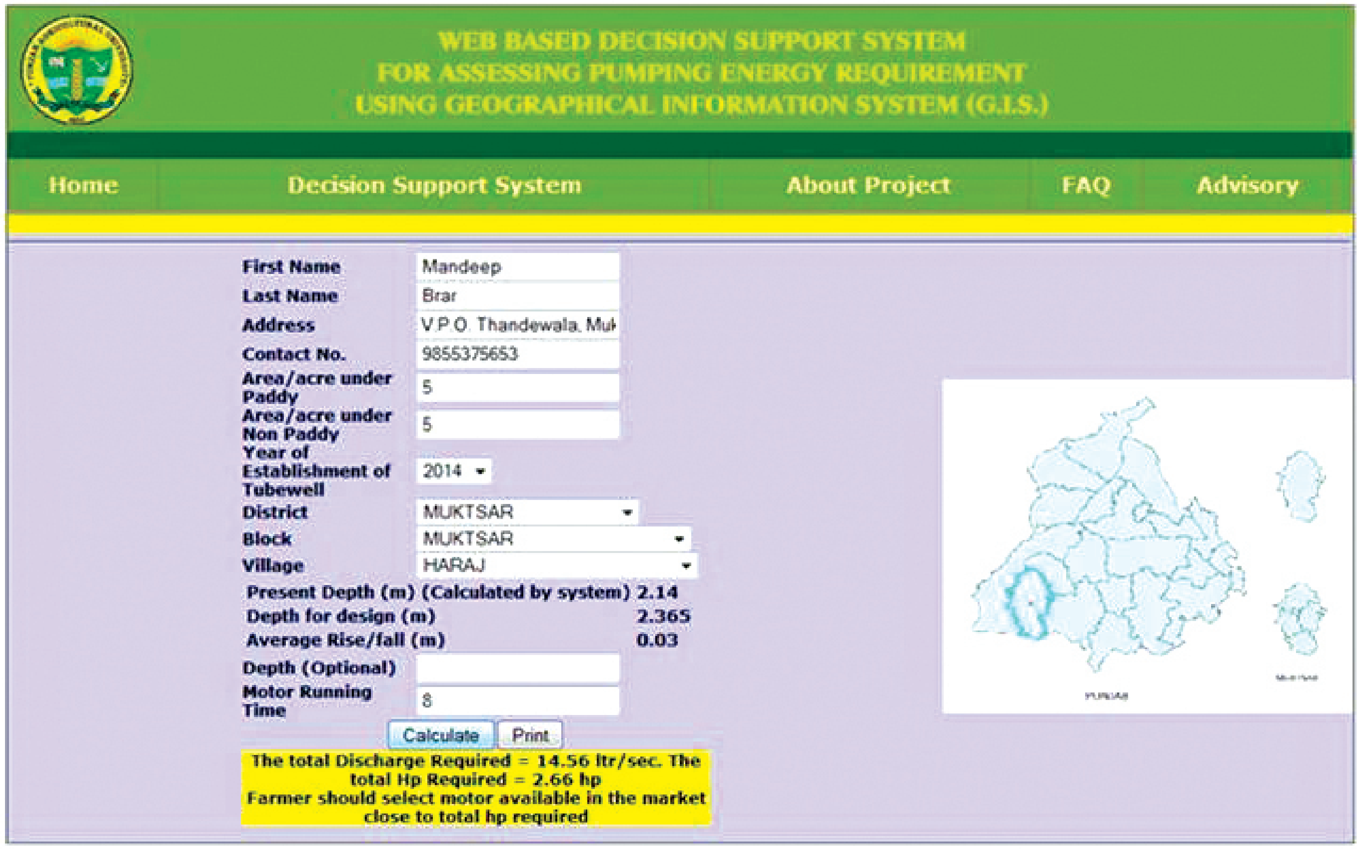


Fig. 14 – Cadastral map displaying field numbers

Decision Support System (DSS) was developed under 'PHP' server side scripting language by Ludhiana centre which provides the information of energy requirement for pumping set at micro level in time and space and helped for proper selection of pumping sets. For this groundwater maps of pre monsoon were prepared for last 16 years (1998-2013) which was analyzed with the help of Geographical Information Systems (GIS). Also average rise/fall of each village of Punjab was assessed by using GIS. GIS is one of the important tools for integrating and analyzing spatial information from different sources or disciplines. By creating groundwater level maps, the behavior of the groundwater system is visualized in a context that is easy for many people to understand. It will be beneficial to the farmers and policy makers to arrange cropping pattern with groundwater availability and irrigation security on long term basis.

groundwater level as influenced by net agriculture water use (irrigation and deep percolation) in kharif season (rice). During the current year, a field experiment was conducted at the Research Farm, Department of Soil Science, to estimate water balance component in rice crop (PR 121). Three different dates of transplanting and two treatments of irrigation viz. 2 days drainage and tensiometer based were triplicated. Observation on soil properties, plant parameters and drainage parameters were periodically recorded. The data is being analyzed and input files of crops, soil and weather will be prepared for simulation of DSSAT model.

The centre also carried out studies on estimation of carbon emissions for groundwater pumping in Central Punjab using Geoinformatics. Carbon emissions from groundwater pumping in central Punjab was estimated using geoinformatics.



Ludhiana centre also carried out studies on evaluation of cropping system model for estimation of groundwater use using the process based crop models such as CERES, EPIC, and WOFOST etc. for estimating crop water use from climate input, soil and water management. The study was undertaken to correlate the

Blockwise data, on the number and source of pumps (electricity or diesel) was obtained from the Department of Agriculture, Punjab for fourteen years viz. 1998 to 2012. The water table change maps were prepared for central Punjab. During the last 14 years, the area under different under water table 3-10 m has reduced from 53.0 to 21.9

per cent, whereas the area with water table depth greater than 20 m depths has rose from 0.0 to 24.6 per cent indicating that central Punjab is under severe declining water table problem. The pump density (no of pumps per 1000 ha) for both diesel and electric operated tubewells for the individual years (Fig 19 & 20) were observed and maps were prepared. The electric pumpset in SC-III had sharply increased and followed an exact linear trend from 2000-2011 SC-III and BM-III witnessed a 67% and 42% increase in electrical pumpset density respectively during the study period. In case of diesel pump sets, UB-III and SC-III witnessed a 11% and 7% decrease in the density respectively whereas BD-III and BM-III showed an increase of 49% and 46% respectively during the study period.

1.8 Belvatagi

In Byahatti Malaprava RBC, assessment of irrigation water supply, demand and studies on water distribution pattern was carried out during the study year. The total amount of water required for maize (150 ha), cotton (75.50 ha), sorghum (25.60 ha) sunflower (20.50 ha) and onion (17.34 ha) crops for irrigation during Kharif-2014 was 9,

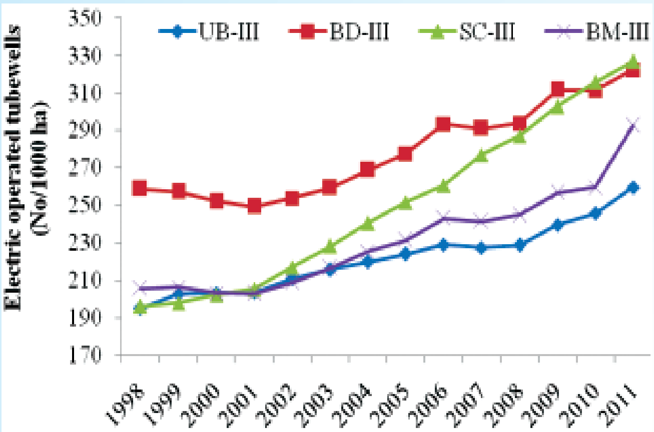


Fig. 19 Density of electric operated tubewells in four zones

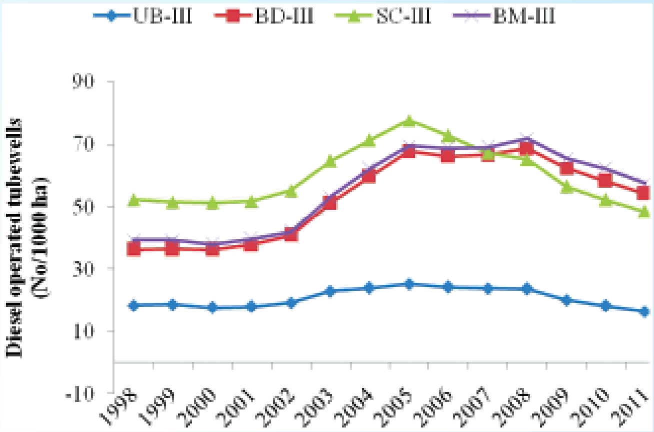


Fig.20 Density of diesel operated tubewells in four zones

Table 1.2 Details on irrigation water applied, in the command of 23rd Block 12 L distributary near Hebsur Malaprabha RBC during, kharif 2014.

Sl. No.	Crops	Area (ha)	Irrigation Numbers	Irrigation Method	Applied Canal Water (Effective rain fall)	Crop Water Demand	Excess (+)/ Deficit (–)	Percent Excess/ Deficit over recomm-ended
Kharif 2014								
1.	Maize	150.00	—	—	314265	500205	-185940	-37.18
2.	Sorghum	25.60	—	—	53630	79505	-25875	-32.54
3.	Sun Flower	20.50	—	—	42945	59590	-16650	-27.94
4.	Cotton	75.50	—	—-	158180	234955	76775	-32.67
5.	Onion	17.34	—	—	36329	53203	-16874	-31.70
	Total	**288.94**		**Mean -32.00**				
Rabi 2014								
1.	Wheat	103.4	3	Boarder strip	359561	302187	48374	+16.00
2.	Chick-pea	70.2	2	Boarder strip	94447	74621	114089	+26.56
3.	Cotton	75.5	3	Furrow	248259	239970	8288	+03.42
4.	Sorghum	12.84	3	Normal	46911	41515	6999	+13.00
	Total	**288.94**		**Mean +17.00**				

27,158 m^3. The total effective rain fall received was 6, 05,349 m^3. Hence, the excess water balance was 3, 21,809 m^3. Based on data the current year (Kharif-2014) crop was satisfactory condition. During rabi 2014, the crops under observation were wheat (130.40 ha), chick pea (70.20 ha) and cotton (75.50 ha). The net amount of water demand during rabi-2014 for all crops was worked out to be 6, 58,293m3. Gross canal supply and net canal supply was observed 5, 64,321 m^3 and 4, 70,268 m^3 respectively. The effective rain fall received worked out was 3, 48,390 m^3. The excess water supplied was worked out 1, 60,365 m^3.

The results revealed that, average deficit of water for all study crops was recorded 32 per cent during Kharif 2014 (Table 1.2). For the maize crop deficit of water was 37.18 percent, sorghum 32.54, sun flower 27.94 for cotton 32.67 per cent and for onion 31.70 per cent. During rabi 2014 the excess irrigation water supply was given by the farmers to wheat, chick pea, cotton and sorghum crops which was 16, 26.56, 3.42 and 13 per cent excess respectively. The overall excess water applied was 17 per cent.

1.9 Bhavanisagar

The Bhavanisagar centre carried out studies on water table fluctuations in the Lower Bhavani distributary. The mean value of water table depths in the selected wells in head, middle and tail reaches of the distributary, rainfall and evaporation data in the study area are collected. Water was released for irrigation to wet crop from 25.08.2013 to 08.01.2014 for I turn command area. During 2014, special supply during April was given for 9 days for recharge of well water and to solve drinking water problem. There was no rainfall from Jan – April 2014 and from May to December 2014. During North East monsoon period, higher rainfall of 142.6 mm in September and 308 mm in October was received.

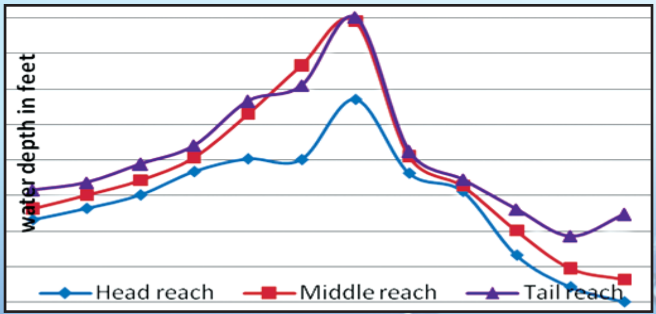


Fig 21. Water table depth in selected wells of turn I

The water table depth in the II turn command area are more or less same as that of I turn wells. The difference is only 5 to 10 feet more in II turn command upto July 2014, since water was not released to these II turn sluices during 2014. Here also due to heavy down pour during NE monsoon coupled with the effect of irrigation to wet crops in the I turn command, the water table reached GL to 4 feet in head, middle and tail reaches of the distributary.

The centre also carried out assessment of water availability in the system tank under PVC and to devise interventions for matching water supply with the agricultural production system demand and supply and GIS mapping. For the cultivated area of 46.56 hectares, water need was assessed for its total duration and the supply was assessed from the water realized into the tank. During the reporting period there was a supply of 4, 86,772 m^3 of water into the tank whereas the demand was assessed to be 5, 58,348 m^3. The water supply for the crops through effective rainfall is 68, 836.76. Hence there was a shortage of 2756 m^3. The shortage was made up by following efficient water management and stress management technologies adopted by the farmers based on our suggestion.

1.10 Madurai

The Madurai centre in Tamilnadu carried out study on water use efficiency in PeriyarVaigai Command. The rainfall data of Melur block were collected for 12 years from Assistant Director of Statistics office, Madurai. Out of 12 years, six years normal rainfall was recorded. Three years excess and three years deficit rainfall were recorded as against the normal rainfall of 965.7 mm. During the reporting period the basic data relating to water release for the last thirteen years were obtained from Water Resource Organization (PWD). The water release from PeriyarVaigai to Melur Block for the reporting period was not uniform. The highest water release (10435.56 mcft) was recorded during the year 2008 due to high rainfall. It was also observed that the rainfall in melur block was not uniform. It was found that groundwater table has gone up to 2.86 m during the year 2008 due to groundwater recharge through surplus rainfall and higher release of water in the command. After that the subsequent years the groundwater moved to the deeper level ollowing failure of consecutive monsoon. The net and gross irrigated areas were maximum on the higher side in the block coincided with the year of higher rainfall and more release of water from the canal. The total irrigated areas recorded in the Melur block were highest during the year 2005- 2006 which coincided with the year of excess rainfall.

1.11 Bilaspur

In the year 2014, flow in Banahil distributory was started from 6th July upto 29th October 2014. Banahil distributory covers about 21 villages with command area of 10854 ha, mainly under paddy crop.Near about 28%, 64%, 5.3% and 0.1% area of rice was covered by broadcast biasi, transplanting, lehi and SRI system of rice cultivation. Under minor distributaries near about 9%, 66%, 14% and 10% area of rice was covered by broadcasting biasi, transplanting, lehi and SRI system of rice establishment system respectively. Common varieties of rice grown in the command were MTU1010, MTU 1001, Swarna, Mahamaya, IR36, HMT, etc. Generally water flows from field to field in the command. It was observed that farmers kept 10-15 cm pounding of water in their rice fields. However some progressive farmers were conceived to keep 5±2 cm depth of water after demonstration that there is no reduction in the yield of rice due to low submergence. Farmers agreed but they were reluctant to keep 5±2 cm water level due to uncertainty in the supply system. Farmers were also advised to grow early duration rice varieties. So, that rabi crops can be raised in time. In the year 2014 irrigation water was not supplied during rabi/summer through Banahil distributory.

1.12 Chiplima

The distributarywise deficit-surplus analysis of canal water in the command area of Retamunda Branch Canal under Hirakud command for rabi season depicts that all the outlets are operating under sub-optimal conditions (Table 1.3). 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 distributaries except for the Kebar Disty. The optimal cropping pattern, suggested under Scenario I, is 98% of the CCA to be irrigated during the season with lower net return per hectare. Under Scenario – II, the entire CCA of the distributary can be used for cultivation with the designed cropping pattern assuring higher net return. Since the entire command area is put under agriculture, it would generate more employment for the agricultural labourers. Restricting 1/3rd of the CCA for cultivation of heavy duty crops in Scenario – III, increase the net benefit. The optimal cropping pattern for maximization of net benefit under Scenario – IV suggests allocation of 77% and 23% 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 1.3. Deficit - surplus analysis of the Retamunda Branch Canal

Sl. No.	Distributary	Discharge (cumec)	CCA (ha)	WR (ha-cm)	WA (ha-cm)	Status	Actual Area (ha)	Net Return	
								(Rs.)	Rs/ha
1	Bahubasa Disty.	0.28	367.46	36746	24451	Deficit	245	6112800	16635
2	Beheramal Disty.	0.37	498.68	49868	31795	Deficit	318	7948800	15940
3	Salhepali Disty.	1.16	1445.58	144558	100224	Deficit	1002	25056000	17333
4	Sukha Disty.	7.11	6645.51	664551	614045	Deficit	6140	153511200	23100
5	Kebar Disty.	3.48	2315.28	231528	300845	Surplus	2315	57882000	25000
	Total	12.40	11272.51	1127251	1071360	Deficit	10020	250510800	22223

Scenario – I

The optimal allocation of areas under different types of crops under this scenario for each outlet showed that to maintain the optimality of water use (with no surplus or deficit), about 98% of the total command area can be irrigated. However, there would be surplus water in the command area of Kebar distributary even if the entire CCA is cultivated with heavy duty crops. This also indicates that the more water could be diverted to the Sukha Distributary or the surplus water could be provided to the upper reach distributaries to increase the cultivated area under the later. Under this scenario 11068.94 ha of the total command area of 11272.51 ha can be provided irrigation for the rabi season with average rate of net return of Rs 24,348/- per hectare of the irrigated area.

Scenario – II

The optimal allocation of areas under different types of crops under this scenario for each outlet showed 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 Kebar distributary. Though the total command area can be provided irrigation under this scenario, there would be marginally reduced average rate of net return (Rs 24,332/-) 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 showed that this scenario would give more net return than that of the first two scenarios, with provision of irrigation for 100% of the CCA with increased average rate of net return (Rs 24,408/-) per hectare.

Scenario – IV

The optimal allocation of areas under different types of crops under this scenario for each outlet showed that cropping pattern under this scenario would give the maximum net agricultural return from the command area of the system 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 summary of the scenario analysis is presented in Table 1.4 and Fig. 22.

Table 1.4. Summary of Scenario Analysis

Scenario	Heavy	Medium	Low	Uncultivated	Total	% CCA Cultivated	Net Return (Rs.)	Net Return (ha)
Scenario - I	9114.86	1596.72	357.36	203.56	11068.94	98.19	269515578	24349
Scenario - II	8860.89	2180.29	231.33	0.00	11272.51	100.00	274280039	24332
Scenario - III	8798.28	2399.42	74.81	0.00	11272.51	100.00	275140887	24408
Scenario - IV	8768.35	2504.16	0.00	0.00	11272.51	100.00	275552401	24445

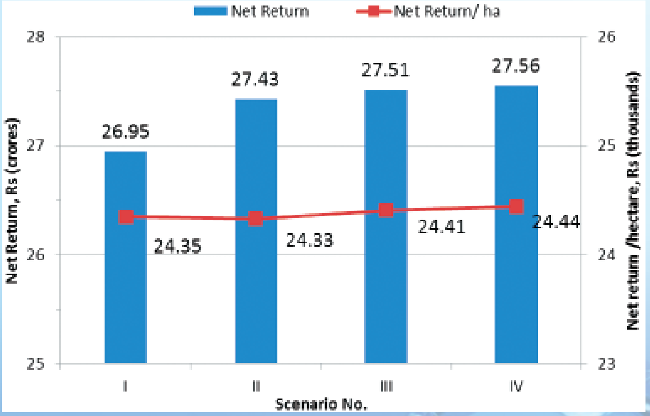


Fig. 22. Net return and net return per unit area under different scenarios

1.13 Gayeshpur

Spout-wise crops, area coverage and water demand (crop evapotranspiration, ETc + pre-sowing/land prepation/puddling) have been estimated. Accordingly, spout-wise irrigation water supply and rainfall received during the crop growing period were recorded. Rainfall received were 96.1 cm for summer rice, 16.8 cm for wheat, 3.6 cm for mustard, 14.0 cm for lentil and 265.1 cm for jute during non-rainy season (November to May). On this basis, calculation was being made on the demand and supply of water; spouts are categorized and efforts have been made to bring equilibrium through spout wise crop planning on the basis of water availability. Actual spout wise water demand and supply revealed that excess water supply was made to the tune of 11.53 % in case of summer rice but a deficit water supply of 1.2 % was occurred in dry crops like sunflower, mustard and wheat. Deficit of water supply in winter crops in the command was mitigated by significant contributions from soil profile moisture (4.2 – 32.0 cm).

1.14 Jorhat

Jorhat centre carried out integrated approach using Remote Sensing and GIS techniques for mapping of groundwater prospects in Jorhat district, Assam. Out of the 336 numbers of geo-referenced observations recorded from 56 villages of Jorhat district covering all eight blocks, pre-monsoon groundwater table depths ranged from 2.22 to 17.58 m bgl. Area (in sq.km) under each category of pre-monsoon groundwater potential zone is furnished below: Groundwater prospect mapping using Remote sensing and Geographic Information System (GIS) as tool for demarcating the potential groundwater resource during pre-monsoon season for the entire Jorhat district covering 2852 sq.km was completed highlighting with area-wise groundwater potential information in the form of map. Maximum area (739.50 sq. km) was observed in groundwater table depth of 6.16 – 6.82 m bgl and minimum (78.34 sq. km) in groundwater table depth of 4.20-4.95 m bgl. Based on the depth of groundwater resource, selection of pump suitable for lifting water and possibility of using such pump to irrigate unit area were prepared in the form of map. Post-monsoon groundwater potential zone mapping is in progress.

The centre also carried out Sustainability studies of water resources of Brahmaputra basin. Scarcity of fresh water in the face of increasing demand to sustain agricultural and industrial growth in India is a major concern for policy planers, scientists and water professionals. Brahmaputra is an important river system having highest amount of unutilized water resources. However growing demand for water in the basin requires an in depth study. This work is an attempt to study the Brahmaputra river water system through a system dynamics model. The model has been tested with time series data of Brahmaputra basin for 30 years. Test scenario generation using the model suggests that water consumption pattern for Brahmaputra Basin has showed a rising trend during years 2025- 2050. The water availability in the River Basin has showed wide seasonal variation. The water supply remained more or less same whereas the consumption has been rising; therefore water availability status for the basin has been going down over the years. With the present consumption pattern the basin will face water scarcity during the lean season (December to February) before the year 2050. Flood storage reservoir to store excess water during high flood and augment flow during lean season may be a viable option

1.15 Ludhiana

The Balluana minor of the Behman distributary of Bathinda branch was selected to evaluate irrigation system performance and to work out intervention for improvement of irrigation system and its management as well as crop and water productivity. The Balluana minor takes off from the Behmandistributary 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 Gurudwara sahib and school, respectively) are selected. The contribution through total effective rainfall is presented in Table I.7 and was varying between 4550.7 and 7465.8 ha-cm at different outlets. The crop water requirement of wheat, barley, raya/chickpea and other crops was calculated at all the outlets and was varying between 26297.8 and 43312.2 ha-cm. The discharge and temporal release of water in outlets command area is presented in Table I.5a. The total running days of canal water was 145 days on each outlet (Table I.5) and release of water varying between 5640.6 and 9223.6 ha-cm, respectively during the Kharif, 2014.

Table.1.5: Temporal release of water in outlets in command area during Kharif 2014

Outlet No.	Discharge (Cusec)	Running Days	Cusec Days	Cusec Days (ha–cm)
3758/R	2.05	145	297.25	7272.4
14025/L	1.84	145	266.8	6527.5
14040/R	1.77	145	256.65	6279.1
18163/R	1.76	145	255.2	6243.7
20170/L	2.6	145	377	9223.6
25000/L	2.18	145	316.1	7733.6
26630/L	2.42	145	350.9	8585.0
35977/TL	2.45	145	355.25	8691.5
35977/TR	1.59	145	230.55	5640.6

Table 1.6. Crop wise area (ha) Kharif, 2014

Outlet	Cotton	Rice	Guar/ Moong	Vegetable	Orchard	Fodder & Other	Total
3758/R	397.2	190.2	26.8	4.0	3.8	38.6	660.6
14025/L	361.9	211.2	1.5	1.9	3.0	23.4	602.9
14040/R	348.4	203.3	1.4	1.8	2.9	22.6	580.5
18163/R	345.7	201.8	1.4	1.8	2.9	22.4	576.0
20170/L	556.4	217.2	18.5	2.2	23.6	36.3	854.2
25000/L	556.3	71.5	27.5	0.0	34.3	27.7	717.4
26630/L	617.2	79.3	30.5	0.0	38.1	30.7	795.8
35977/TL	630.6	59.9	68.9	1.4	19.0	23.7	803.5
35977/TR	399.8	55.8	38.8	0.7	10.1	15.6	520.7

Table 1.7. Contribution through rainfall (Kharif, 2014)

Outlet No.	CCA (ha)	Rainfall (cm)	Effective Rainfall (ha-cm)
3758/R	660.62	278.6	18404.9
14025/L	602.86	278.6	16795.7
14040/R	580.5	278.6	16172.7
18163/R	576	278.6	16047.4
20170/L	854.21	278.6	23798.3
25000/L	717.36	278.6	19985.6
26630/L	795.83	278.6	22171.8
35977/TL	803.46	278.6	22384.4
35977/TR	520.68	278.6	14506.1

1.16 Sriganganagar

The Khetawali distributary (KWD) was 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 distributary 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 distributary has two minors namely Khetawali minor and Amarpura minor with total 24 outlets.Out of 24 outlets in Khetawalidistributory system, 16 outlets are in Khetawalidistributory itself, 6 outlets are in Khetawali minor and 2 outlets are in Amarpura minor. Position of off takes of Khetawalidistributory (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 Khetawalidistributory system, KWM and ARM are 74.64, 17.05 and 4.0 cusec, respectively. Total length of KWD system is 22341.84 m (Table 1.9).

The requirement of warabandi, although in terms of equity is fulfilled to a certain extent, but in practice farmers at head reaches get more water as compared to tail enders. Sometimes, when canal due to one reason or the other is closed without completing its full turn, the farmers left under such situation do not get the water of their turn.The process of distribution of water in distributary/minor from main canal is called regulation or rostering. The supply of main canal is distributed to different branches or distributaries in accordance with the supply and demand on different channels. The main aim of rotation of water distribution is to regulate and evenly distribute the water over the command area of the canal system. The system also eliminates the possibility of complete drought in pocket area. But in reality there is no match of actual flowing of canal water and canal regulation forecasted earlier.

The canal water flow during rabi 2013-14 was lesser than design discharge. The flow in KWD, KWM & APM systems of Khetawalidistributory was recorded as 72 cusec, 14.9 cusec and 2.5 cusec, respectively. However the flow has been almost constant during entire rabi season.The area covered by wheat crop was the largest in the distributory followed by mustard and barley. Some

Table.1.8. System wise area under different crops (ha) during Rabi 2013-14

System	Wheat	Mustard	Barley	Gram	Fodder	Vegetables	Total
KWD	2006	439	97	10	49	1	2602
KWM	626	92	23	2	15	-	758
APM	71	20	7	-	2	1	101
Total	2703	551	127	12	66	2	3461

In Rabi the wheat crop was the major crop in the area and utilized most of the canal water.

Table:1.9 Irrigation water requirements (ha-cm) in systems KWD, KWM & ARM during Rabi 2013-14

System	Wheat	Mustard	Barley	Gram	Fodder	Vegetables	Total
KWD	108324	16901.5	4268	305	2450	50	132298.50
KWM	33804	3542	1012	61	750	-	39169.00
ARM	3834	770	308	-	100	50	5062.00
Total	145962	21213.5	5588	366	3300	100	176529.50

Table 1.10- Relative water supply (RWS) during Rabi 2013-14

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
KWD	114831.55	71172.59	13530.40	84702.99	132298.50	0.64
KWM	31012.79	19953.63	3941.60	23895.23	39169.00	0.61
APM	5272.95	3496.49	525.20	4021.69	5062.00	0.79
Total	151117.30	94622.71	17997.20	112619.90	176529.50	0.64

area under fodder and gram has been also recorded. The relative water supply has been found low (0.64). 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. The overall relative water supply during kharif was deficit (0.70). Some of the area under A. cotton need to be replaced by low water requiring crops like guar & moong.

1.17 Coimbatore

The Coimbatore centre carried out studies on alternate wetting and drying irrigation regimes management through field water tube device in rice in tubewell command. The field water tube is

Table 1.11 Relative water supply (RWS) during Kharif 2014

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
KWD	76150.80	47198.27	72561	119759.3	169488.5	0.71
KWM	20781.08	13370.55	21546	34916.6	54316.0	0.64
APM	3486.76	2312.77	2679	4991.8	5104.0	0.98
Total System	100418.6	62880.89	96786	159667.7	228908.5	0.70

a PVC pipe of 15cm diameter, length of 40cm in which 20cm pipe is perforated with holes, which is sunk into the rice field until 20cm protrudes above soil level, the tube can be placed in a flat part of the field close to a bund, so it is easy to monitor the ponded water depth. When the water level inside the field water tube drops to 15cm below ground level, The field is ready to be re-flooded. This threshold is called 'safe AWD' as it does not impact on yield. To evaluate the impact of Safe AWD in lowland rice, a research project was formulated with 8 treatments viz., T1- Irrigation after 10cm depletion of ponded water (DPW)(from ground level) from seven days after transplanting (DAT) to 10 days prior to harvest, T2 - Irrigation after 15cm DPW (from ground level) from 7DAT to 10 days prior to harvest, T3- Irrigation after 20cm DPW (from ground level) from 7DAT to 10 days prior to harvest, T4- Irrigation after 15cm DPW (from ground level) up to max. tillering stage (30-35DAT) and 10 cm DPW up to 10 days prior to harvest, T5- Irrigation after 15cm DPW (from ground level) up to max. tillering stage (30-35 DAT) and continuous submergence up to 10 days prior to harvest, T6- Irrigation after 15cm DPW (from ground level) up to panicle initiation stage (45 DAT- 50 DAT) and 10 cm DPW up to 10 days prior to harvest, T7- Irrigation after 15cm DPW (from ground level) up to panicle initiation stage (45 DAT- 50 DAT)and continuous submergence up to 10 days prior to harvest, T8- Responding to 5 cm one day after disappearance of ponded water – (conventional practice).

Higher grain and straw yield of rice was recorded under conventional irrigation practice (T_8) which was on par with scheduling irrigation after 15 cm DPW upto maximum tillering and continuous submergence upto 10 days prior to harvest (T_5) and irrigation after 15 cm DPW upto panicle initiation and continuous submergence upto 10 days prior to harvest (T_7). The total water use by rice was higher under the current recommended irrigation practice of recouping 5 cm submergence one day after disappearance of ponded water followed by irrigation after 15 cm DPW upto maximum tillering and continuous submergence thereafter (T_5). The maximum water saving was noticed under irrigation after 20 cm DPW from 7 DAT to 10 days prior to harvest (T_3) followed by irrigation after 15 cm DPW from 7 DAT to 10 days prior to harvest (T_2). Higher WUE of 5.77 kg ha^{-1} mm^{-1} was noticed under irrigation after 15 cm DPW from 7 DAT to 10 days prior to harvest (T_2) while lower WUE was observed under the conventional irrigation practice (T_8) (Table 3). The net return and B: C ratio were higher with conventional irrigation practice (T_8) and irrigaion after 15 cm DPW upto maximum tillering and continuous submergence upto 10 days prior to harvest (T_5).

Plate 1. Field Water Tube Device

Table 1.12. Total water use as influenced by AWDI

Treatments	Irrigation water applied (mm)	Effective rainfall (mm)	Total water use (mm)	Rate of water used day^{-1} (mm)	Percent water saving	WUE (kg ha mm^{-1})
T_1	988	68	1056	12.57	8.5	5.35
T_2	886	68	954	11.49	17.3	5.77
T_3	849	68	917	11.60	20.5	5.25
T_4	954	68	1022	12.77	11.4	5.29
T_5	1019	68	1087	12.78	5.8	5.38
T_6	943	68	1011	12.18	12.4	5.25
T_7	999	68	1067	12.55	7.5	5.36
T_8	1086	68	1154	13.26	–	5.17

Theme II

Design, development and refinement of surface and pressurized irrigation systems including small holders' systems for enhancing water use efficiency and water productivity for different agro-eco systems.

2.1 Bilaspur

2.1.1 Effect of different levels of irrigation and mulch on growth and yield of capsicum (capsicum annum var. gossum l.)

The above effect was studied under drip environment. The fruit yield on irrigation at 100% PE with 24.76 cm Water Expanse (WE) produced significantly higher yield (38.37 q/ha) than at 80% PE (24.76 cm WE). Black film mulch produced significantly higher yield (46.53 q/ha) than all other mulches and no mulch, followed by Blue LLDPE (43.01 q/ha) (Table 2.1).

Table 2.1 Growth, yield attributing characters, WE & WEE of capsicum as influenced by different treatments.

Treatment.	Plant height (cm)	No of branh/plant	Periphery of fruit (cm)	Wt/ Fruit (g)	WE, (cm)	WEE, (kg/ha-cm)	Yield, (q/ha)
Main I_1	34.13	5.42	20.95	92.77	24.76	154.96	38.37
I_2	33.42	5.12	19.00	71.38	19.96	178.85	35.70
CD $_{5\%}$	NS	NS	1.51	7.26			1.64
Sub M_1	28.79	4.53	17.06	65.00	23.97	98.08	23.51
M_2	38.45	5.66	22.05	108.33	21.56	215.81	46.53
M_3	35.38	5.53	20.46	80.83	21.56	185.94	40.09
M_4	36.58	5.56	20.75	93.33	21.56	199.48	43.01
M_5	31.53	5.33	20.15	75.00	21.56	169.34	36.51
M_5	31.92	5.00	18.76	70.00	23.97	135.71	32.53
CD $_{5\%}$	3.28	0.58	2.09	23.79			2.86
CV%	8.07	9.14	8.72	18.08			6.46

Rainfall12.04 cm

2.1.2 Effect of level of irrigation and micro nutrient (zinc and sulpher) on growth and yield of onion.

The bulb yield of onion under different irrigation levels, irrigation at 60% CPE produced significantly higher bulb yield (208.56 q/ha) than irrigation at 120% CPE, 100% CPE and (80% CPE. Similarly, under different micronutrients Zn-5 kg/ha + S-20 kg/ha produced significantly higher bulb yield (172.86 q/ha) than Control and Zn-5 k/ha but at par with S-20 kg/ha. Water Expanse varies from 18.06 to 33.06 cm (2 to 5 irrigations) with Water Expanse Efficiency of 613.29 to 677.84 kg/ha-cm. Higher Net Return of Rs. 153287/- was found 5 irrigations followed by 4 irrigation Rs 117117/. Similarly, application of Zn-5 kg/ha+S-20 kg/ha gave higher net return (Rs 115887/-) with higher WEE (676.29 kg/ha-cm) followed by S-20 kg/ha (Table 2.2).

Among the growth and yield attributing parameters of onion under different irrigation levels, the treatment I_4 (60% CPE) gave significantly plant height (56.51 cm), No. of leaves/plant (8.50), periphery of bulb (18.53 cm) and Wt/bulb (69.0 g) than the I_1 (120% CPE) and I_2 (100% CPE) but at par with I_3 (80%). Similarly, under different micronutrient F_4 (Zn-5 kg/ha + S-20 kg/ha) gave significantly higher no. of leaves/plant (8.70), periphery of bulb (18.31 cm) and Wt/bulb (65.58 g) than F_1 (Control) and F_2 (Zn-5 k/ha) but at par with F_3 (S-20 kg/ha). The bulb yield of onion under different irrigation levels, the treatment I_4 produced significantly higher bulb yield (208.56 q/ha) than I_1, I_2 and I_3. Similarly, under different micronutrient F_4 produced significantly higher bulb yield (172.86 q/ha) than F_1 and F_2 but at par with F_3. Under different irrigation levels the no. of irrigation varies from 2-5 with, WE 18.06 to 33.06 cm with, WEE of 613.29 to 677.84 kg/ha-cm in I_1 to I_4. Higher Net Return of Rs. 153287/- was found under 5 irrigations followed by 4 irrigation Rs 117117/-. Similarly, F_4 gave higher net return of Rs 115887/- with higher WEE 676.29 kg/ha-cm followed by F_3 (Table 2.3).

Table 2.2 Yield attributing parameters and yield of Onion as influenced by different treatments.

Treatment.	Plant population/m	Plant height (cm)	No. of leaves/ plant	Periphery of bulb, cm	Wt,/ bulb, g	Bulb yield q/ha
Main I_1	10.45	51.14	7.51	16.61	52.75	114.13
I_2	10.58	52.47	7.91	17.04	55.83	156.31
I_3	10.58	52.97	8.35	18.49	64.58	172.09
I_4	10.58	56.51	8.50	18.53	69.00	208.56
CD $_{5\%}$	NS	2.96	0.43	1.22	11.22	18.40
Main F_1	10.60	52.23	7.51	16.95	55.08	152.57
F_2	10.55	52.57	7.93	17.42	58.16	159.32
F_3	10.58	53.68	8.13	17.98	63.33	166.40
F_4	10.46	54.61	8.70	18.31	65.58	172.86
CD $_{5\%}$	NS	NS	0.60	0.72	5.96	7.51
CV%	5.59	6.60	8.83	7.83	11.69	8.48

Table 2.3 Yield attributing parameters and yield of Onion as influenced by different treatments.

Treatment	Bulb yield q/ha	Water Expanse (cm)	WEE (kg/ha-cm)	Total Income (Rs.)	Cost of cultivation (Rs.)	Net profit (Rs.)
Main I_1	114.13	18.06	631.94	114130	54373	59757
I_2	156.31	23.06	677.84	156310	54673	101637
I_3	172.09	28.06	613.29	172090	54973	117117
I_4	208.56	33.06	630.85	208560	55273	153287
CD $_{5\%}$	18.40					
Sub F_1	152.57	25.56	596.90	152570	52673	99897
F_2	159.32	25.56	623.31	159320	55173	104147
F_3	166.40	25.56	651.01	166400	54473	111927
F_4	172.86	25.56	676.29	172860	56973	115887
CD $_{5\%}$	7.51					

Rate of Bulb Rs. 10/kg, Rainfall 10.8 cm

2.2 Dapoli

2.2.1 Comparative performance of irrigation methods and levels of irrigation on growth and yield of arecanut

The irrigation treatments were imposed from 1st December, 2013 and terminated after the onset of effective monsoon (9th June) of the year 2014. Irrigation was scheduled as per the approved technical program with three irrigation levels (0.2PE, 0.4PE, and 0.6 PE) in drip irrigation system. The volume of water applied (lit/plant) in each treatment along with evaporation during the crop season are tabulated in Table 2.4.

2.2.2 Effect of irrigation and fertigation levels on yield and quality parameters of Aonla (Emblica officinalis Gurtn) Cv. NA-7 under drip irrigation system

The irrigation treatments were imposed from 1st December-2013 and terminated after the onset of effective monsoon (9th June) of the year 2014. Irrigation was scheduled as per the approved technical program with three irrigation levels I_1 (100 % ET_{crop}), I_2 (80% ET_{crop}) and I_3 (60% ET_{crop}) through drip irrigation. The volume of water applied (lit/day/plant) in each treatment along with evaporation during the crop season are tabulated in Table 2.5.

Table 2.4 Monthly evaporation and volume of water applied lit/plant to arecanut under different treatments during 2013-14

Month	Evaporation(mm)	Water requirement Drip irrigation (lit/plant)			Ring method (mm)
		I_1	I_2	I_3	
December	120.2	105	210	315	180
January	109.4	95	192	287	180
February	110.0	96	193	288	150
March	143.8	126	252	378	180
April	153.4	134	268	402	180
May	167.8	127	254	380	180
June	44.3	40	80	116	60
Total, mm	849	170	340	509	1110
Water saving over surface method (%)		84.7	69.4	54	-

Total amount of water applied per plant under treatment I_1 (0.2PE), I_2 (0.4PE), I_3(0.6PE) was 170, 340, 509 mm, while 1110 mm water was applied in case of control treatment (ring method). It resulted in the water saving of 84.7, 69.4 and 54 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 849 mm.

Total amount of water applied to Aonla crop under treatment I_1, I_2 and I_3 were 340, 272 and 204 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 849 mm. The influence of incorporated treatments of irrigation and fertigation levels on biometric observations like

Table 2.5 Monthly evaporation, ET_{crop} and volume of water applied per plant per day to Aonla under different treatments during the year 2013-14

Month	Evaporation, mm	ET_{crop}, mm	Volume of water applied (lit/day/plant)		
			I_1	I_2	I_3
December	120.2	48.0	38	30	23
January	109.4	43.7	36	29	22
February	110.0	44.0	37	29	22
March	143.8	57.5	45	36	27
April	153.5	61.4	50	40	30
May	167.8	67.1	53	42	32
June	44.3	17.7	48	38	29
Total, mm	849	339.6	340	272	204

plant height and average stem girth were observed and the results are presented and discussed in the following sections. The irrigation levels produced significant effects on height of Aonla plant. The treatment I_2 (80% ET_{crop} through drip) has shown highest height of 3.82 m which was significantly superior over I_1 and I_3. The different levels of water soluble fertilizers produce significant effects on height of Aonla plant. The maximum plant height (3.80 m) was observed at 100% RDF through drip irrigation. The Interaction effects of irrigation and fertigation levels showed that treatment combination I_2F_1 has shown highest height of 4.28 m which was significantly superior to rest of treatment combinations.

The fruit yield of Aonla Kg per plant was recorded and yield per hectare is calculated in each treatment as reported in Table 2.6. From the yield data it is seen that, maximum yield (6.1 kg/plant) was observed in I_2F_1 treatment as compared to all other treatments. Minimum yield (1.63 kg/plant) was observed in control (rainfed) treatment. This clearly indicated that the aonla responds to irrigation as well as fertigation to produce the yield significantly as compared to no irrigation of aonla crop.

Table 2.6 Effect of irrigation and fertilizer levels on yield of Aonla (kg/plant) during year 2013-14

Treatments	**Yield Aonla (kg/plant)**			**Mean**
	I_1	**I_2**	**I_3**	
F_1	4.25	6.10	4.10	4.81
F_2	4.03	4.77	3.93	4.24
F_3	3.53	3.88	3.5	3.63
Mean	3.94	4.92	3.84	
	I	F	I x F	
SE (m)±	0.13	0.14	0.23	
C.D. at 5%	0.52	0.42	0.92	
Control				1.63

The maximum water use efficiency (WUE) of 44.90kg/ha-cm was observed in I_2F_1 treatment followed by 40.2 kg/ha-cm in I_3F_1 treatment. Minimum water use efficiency (20.78 kg/ha-cm) was found in I_1F_3 treatment (Table 2.7).

Table 2.7 Yield of Aonla as affected by different irrigation treatment and water use efficiency during the year 2013-14

Treatment	Yield		Total water applied, ha-cm	WUE, Kg/ha -cm
	Kg/plant	q/ha		
I_1F_1	4.25	8.5	33.96	25.02
I_1F_2	4.03	8.06	33.96	23.73
I_1F_3	3.53	7.06	33.96	20.78
I_2F_1	6.10	12.2	27.17	44.90
I_2F_2	4.76	9.52	27.17	35.0
I_2F_3	3.88	7.76	27.17	28.5
I_3F_1	4.10	8.2	20.36	40.2
I_3F_2	3.93	7.86	20.36	38.6
I_3F_3	3.5	7.0	20.36	34.3
Control	1.63	3.26	-	-

2.2.3 Response of cashew (Anacardium occidentale) Cv. Vengurle-4 to irrigation and fertigation levels under drip irrigation

The irrigation treatments were imposed from 1st December, 2013 and terminated after the onset of effective monsoon of the year 2014 i.e. from 9th June 2014. Irrigation was scheduled as per the approved technical program with three irrigation levels I_1 (100 % ET_{crop}), I_2 (80% ET_{crop}) and I_3 (60% ET_{crop}) through drip irrigation. The percent wetted area is considered as 45%. Total amount of water applied to cashew crop under treatment I_1, I_2 and I_3 were 340, 272 and 204 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 reference evapotranspiration during the study period was 849 mm, whereas ET_{crop} was 340 mm. The water applied for treatment I_1 from December 2013 to May 2014 was in the range of 31 to 48 lit/day/plant. Irrigation levels produced significant effects on height of cashew plant. The treatment I_2 (80% ET_{crop} through drip) has shown highest and significantly superior height (3.89 m) over treatment I_3 and was at par with I_1. Different levels of fetigation produced significant effect on height of cashew plant. Treatment F_2 (80% RDF) has shown highest and significantly superior height (3.76 m) over treatment F_3 and was at par with F_1.

2.3. Gayeshpur

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

Plant quality parameters and flower production of gladiolus was assessed under four irrigation levels (conventional surface irrigation, gravity drip at 1.0, 0.8 and 0.6 Eo) and three nitrogen levels (100% vermicompost, 50% vermicompost + 50% inorganic, 100% inorganic) during rabi 2011-2012 to 2013-2014. The results showed that drip irrigation at 1.0 Eo (evaporation replenishment) with conjunctive use of 50% inorganic N plus 50% organic N through vermicompost produced significantly the highest number of spikes/plot (72.6), number of florets per spike (10.3), longer spike length (65.9 cm), higher weight of single spike (43.2 g) and spike yield (9886 kg/ha), which was competitive with the drip irrigation at 0.8 Eo supplemented with 50% inorganic N plus 50% organic N as vermicompost. Maximum water use efficiency of 65.6 kg/ha-mm was obtained with drip irrigation at 0.6 Eo. Based on polynomial equation, maximum flower yield of 9.4 t/ha was found 118 .8 mm water application through drip system in several splits which is much beneficial to the resource poor gladiolus growers in the region.

2.4 Hissar

2.4.1 Performance of mini-sprinkler in mungbean-wheat sequence.

The system mini-sprinklers of varying flow rates were installed in wheat just after sowing during 2008-09. The flow rates vary from a minimum of 16 to a maximum of 144 lph having the corresponding wetting diameters of 2.4 to 6.0 m. 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 depth of irrigation water applied with mini-sprinklers of various wetting diameters varied from 12.18 to 12.64 cm with an average depth of 12.4 cm as compared to 16.6 cm under surface method of irrigation (Table 2.8 & Fig. 2.1), thus amount of irrigation water applied was 4.2 cm less under mini-sprinklers system as compared to surface irrigation. The soil moisture depletion (SMD) among mini-sprinklers of various wetting diameters varied from 8.14 to 8.68 cm with an average value of 8.37 cm while it was 8.72 cm under surface irrigation. Similarly, the ground water contribution (GWC) towards crop ET under irrigation with different wetting diameter mini-sprinklers ranged from 10.18 to 10.56 cm whereas it was 11.14 cm under surface irrigation. The consumptive use (CU) under varying wetting diameter mini-sprinklers was almost similar (36.98 to 37.83 cm) as against 42.61 cm under surface irrigation.

Table 2.8 Water use components in wheat under different mini-sprinklers and surface irrigation during 2013-14

Wetting dia. (m)	Water use (cm)				
	Irrigation	Rainfall	SMD	GWC	CU
2.4	12.60	6.15	8.14	10.22	37.11
3.4	12.44	6.15	8.68	10.56	37.83
4.2	12.32	6.15	8.26	10.25	36.98
5.6	12.18	6.15	8.57	10.54	37.44
6.0	12.64	6.15	8.18	10.18	37.15
Surface	16.60	6.15	8.72	11.14	42.61

SMD-soil moisture depletion, GWC- ground water contribution, CU- consumptive use

Note: Water table depth of the field varied 65 to 108 cm during the crop season.

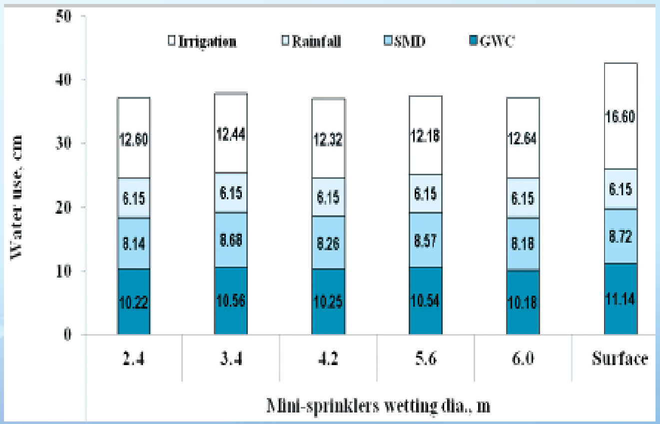


Fig. 2.1 Water use components in wheat under different mini-sprinklers and surface irrigation during 2013-14

Table 2.9 Yield parameters and grain yield of wheat under different mini-sprinklers and surface irrigation during 2013-14

Wetting dia.(m)	Effective tillers/m^2	Grains/ spike	Test wt.(g)	Yield, kg/ha		Harvest
				Grain	Straw	
2.4	345.0	41.2	38.0	5193	6906	42.9
3.4	346.0	41.1	38.2	5205	6819	43.3
4.2	345.5	41.0	38.1	5168	6822	43.1
5.6	345.8	40.8	38.2	5171	6981	42.6
6.0	346.0	41.2	38.2	5244	6817	43.5
Surface	343.0	40.5	37.4	5031	6993	41.8
CD at 5%	NS	NS	0.5	NS	NS	-

The yield parameters viz., effective tillers/m^2 and grains/spike under mini-sprinklers and surface did not differ markedly; however, the 1000-grain wt. (g) was significantly higher with mini-sprinklers over surface irrigation (Table 2.9). Average grain yield of wheat (5196 kg/ha) was higher under mini-sprinklers of different diameters over the surface method of irrigation (5031 kg/ha). Among the mini-sprinklers, maximum grain yield of 5244 kg/ha was recorded when irrigations were applied using mini-sprinkler of 6.0 m wetting diameter. The straw yield did not differ significantly and the harvest index was found lower under surface irrigation as compared to mini-sprinkler system.

The WP of irrigation water under surface method was 3.30 kg/m^3 which increased to 4.18 kg/m^3 using mini-sprinkler system of irrigation. The WP of total water use did not vary much among the mini-sprinklers of different wetting diameters (1.38 to 1.41 kg/m^3) with irrigation of different wetting diameter but it was substantially lower under surface irrigation i.e. 1.18 kg/m^3.

2.4.2 Performance of mini-sprinklers in wheat over the years (2008-09 to 2013-14)

The grain yield of wheat irrigated with mini-sprinklers of 6.0 m wetting diameter was highest in all the years (Table 2.10) among sprinklers of different wetting diameter and over surface irrigation. During 2008-09, the grain yield was significantly higher with mini-sprinklers of 6.0 m as compared to surface irrigation and mini-sprinklers of 3.4, 4.2, and 5.6 m wetting diameter. However, in 2009-10 and 2010-11, it was significantly higher over only surface irrigation, and the difference among mini-sprinklers of varying wetting dia. was not marked. During 2012-13 and 2013-14, the grain yield did not vary substantially between the surface and mini-sprinklers. The mean grain yield of the five crop seasons with mini-sprinklers of 6.0 m wetting diameter was 5160 kg/ha which was significant higher by 477 kg/ha as compared to surface irrigation. The variation in grain yield under irrigation with mini-sprinklers of varying wetting

Table 2.10 Grain yield of wheat under different mini-sprinklers and surface irrigation during from 2008-09 to 2013-14

Wetting dia., m	Grain yield, kg/ha					
	2008-09	2009-10	2010-11	2012-13	2013-14	Mean
2.4	5426	4686	5405	4342	5193	5010
3.4	5124	4556	5333	4276	5205	4899
4.2	5238	4632	5307	4309	5168	4931
5.6	5045	4598	5432	4288	5171	4907
6.0	5672	4761	5737	4388	5244	5160
Surface	4768	4217	5155	4246	5031	4683
CD at 5%	267	208	296	NS	NS	326

diameter was not significant. Therefore, irrigation with sprinklers having wetting diameter of 6 m was found to be most efficient as compared to the sprinklers of other wetting diameters and surface irrigation in wheat.

Water use and water productivity (WP):

The average water use from all sources i.e. soil moisture depletion, ground water contribution from shallow water table, effective rainfall and irrigation water applied varied between a narrow margin of 38.1 to 39.6 cm with irrigation from different wetting diameter mini-sprinklers (Fig. 2.2). It was 43.2 cm in surface method of irrigation. Likewise, the total depth of irrigation water applied was 20.0 cm in surface method of irrigation while with irrigation from different wetting dia. mini-sprinklers it varied from 15.1 to 17.7 cm. The WP of the total water use was 2.91 kg grain/m^3 with 6.0 m and 3.25 kg grain/m^3 with 5.6 m wetting dia. mini-sprinkler. It was substantially lower i.e., 2.35 kg grain/m^{3}with surface method of irrigation in wheat. The WP of irrigation water applied did not vary among the mini-sprinklers of varying wetting diameter which remained around 1.30 kg grain/m^3 whereas it was only 1.08 kg grain/m^3 under surface irrigation method.

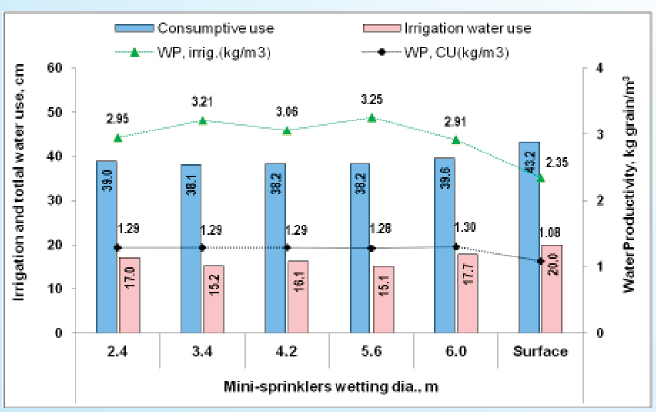


Fig. 2.2 Average Irrigation and total water use, and water productivity of wheat under different mini-sprinklers and surface (2008-09 to 2013-14)

Taking into account the initial cost of installation of mini-sprinklers and the value of additional yield obtained during the last five years, the net profit was maximum (Rs 28427/ha) with mini-sprinklers of 6.0 m wetting diameter. After 5 years of irrigation with mini-sprinklers, the B:C was found to increase with increase in wetting diameter of the mini-sprinklers.

2.4.3 Evaluation of irrigation scheduling with different methods of irrigation and mulching in cotton cultivar

The crop was planted on 20th may, 2014 after a pre-sown irrigation. A total of 282 mm rainfall was received during the crop season out of which 223 mm was calculated to be effective. The cumulative values of Pan Evaporation, rainfall and the gap is shown in Figure 2.3. It is clear from the figure that the gap between cumulative PAN evaporation and rainfall existed from the start of the crop season and widened with the advancement of crop period. The measured amount of irrigation water was applied as per treatments. The data from the Meteorological laboratory located at the research farm was used to calculate the IW/CPE. It indicated that to meet the crop water requirement, frequent irrigations were needed.

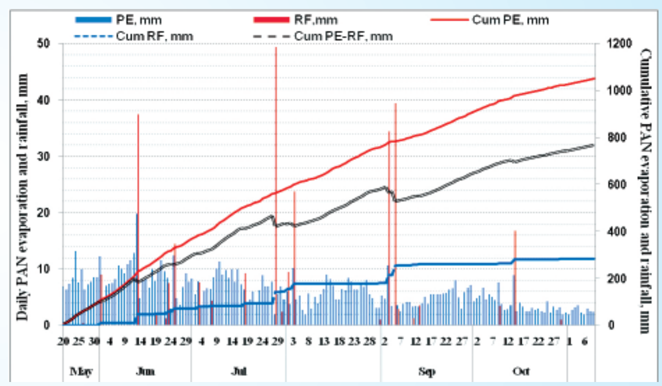


Fig. 2.3 Daily and cumulative PAN evaporation and rainfall, and their difference during the cotton crop growth period of 2014

The first irrigation was applied on 18th June in flood and furrow methods when 65% of available moisture in the 0-90 cm soil profile has depleted in the individual plots. Thereafter, irrigations were applied as per IW/CPE ratios. The depth of irrigation was around 6.0 cm under flood and 5.0 cm under furrow method. Under flood method, six irrigations were applied with a total amount of 35.9 cm at IW/CPE= 0.75, while four irrigation were given at IW/CPE= 0.50 with a total amount of 24.7 cm. In furrow method, seven and five irrigations with a total amount of 34.7 and 25.9 cm were applied at IW/CPE= 0.75 and 0.50, respectively. Under drip, irrigations were applied on alternate days at PE of 0.8 and the total amount of irrigation water applied was 23.5 cm. The volume of water applied (V) through drip was estimated as follows:

$$V = E_p \times K_p \times K_c \times A \times N - R_c \times A$$

Where, E_p is Pan evaporation (mm/day), K_p is Pan factor (0.8 for USDA Class-A Pan), K_c is crop factor during the growth period, A is the effective wetted area (m^2), N is irrigation interval (days), R_c is effective rainfall (mm)

Water use: The depletion of moisture from soil (SMD) was minimum i.e., 5.8 cm with drip irrigation applied at PE=0.8 and highest (6.8 cm) with flood irrigation applied at IW/CPE of 0.50. The contribution from shallow water table (GWC) towards crop ET was higher with irrigations applied either in flood or furrow method at IW/CPE=0.5 as compared to IW/CPE=0.75. The total water use as consumptive use was 60.8 cm with drip irrigation and highest (72.3 cm) with flood irrigation applied at IW/CPE of 0.50. Mulching with wheat straw influenced the water use components as given in Table 2.11. Use of 6 or 4 t/ha wheat straw as mulch resulted in lower SMD and GWC and consequently the consumptive use in cotton crop primarily due to reduced evaporation from the soil surface during initial growth period. The total water use did not differ under 4 or 6 t/ha wheat straw as mulch.

Seed cotton yield and yield parameters: The yield attributing parameters viz. number of opened bolls/plant and boll weight as well as the yield per plant were significantly influenced by varying moisture regimes and mulch rates (Table 2.12). The number of opened bolls/plant were found to be highest (45.06) with drip irrigation applied at 0.8 PE as compared to other methods of irrigations and moisture regimes. Irrigation in furrow applied at IW/CPE=0.50 produced the lowest (34.18) number of opened bolls/plant. Application of irrigation through drip resulted in significantly higher boll weight (3.111 g) as compared to other moisture regimes and methods. Flood irrigation applied at IW/CPE=0.5 had the lowest boll weight

Table 2.11 Values of water use components (cm) in cotton under different methods of irrigation, moisture regimes and straw mulch

Method of irrigation	Moisture regime	Water use (cm)				
		SMD	Irrigation	Eff. RF	GWC	Total
Flood	IW/CPE = 0.75	5.6	35.9	22.3	8.5	72.3
	IW/CPE = 0.50	6.8	24.7	22.3	9.5	63.3
Furrow	IW/CPE = 0.75	6.3	34.7	22.3	8.3	71.6
	IW/CPE = 0.50	6.5	25.9	22.3	9.5	64.2
Drip	PE = 0.8	5.8	23.5	22.3	9.2	60.8
Wheat straw mulch						
	No mulch	6.7	29.1	22.3	9.5	67.7
	4.0 t/ha	6.0	28.9	22.3	8.8	65.9
	6.0 t/ha	5.9	28.8	22.3	8.7	65.7

Table 2.12 Yield parameters and seed cotton yield of cotton under different treatments

Method of irrigation	Moisture regime	Opened	Boll wt. g bolls/plant	Yield/plant, g	Seed cotton yield, kg/ha
Flood	IW/CPE = 0.75	36.26	2.973	106.1	2241
	IW/CPE = 0.50	34.87	2.843	97.5	2061
Furrow	IW/CPE = 0.75	43.54	3.067	131.9	2785
	IW/CPE = 0.50	34.18	2.974	100.4	2124
Drip	PE = 0.8	45.06	3.111	138.7	2918
CD at 5%		1.76	0.023	5.3	159
Wheat straw mulch	No mulch	35.01	2.923	101.1	2138
	4.0 t/ha	40.21	3.024	120.4	2526
	6.0 t/ha	41.13	3.035	123.3	2613
CD at 5%		1.25	0.015	3.7	94

of 2.843 g. The seed cotton yield recorded under drip system of irrigation was significantly higher (2918 kg/ha) than flood irrigation applied at IW/CPE of 0.75 and 0.50, and furrow irrigation applied at IW/CPE of 0.50 but was at par with furrow irrigation applied at IW/CPE of 0.75. Also, application of irrigation at IW/CPE=0.75 through furrows produced significantly higher seed cotton yield over other moisture regimes under flood and furrows. Use of wheat straw mulch either @ 4 or 6 t/ha favourably influenced the yield attributes viz., opened bolls/plant and boll weight, and consequently resulted in significantly higher yield/plant and seed cotton yield over no mulch. However, the difference in yield attributing parameters and seed cotton yield between mulching @ of 4 and 6 t/ha was not marked. The interaction between methods of irrigation at various moisture regimes and mulch rates was found to be non-significant.

Water productivity (WP): The water productivity calculated as seed cotton yield per unit of irrigation and total water use revealed that the productivity of applied irrigation as well as total water use was highest (1.24 and 0.48 kg seed cotton yield/m^3, respectively) when irrigations were applied at PE of 0.8 through drip system over other irrigation methods and schedules (Fig. 2.4). The irrigation water productivity as achieved with irrigation at IW/CPE=0.75 by flood method was found to be lowest i.e. 0.62 kg seed cotton yield/m^3 as against the other moisture regimes by surface (flood and furrow) methods which fluctuated around 0.80 kg seed cotton yield/m^3. Among the surface methods of irrigation, the productivity of total water use was highest (0.39 kg seed cotton yield/m^3) with furrow applied at IW/CPE= 0.75. Mulching with wheat straw @ 4 or 6 t/ha resulted in achieving higher productivity of applied irrigation and total water use (0.38-0.40 and 0.88-0.91 kg seed cotton yield/m^3) as compared to no mulch (0.32 and 0.72 kg seed cotton yield/m^3). However, the difference between mulching @ 4 and 6 t/ha was not found to be pronounced in terms of either irrigation or total water use productivity.

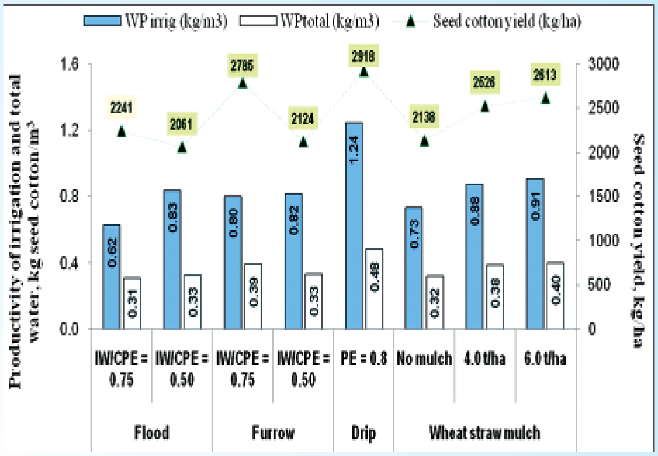


Fig. 2.4 Water productivity and seed cotton yield under different methods of irrigation, moisture regimes and straw mulch

Irrigation applied at 0.8 PE through drip resulted in highest seed cotton yield and water productivity. Among the surface methods irrigation at IW/CPE=0.75 by furrow method yielded higher seed cotton yield as well as water productivity. Mulching with wheat straw @ 4 or 6 t/ha produced similar yield and water productivity but was considerably superior to no mulch.

Table 2.13 Effect of planting geometry and irrigation levels on growth parameters, yield attributes and yield of Tomato

Treatment	Plant height (cm)	No. of Branches/ plant	Fruit Diameter (cm)	Fruig Weight (g)	No. of Fruits/ Plant	Yield (t/ha)
A. Spacing						
S_1	64.8	3.5	15.2	56.0	17.0	16.5
S_2	66.5	4.0	16.5	60.0	19.5	18.1
S_3	63.3	3.0	13.3	48.0	14.5	13.0
CD(5%)	NS	NS	1.8	5.5	2.7	2.1
B. Irrigation levels						
I_1	63.1	3.1	12.5	51.5	15.0	13.5
I_2	65.5	3.7	15.9	55.7	17.7	16.7
I_3	65.8	4.0	16.6	56.8	18.3	17.5
CD(5%)	NS	NS	0.8	2.4	1.2	1.1
C. Absolute control	58.6	2.3	10.3	48.5	11.0	9.5

2.5 Jammu

2.5.1 Evaluation of drip irrigation layout and effect of irrigation on tomato (Lycopersicon esculentum)

The total water applied with drip irrigation system with irrigation levels of I_1,I_2 and I_3 was 82, 167 and 245mm respectively as compared to350mm in control. The water saving in respective irrigation levels ranged from 33-77 percent over control. Growth and yield of Tomato showed that plant height and no. of branches/plant did not vary significantly irrespective of spacing and irrigation treatments applied. However, significant difference existed for fruit diameter, fruit weight and no. of fruits/plant. Spacing treatment S_2 showed significantly higher values over S_3 but at par values with S_1 for fruit diameter, fruit weight and no. of fruits/plant and yield. Similarly, irrigation at I_3 (0.75PE) recorded significantly higher values over I_1 (0.25PE) but at par values with I_2(0.50PE)for fruit diameter, fruit weight and no. of fruits/plant (Table 2.13).

2.6 Jabalpur

2.6.1 Effect of Dripper Spacing on Yield and Water Productivity of Wheat under Drip Irrigation

Field studies were also conducted on use of drip irrigation for Wheat crop. The result indicated that the wheat yield may be improved by 21 %. 60 cm lateral spacing with 40 cm dripper spacing was found significantly superior in terms of yield. The water productivity can be increased upto 1.69 kg/m^3. Mean grain yield for all three dripper spacing (30, 40, 50 cm) at lateral spacing of 60 cm produces significantly higher wheat yield (46.33 q ha^{-1}) followed by 80 cm lateral spacing (43.70 q ha^{-1}) and 100 cm lateral spacing (41.77 q ha^{-1}). Mean wheat yield as recorded in all lateral spacing (60, 80, 100 cm) was maximum with 30 cm dripper spacing (45.22 q ha^{-1}) closely followed by 40 cm dripper spacing (43.56 q ha^{-1}) and 50 cm dripper spacing (43.06 q ha^{-1}).

The lateral spacing of 60 cm with drippers at 30 cm interval resulted highest grain yield of 47.16 q ha^{-1} which is 18.43% higher as compared to supervised pipe irrigation. It also saves 24.86% water applied and thus improves water productivity by 47.30%. On the basis of economical analysis, wheat cultivated under 100 cm lateral spacing with dripper at 30 cm interval resulted the highest net profit of Rs. 47,574 per hectare with maximum economic water productivity of 10.94 Rs/m^3 of water used. Based on present study with all statistical analysis and economical gain, 60 cm lateral spacing with 50 cm dripper spacing may be recommended for wheat crop which may result in 46.36 q ha^{-1} of wheat with use of water up to 32.3 cm. The yield obtained in supervised pipe irrigation was 39.82 q ha^{-1} with water use of 43.0 cm. Thus drip irrigation as recommended may improve yield by 16.42% and save water by 24.86%.

2.7 Jorhat

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

The result showed that for first two years of the trial , different treatments failed to influence the yield of Assam lemon plants significantly. However treatments became significant during 3rd and 4th year of the experimentation. It was interesting to note that even 50% of recommended dose of N application through vermiwash application resulted in better or at par yield that of soil application with 100% recommended dose of NPK (Table 2.14). Compared to conventional drip fertigation vermiwash fertigation resulted in significantly better yield. The yield of Assam lemon plants fertigated with vermiwash @ 50% recommended dose of N were at par with conventional fertigation of 100% RD during 2012-13, 2013-14 and in pooled. Vermiwash fertigation @120% of recommended dose of N resulted in the highest yield during all the years of experimentation as well as in pooled. The better yield of verimwash fertigated plants compared to soil application of fertilizer may be due to better availability of nutrient to the plant. Further it was noticed that if sufficient care is not taken in soil application of fertilizer considerable damage of feeder roots in the surface layers takes place which affects the nutrient uptake of the plant. Soluble Nitrogen, Phosphorus and Potash are the main nutrients in vermi wash. Hormones such as Cytokinins, Oxyn etc., Amino Acid, Vitamins, Enzymes, some other secretions and many useful microbes such as heterotrophic bacteria, fungi, actinomycetes including nitrogen fixers, phosphate solubilisers present in the vermiwash (not qualtified) might have played role in getting better yield of plants. Another reason might be

Table 2.14 Effect of vermiwash as liquid fertilizer on yield of Assam lemon

Explanation	Treatments	Yield (no. of fruits per plant)				
		2010-11	2011-12	2012-13	2013-14	Pooled
Rain fed + Soil application (100% of RDF)	T_1	20.00	32.75	74.00	172.50	74.81
Fertigation (120 % RDF) conventional drip	T_2	18.25	33.50	116.00	237.25	101.25
Fertigation (100 % RDF) conventional drip	T_3	21.50	31.25	87.50	223.00	80.81
vermiwash (120 % of recommended dose of N) through low cost drip	T_4	24.0	34.00	118.25	238.75	103.75
vermiwash (100% of recommended dose of N) through low cost drip	T_5	24.75	30.50	98.00	221.00	93.56
vermiwash (75 % of recommended dose of N) through low cost drip	T_6	24.5	34.50	84.00	209.50	88.12
vermiwash (50% of recommended dose of N) through low cost drip	T_7	21.25	32.50	70.50	195.25	79.87
CD at 5 %		NS	NS	16.07	39.70	10.7
CV		31.22	21.20	11.69	12.50	16.86

that Amino Acids in the vermiwash are easily available for plants and therefore that explains better yield.

The benefit cost analysis of the experiment is presented below. For analysis of benefit cost ratio pooled yield of the results were taken. Economic analysis of Assam lemon cultivation from 1 ha area using the treatments was done. Although highest yield was obtained in the plants with vermiwash fertigation with 120 % of recommended dose of N through low cost drip, the net seasonal income was found to be highest (₹ 200975/ha) in conventional fertigation with 120% NPK. Highest benefit cost ratio of 3.85 was also obtained in the same treatment. There was negative benefit cost ratio in the tertaments with vermiwash fertigation because of higher cost of vermiwash (@ Rs 2 per l). To get an equivalent B: C ratio (3.81, 3.35, 3.09 & 2.71 for 120, 100, 75 & 50 % of RD of N through vermiwash), the cost of vermiwash has to be Rs 0.10 per l). Alternatively seliing the fruit with a premium price of Rs 10 per fruit (as organic) will result in comparable B: C ratio (3.22, 2.81, 2.59 & 2.25 for 120, 100, 75 & 50 % of RD of N through vermiwash).

Table. 2.15: Water use efficiency in turmeric Cost of cultivation and economics

Treatments	Irrigation water (mm)	Effective RF (mm)	Total water used (mm)	Yield (kg/ha)	WUE (kg/ha.mm)
I_1	907	162	1069	33618	31.44
I_2	740	162	902	33413	37.04
I_3	572	162	734	31770	43.28
I_4	1305	162	1467	33292	22.69
I_5	1137	162	1299	30987	23.85
I_6	970	162	1132	26997	23.84
I_7	812	162	974	23128	23.74

2.8 Bhavanisagar

2.8.1 Optimisation of irrigation and fertigation schedule to turmeric under different lateral spacing and the moisture and nutrient movement in soil.

Seven irrigation treatments such as I_1 : Drip irrigation at 80% of PE with lateral spacing of 90 cm, I_2 : Drip irrigation at 60% of PE with lateral spacing of 90 cm, I_3 : Drip irrigation at 40% of PE with lateral spacing of 90 cm, I_4 : Drip irrigation at 120% of PE with lateral spacing of 150 cm, I_5 : Drip irrigation at 100% of PE with lateral spacing of 150 cm, I_6 : Drip irrigation at 80% of PE with lateral spacing of 150 cm, I_7 : Drip irrigation at 60% of PE with lateral spacing of 150 cm and three fertigation levels viz. F_1 :Fertigation at 125% of recommended N & K, F_2 :Fertigation at 100% of recommended N & K and F_3 :Fertigation at 75% of recommended N & K were taken for the above evaluation. Among the different irrigation levels given I_1, I_2 and I_4 are found to be the best and on par with each other and they are followed by irrigation level I_3. Among the three fertigation treatments given F_1 and F_2 are found to be best and on par with each other, followed by F_3. Between the different interaction levels I_2F_2 is found to be best and it is followed by I_2F_2 and I_4F_1.Water use efficiency was the maximum in the treatment I_3 and I_4 (drip irrigation at 40% of PE and 60% of PE with lateral spacing of 90 cm. The treatments I_4 to I_7 recorded lower water use efficiencies because of increased water use due to increased lateral spacing of 150 cm.

The cost of drip system is taken as Rs 1,00,000 / ha in 90 cm lateral spacing and 75,000 / ha in 150 cm lateral spacing. 10 per cent on interest and 10 per cent on depreciation was added to the cost of cultivation in the respective treatments. Cost of turmeric rhizomes was taken Rs. 10 / kg. The treatments I_4F_1 recorded the highest B : C ratio and it was followed by I_4F_2 and I_2F_2. The treatments in I_1, I_2, I_3, I_4, I_5 recorded B: C ratios higher than 4. The treatments in I_6, I_7 recorded comparatively lower B: C ratios.

Table 2.16: Cost of cultivation and economics of the treatments

Treat-ments	Cost of Cultiva-tion (Rs.ha^{-1})	Yield (Kg ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C Ratio
I_1F_1	77000	33700	337000	260000	4.38
I_1F_2	75000	33060	330600	255600	4.41
I_1F_3	73000	32100	321000	248000	4.40
I_2F_1	77000	33330	333300	256300	4.33
I_2F_2	75000	35800	358000	283000	4.77
I_2F_3	73000	31110	311100	238100	4.26
I_3F_1	77000	31860	318600	241600	4.14
I_3F_2	75000	33460	334600	259600	4.46
I_3F_3	73000	30000	300000	227000	4.11
I_4F_1	72000	34820	348200	276200	4.84
I_4F_2	70000	33460	334600	264600	4.78
I_4F_3	68000	31610	316100	248100	4.65
I_5F_1	72000	32720	327200	255200	4.54
I_5F_2	70000	30990	309900	239900	4.43
I_5F_3	68000	29260	292600	224600	4.30
I_6F_1	72000	28400	284000	212000	3.94
I_6F_2	70000	26790	267900	197900	3.83
I_6F_3	68000	25810	258100	190100	3.80
I_7F_1	72000	24450	244500	172500	3.40
I_7F_2	70000	23090	230900	160900	3.30
I_7F_3	68000	21850	218500	150500	3.21

2.8.2 Optimizing irrigation schedule for redgram under drip fertigation system

For Optimizing irrigation schedule for redgram under drip fertigation system, following treatment schedule such as T_1- Conventional sowing and surface irrigation with soil application of RDF, T_2 - Transplanting and surface irrigation with soil application of RDF, T_3- Conventional sowing under drip irrigation at 40% PE and fertigation RDF, T_4- Conventional sowing under drip irrigation at 60% PE and fertigation RDF, T_5- Conventional sowing under drip irrigation at 80% PE and fertigation

RDF, T_6- Transplanting under drip irrigation at 40% PE and fertigation RDF, T_7- Transplanting under drip irrigation at 60% PE and fertigation RDF, T_8- Transplanting under drip irrigation at 80% PE and fertigation RDF , T_9- Transplanting 30 days old seedlings grown in polybags and surface irrigation with soil application of RDF.

Based on the result of the first year the treatments have been modified as below and the same will be followed during 2014 and 2015. In the place of 75 x 18 cm under drip and 45 x 30 cm under surface irrigation, 75 x 30 cm under drip and 60x 30 cm under surface irrigation will be followed. Further one additional treatment of 30 days old seedling grown in poly bag has been included. Hence, the following are the treatment structure for 2014 and 2015.The results indicated that sowing by dibbling of redgram seeds with dirp irrigation at 60% pan evaporation and fertigation of RDF resulted in better growth attributes, yield attributes and grain redgramyield. Though the above treatment resulted in higher grain yield, it was comparable with transplanting of redgram and given with drip irrigation at 60% PE and fertigation of RDF. Sowing by dibbling with drip irrigation at 60% PE and fertigation of RDF registered a higher grain yield of 1640 kg/ha and next to this treatment transplanting of redgram and given with drip irrigation 60% PE and fertigation recorded 1600 kg/ha.

2.9 Ludhiana

2.9.1 Evaluation of drip irrigation system in vegetable crops using brackish water under different cropping system.

Cauliflower:

The results of different quality of water on curd yield, water expense and water expense efficiency of cauliflower are presented in Table 2.18. The results revealed that maximum curd yield (215.3 q/ha) and average curd weight (736 gm) was obtained in CW (canal water) treatment and was significantly higher than other treatments except 1CW:1TW treatment. Maximum water expense efficiency (WEE) was in CW treatment followed by 1 CW: 2 TW and lowest in TW treatment.

Table 2.17: Effect of treatments on economics of redgram

Treatment	WUE (kg/ha/ mm)	Grain yield (kg/ha)	Net income (Rs./ha)	B:C Ratio	Cost of cultiva-tion (Rs./ha)	Gross income (Rs./ ha)
T_1 : Conventional sowing and surface irrigation with soil application of RDF	1.53	1205	30150	1.87	32120	60250
T_2 : Transplanting and surface irrigation with soil application of RDF	2.23	1170	23500	1.67	35000	58500
T_3 : Conventional sowing under drip irrigation at 40% PE and fertigation RDF	3.40	1420	33000	1.86	38000	71000
T_4 : Conventional sowing under drip irrigation at 60% PE and fertigation RDF	2.88	1640	44000	2.15	38000	82000
T_5 : Conventional sowing under drip irrigation at 80% PE and fertigation RDF	2.14	1520	38000	2.00	38000	76000
T_6 : Transplanting under drip irrigation at 40% PE and fertigation RDF	3.88	1385	29500	1.74	39750	69250
T_7 : Transplanting under drip irrigation at 60% PE and fertigation RDF	3.52	1600	40250	2.01	39750	80000
T_8 : Transplanting under drip irrigation at 80% PE and fertigation RDF	2.54	1475	34000	1.85	39750	73750
T_9 : Transplanting 30 days old seedlings grown in polybags and surface irrigation with soil application of RDF.	2.34	1230	26000	1.73	35500	61500
	SED		45.5			
	CD (P=0.05)		91.3			

Table 2.18.: 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)	Plant height (cm)	Average curd weight (gm)	Curd yield (q/ha)	WEE (q ha^{-1} ch^{-1})
CW	4.10	18.70	45.1	736	215.3	11.5
1 CW:1 TW	4.93	19.53	43.7	692	201.8	10.3
1 CW:2 TW	4.32	18.92	42.9	683	197.9	10.5
1 CW:3 TW	3.84	18.44	42.0	668	193.5	10.5
TW	4.50	19.10	41.3	652	190.1	10.0
CD @ 5%			NS	47	15.9	

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

Cucumber:

The results of different quality of water on yield, water expense and water expense efficiency of cucumber revealed that maximum yield (153.8 q/ha) was obtained in CW (canal water) treatment and is significantly higher than other treatments. Maximum water expense efficiency (WEE) was in CW treatment followed by 1 CW: 1 TW and lowest in TW treatment.

Bottle gourd:

The results of different quality of water on yield, yield contributing characteristics, water expense and water expense efficiency of bottle guard results revealed that maximum yield (379.6 q/ha) and numbers of fruits per plant (10.6) of bottle guard were obtained in treatment T_1 where canal water was used for irrigation and was significantly higher than other treatments except 1 CW: 1 TW treatment. However, the effect of water quality on fruit weight was found to be non-significant. Maximum water expense efficiency (WEE) was observed in canal water treatment and lowest in 1 CW: 3 TW and TW treatments.

2.9.2 Growth and yield response of Bt cotton to water quality and fertigation levels under drip system

The effect of irrigation water quality and fertigation levels on different growth and water use parameters show that seed cotton yield recorded significantly higher values when canal irrigation or alternate irrigation of canal and tubewell was applied than with tubewell water alone. On an average the observed seed cotton yield was 3182.4 kg/ha with canal water followed by 3056.7 kg/ha with alternate irrigation of canal &tubewell water and 2493.5 kg/ha with tube well water alone. Similar trends were observed in other growth parameters i.e. no. of bolls/plant and no. of sympods / plant. However, plant height had non-significant results under different water qualities. Among different fertigation schedules, the seed cotton yield was at par when 80% and 100% of recommended dose of fertilizer was applied. Both treatments had significantly higher yield than treatment in which 60% of recommended dose of fertilizer was applied. The water expense efficiency was highest in canal water and least in tubewell water treatments.

2.9.3 Optimum irrigation schedule for bitter gourd through drip under low tunnel

On the basis of experimentation, it was observed that the fruit yield of bitter gourd 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 fruit yield significantly.The maximum fruit yield of bitter gourd (528.24 q/ha) was recorded with drip irrigation at 1.2 Etc (LT) which was at par with the yield received with 0.8 Etc (LT) and 1.0 Etc (LT). Thus drip irrigation at 0.8 Etc (LT) was found optimum irrigation schedule for bitter gourd. It gave 18.96 % higher fruit over surface irrigation.The water expense efficiency was higher in the drip-irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 118.80 kg/ha mm was recorded under 0.8 ETc, followed by 112.35 kg/ha mm under 0.6ETc treatment. (Table 2.19)

Table 2.19: 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)
0.6 ETc	177.1	193.48	416.36	112.35
0.8 ETc	177.1	250.77	508.33	118.80
1.0 ETc	177.1	307.86	496.14	102.30
1.2 ETc	177.1	365.25	528.24	97.40
Flood irrigation	177.1	800.0	427.31	43.73

Table 2.20: Plot wise fruit yield of bitter gourd under different treatments

Treat-ments	Plot wise yield of bitter gourd (kg/plot)				Fruit yield (q/ha)
	R_1	416.36	R_3	Total	416.36
0.6 ETc	72.40	508.33	105.20	269.80	508.33
0.8 ETc	109.90	496.14	102.40	329.40	496.14
1.0 ETc	111.90	528.24	100.20	321.50	528.24
1.2 ETc	113.40	427.31	113.20	342.30	427.31
Flood irrigation	92.30	29.73	91.90	276.90	-
CD at 5%					64.78

2.9.4 Response of tomato to fertigation under low tunnel

A post transplanting irrigation of 100 mm in surface method and in drip irrigation treatments the drip was operated 5.5 hr in December to ensure good establishment of seedlings. Remaining irrigations were applied as per treatment. The water expense efficiency was increased with increasing levels of fertilizer application up to 120% RD of nutrient. The maximum water expense efficiency of 39.84 kg/ha mm was recorded under application of 120%RD of nutrient, followed by 39.774 kg/ha mm under application of 100%RD of nutrient. The fruit yield of tomato significantly increased with every increase in fertilizer levels with drip irrigation up to the application of 100 % RD of nutrient. After that the increase in yield was not significant. The maximum fruit yield of tomato (227.41 q/ha) was recorded with 120%RD of nutrient which was significantly higher as compared with the application of 60, 80 percent of recommended doses of nutrients with drip and flood irrigation and at par with 100 percent of nutrient application with drip irrigation under low tunnel.

Table 2.21: Effect of different irrigation treatments on water use and expense efficiency

Irrigation schedule	Effective rainfall	Irrigation water applied (mm)	Total water use (mm)	WEE (kg/ha (mm)
60% of RD	177.1	393.7	570.8	20.418
80% of RD	177.1	393.7	570.8	30.183
100% of RD	177.1	393.7	570.8	39.775
120% of RD	177.1	393.7	570.8	39.840
Control	177.1	800	977.1	17.398

2.10 Navsari

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

Feasibility study of drip irrigation in pigeon pea (rabi) with and without mulch was undertaken with following treatments such as I_1(Drip at 0.4

Table 2.22: Plot wise fruit yield of Tomato under different treatments

Treatments	Plot wise yield of Tomato (kg/plot)				Fruit yield (q/ha)
	R_1	116.54	R_3	Total	116.54
60% RD	63.80	172.28	64.20	188.80	172.28
80% RD	82.50	227.04	110.00	279.10	227.04
100% RD	113.40	227.41	136.90	367.80	227.41
120% RD	139.60	170.00	111.70	368.40	170.00
Flood	84.40	20.01	102.10	275.40	170.00
Total	483.70	43.60	524.90	1479.50	-
CD 5%					43.60

PEF), I_2 (Drip at 0.6 PEF), I_3 (Drip at 0.8 PEF) and I_4(Surface irrigation at 0.8 IW/CPE)M_0(No mulch), M_1(Sugarcane trash @5 t/ha), M_2(Black plastic mulch 50μ).It was observed that treatment I_3 recorded significantly higher grain yield as compared to rest of the I levels, but it remained at par with treatment I_2. During all the individual years as well as in pooled results, black plastic mulching treatment (M_2) out yielded than rest of mulching treatments by recording significantly higher grain yield of pigeon pea. The yield recorded with M_2 treatment during 2011-12, 2012-13, 2013-14 and pooled result were 1616, 1915, 1280 and 1604 kg/ha. During first year treatment combinations I_3M_2 (1732 kg/ha) registered significantly higher grain yield as comparison to rest of the treatment combinations, but it remained at par with treatment I_2M_2 (1630 kg/ha), I_3M_1 (1580 kg/ha) and I_1M_2 (1630 kg/ha). During subsequent two years and in pooled results, treatment I_2M_2 recorded significantly higher grain yield as compared to rest of the treatments, but it remained at par with treatment combinations I_1M_2. The grain yield recorded with treatment I_2M_2 during 2nd, 3rd year and in pooled results were 2254, 1440 and 1774 kg/ha, respectively. The average water applied in I_1, I_2, I_3 and I_4 were 347, 461, 574 and 680 mm, respectively which getting 49, 32 and 16 per cent water saving with I_1, I_2 and I_3, respectively over surface irrigation (I_4). Irrespective of treatments, the WUE was ranging from 1.64 kg/ha mm with I_4M_0 to 4.76 kg/ha-mm with I_1M_2.Since interaction effect of irrigation and mulch levels on grain yield was found significant, therefore, cost economics was calculated for different treatment combinations (Table 2.20.7). Considering grain, stalk and stover yields of pigeon pea, maximum net profit realized under treatment combination I_2M_2 (Rs.51970/ha).

Table 2.23: Economics of different treatments

S. N.	Treat.	Total Cost (Rs./ ha)	Yield (kg/ha)		Gross income (Rs./ha)	Net Profit (Rs./ ha)
			Grain	Stalk + Stover		
1	I_1M_0	36279	855	3813	51359	15080
2	I_1M_1	41779	1300	4888	73996	32217
3	I_1M_2	47342	1651	5909	92631	45288
4	I_2M_0	36385	1166	4976	69032	32647
5	I_2M_1	41885	1245	5030	72435	30550
6	I_2M_2	47448	1774	6324	99418	51970
7	I_3M_0	36492	1198	5042	70609	34117
8	I_3M_1	42992	1474	6861	89835	46843
9	I_3M_2	47555	1554	6697	92297	44742
10	I_4M_0	28747	1118	5046	67427	38680
11	I_4M_1	34247	1331	5907	79822	45575
12	I_4M_2	39810	1435	6016	84472	44662

* Selling price of grain @ Rs.40/kg and stover @ Rs.4.5 /kg

2.10.2 Levels of nitrogen and intra-row spacing on yield of drip irrigated castor (rabi).

Pooled results of three years showed that treatment N_3 registered significantly higher castor

Table 2.24: Economics of different treatments

Treatments	Fixed cost (Rs./ha)	Variable cost (Rs./ha)	Total cost (Rs./ha)	Seed yield (kg/ha)	Gross income (Rs./ha)	Net Profit (Rs./ha)	BCR
Intra row spacing (m)							
S_1 (0.6)	16097	23734	39831	2941	108817	68986	2.73
S_2 (0.9)	16097	23384	39481	2823	104451	64970	2.65
S_3(1.2)	16097	23184	39281	2618	96866	57585	2.47
Nitrogen level (kg/ha)							
N_1 (80)	16097	22559	38656	2634	97458	58802	2.52
N_2(120)	16097	23436	39533	2772	102564	63031	2.59
N_3(160)	16097	24314	40411	2977	110149	69738	2.72
Control							
Paired row planting	19177	24607	43784	2404	88949	45165	2.03

Selling price of produce: Castor seed = Rs. 37/kg seed yield as compared to rest of N levels. However, it remained at par with treatment N_2 during first two years. Castor seed yield recorded with treatment N_3 during year 2011-12, 2012-13, 2013-14 and in pooled results were 3057, 3036, 2837 and 2977 kg/ha, respectively. In case of intra row spacing, during all the individual years as well as pooled results, treatment S_1 recorded significantly higher castor seed yield as compared to rest of levels, but it remained at par with treatment S_2 during last two years. With respect to control v/s rest analysis, there were non significant differences in castor seed yield between treatment mean and control during individual year. However, in pooled results, treatment mean (2794 kg/ha) had an edge over control treatment (2404 kg/ha). Apart from castor yield, WUE in terms of kg/ha-mm was also calculated. Irrespective of treatments, the WUE was ranging from 7.35 kg/ha-mm (N_3) to 5.93 kg/ha-mm (control). All the treatments registered higher WUE in comparison to control.As NxS interaction effect was not significant, the economic is calculated for individual factor only. The data reported in table 2.24 indicated that the maximum net profit of Rs. 69738/ha with BCR 2.72 were recorded in N_3 treatment followed by treatment N_2 (Rs. 63031/ha). Similarly, 0.6 cm intra row spacing recorded higher net profit of Rs.68986/ha (S_1) with BCR 2.73.

2.11 Palampur

2.11.1 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 (2.18,1.09,1.11 & 1.14 times) 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, 2.35 & 2.25 times) due to lower irrigation water use (40.91, 49.40, 51.25 & 46.58 %) than recommended practices. Gross returns were higher (21.59, 9.30, 10.50 & 13.40 %) in broccoli grown with NPK fertigation than recommended practices. Net returns were significantly higher (17.62 %) in broccoli grown with NPK fertigation than recommended practices during first year. However, in later years and on mean basis, net returns were significantly lower (24.22, 17.23 & 18.88 %) in broccoli grown with NPK fertigation than recommended practices mainly due to higher cost of soluble fertilizers. The B: C ratio was lower (63.51, 66.50, 59.38 & 63.28 %) in broccoli grown with NPK fertigation than recommended practices.

During all the year as well as on mean basis, an increase in irrigation depth resulted in consistent increase in broccoli yield. However, difference in yields were not significant when irrigation depth was increased from 0.6 CPE to 0.8 time CPE during first year and on mean basis. Likewise during second year, increases in yield were not significant when irrigation depth were increased from 0.4 to 0.6 CPE and again from 0.8 to 1.0 CPE. During third year, an increase in irrigation depth resulted in consistent and significant increase in broccoli yield (Table 4).

On the contrary, during all the years as well as on mean basis, 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 CPE to 0.6 CPE during first year. Highest WUE of broccoli (3.47, 4.02, 5.59 & 4.36 Mg m^{-3} water) was obtained with water depth of 0.4 CPE.Further, during all the years and on mean basis, increase in irrigation depth resulted in consistent increase B: C ratio, with highest values at irrigation depth of 100 per cent CPE. However, the increases in B: C ratios were not significant when irrigation depth was increased from 0. 4 to 0.6 CPE and again from 0.6 to 0.8 CPE during first year; and from 0.4 to 0.6 CPE and again from 0.6 to 0.8 CPE and further from 0.8 CPE to 1.0 time CPE during second year. On mean basis also, the increase in B: C ratio was not significant when irrigation depth was increased from 0.6 to 0.8 CPE (Table 5). 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 fertigation with an interval of at least 11 days between two successive fertigation.

2.11.2 Effect of drip irrigation and fertigation frequencies on crop growth, water use and productivity of summer brinjal.

During both years, brinjal crop grown with 75 per cent of recommended NPK fertigation under gravity fed drip irrigation had no effect on brinjal yield and gross returns than crop grown with recommended package of practices i.e. fertilization with recommended NPK and surface irrigation of 5 cm at 7 day interval. During 2013, brinjal crop grown with 75 per cent of recommended NPK fertigation under gravity fed drip irrigation had no effect on net returns than crop grown with recommended package of practices. However, during 2014, crop grown with 75 per cent of recommended NPK fertigation under gravity fed drip irrigation resulted in significantly lower (23.62 %) net returns than crop grown with recommended package of practices. However, during both years, B: C ratio was significantly lower (34.76 and 41.71 %) in brinjal grown with 75 per cent of recommended NPK fertigation than recommended practices mainly due to higher cost of soluble fertilizers (Table 13). Further, during both years, the brinjal crop grown with 75 per cent of recommended NPK fertigation under gravity fed drip irrigation resulted in significantly higher water use efficiency (1.5 and 2.0 times) due to lower irrigation water use (33.14 and 52.33 %) than recommended practices.

During both years, twice a month fertigation resulted in significantly higher gross returns than fertigation at frequencies of once a week (13.50 & 11.91 %) and twice a week (9.98 & 8.75 %), respectively. Likewise, net returns were also significantly higher during both years, when crops were fertigated at the frequency of twice a month than at the frequency of once (23.37 & 24.19 %) or twice (17.06 &17.60 %) a week. During both years, twice a month fertigation resulted in significantly higher B: C ratio than fertigation at frequencies of once a week (23.74 & 24.24 %) and twice a week (17.81 & 18.27 %), respectively.

At the level of once a week fertigation, irrigation interval of one day resulted in significantly lower brinjal yield than irrigation interval of either two or three day. On the contrary, at the level of twice a week fertigation, irrigation interval of one day resulted in significantly higher brinjal yield than irrigation interval of two day. Similarly, at the levels of twice a month fertigation, irrigation interval of one day resulted in significantly higher brinjal yield than irrigation interval of three day (Table 2.25). At irrigation interval of one day, twice a month fertigation resulted in significantly higher brinjal yield than once a week fertigation. Likewise, at irrigation interval of two day, twice a month fertigation resulted in significantly higher brinjal yield than once a week fertigation as well as twice a week fertigation. Fertigation frequency had no effect on brinjal yield at irrigation interval of three day.Irrigation at two day interval and twice a month fertigation of brinjal crop resulted in highest brinjal yield. However, it was statistically similar to yield obtained by irrigating brinjal crop at an interval of one day and fertigating either twice a week or twice a month.

Table 2.25 : Interaction effect of irrigation interval and fertigation frequency on productivity of brinjal (Mg ha^{-1}) during 2014

Fertigation frequency	Irrigation interval (days)		
	One	Two	Three
Once a week	8.87	10.78	10.72
Twice a week	11.03	9.77	10.45
Twice a month	11.27	11.90	10.82
CD (P = 0.05)		0.96	

Economics of production of brinjal

At the level of once a week fertigation, irrigation interval of one day resulted in significantly lower gross returns, net returns and B: C ratio than irrigation interval of either two or three day. On the contrary, at the level of twice a week fertigation, irrigation interval of one day resulted in significantly higher gross returns, net returns and B: C ratio than irrigation interval of two day. Similarly, at the levels of twice a month fertigation, irrigation interval of two day resulted in significantly higher gross returns, net returns and B: C ratio than irrigation interval of three day (Table 2.26).

2.11.3 Effect of liquid manure based drip fertigation on water use and productivity of onion

Substitution of different proportion of recommended N with various liquid manures resulted in significantly higher green onion yield and economics of drip irrigated (0.6 PE) onion, than crop fertilized with recommended nitrogen through chemical fertilizer either with or without recommended FYM and surface irrigated with water depth of 5 cm. In surface irrigated onion (5 cm water depth), application of recommended nitrogen through chemical fertilizer along with application of recommended FYM resulted in significantly higher green onion yield (37.01 %), gross returns (37.02 %), net returns (61.72 %)

Table 2.26 : Interaction effect of irrigation interval and fertigation frequency on gross returns, net returns and B: C ratio of brinjal during 2014

Fertigation frequency	Irrigation interval (days)		
	One	Two	Three
Gross returns (Rs ha^{-1})			
Once a week	1,33,000	1,61,750	1,60,750
Twice a week	1,65,550	1,46,500	1,56,750
Twice a month	1,69,000	1,78,500	1,62,250
CD (P = 0.05)	14,463		
Net returns (Rs ha^{-1})			
Once a week	56,288	85,451	84,526
Twice a week	88,713	69,901	80,338
Twice a month	92,476	1,02,351	86,176
CD (P = 0.05)	14,463		
B: C ratio			
Once a week	0.73	1.12	1.11
Twice a week	1.16	0.91	1.05
Twice a month	1.21	1.34	1.13
CD (P = 0.05)	0.19		

and B:C ratio (42.71 %) than application of recommended nitrogen through chemical fertilizer. In crop raised under drip irrigation (0.6 PE), substitution of 100 per cent of recommended N with locally prepared liquid manure which was enriched with 1 per cent liquid bio-fertilizer (E100) resulted in highest green onion yield, gross returns, net returns and B:C ratio . However, the values so obtained were at par with values obtained with substitution of 100 per cent of recommended N with locally prepared liquid manure (L100) and substitution of 75 per cent of recommended N with locally prepared liquid manure and enriched with 1 per cent liquid bio-fertilizer (E75U25).

Water use Efficiency

In surface irrigated onion (5 cm water depth), application of recommended N through chemical fertilizer along with application of recommended FYM resulted in significantly higher water use efficiency than application of recommended N through chemical fertilizer due to significantly higher green onion yield in the former treatment.In crop raised under drip irrigation (0.6 PE), substitution of 100 per cent of recommended N with locally prepared liquid manure which was enriched with 1 per cent liquid bio-fertilizer (E100) resulted in highest WUE. However, substitution of 100 per cent of recommended N with locally prepared liquid manure (L100), substitution of 75 per cent of recommended N with locally prepared liquid manure enriched with 1 per cent liquid bio-fertilizer (E75U25), substitution of 100 per cent of recommended N with Banana pseudo stem sap (B100) and substitution of 75 per cent of recommended N with locally prepared liquid manure (L75U25) resulted in statistically similar WUE.

2.12 Parbhani

2.12.1 Response of drip irrigated turmeric crop to different levels of irrigation and fertigation.

Significantly highest fresh rhizome yield was obtained with irrigation at 0.8 PE (295.7 q/ha)and was at par with irrigation at 1 PE (291 q/ha). Lowest irrigation level of 0.6 PE gave lowest fresh rhizome yield (259.9 q/ha).Highest fertigation level of 120 % RDF (240:120:120 NPK kg/ha) gave significantly more fresh rhizome yield(325.7 q/ha) than rest of the lower levels of fertigation, however it was at par with fertigation level of 100 % RDF(305.3 q/ha). RDF through soil application (200:100:100 NPK kg/ha) recorded significantly lower fresh rhizome yield (231.5 q/ha) than rest of the fertigation level.Significantly highest GMR(Rs406560) and NMR(Rs277617) was noted with irrigation at 0.8 PE than rest of the lower irrigation levels, however it was comparable with irrigation at 1 PE in the first year of experimentation. Lowest irrigation level of 0.6 PE recorded significantly lowest GMR and NMR.Highest level of fertigationi.e. 120% RDF (240: 120 : 120 NPK kg/ha) gave maximum GMR (Rs447837) and NMR (Rs304296) and was significantly more than lower levels of fertigation except 100% RDF (200:100:100 NPK kg/ha). RDF through soil application recorded significantly lowest GMR and NMR.Water use efficiency of 637 kg/ha.cm was observed with irrigation at 0.6 PE and it was gradually decreased with increase in irrigation level. Lowest WUE of 345 kg/ha.cm was recorded with irrigation at 1.2 PE.Highest fertigation level of 120% RDF (240:120:120 NPK kg/ha) noted highest WUE (532 KG/HA.CM) and it was gradually decreased with each decreased level of fertigation. RDF through soil application showed lowest WUE of 378 kg/ha.cm

2.12.2 Water Management in Soybean-Chickpea cropping system through sprinkler method.

Soybean seed and straw yield was not significantly influenced by sprinkler method and average soybean yield obtained was 1717 kg/ ha.Significantly highest seed yield was obtained with three sprinkler irrigations at grand growth + flowering + pod formation stage (2973 kg/ha) than rest of the irrigation treatments in case of gram , however it was comparable with two sprinkler irrigations at flowering + pod formation stages (2860 kg/ha). Significantly lowest seed yield was recorded with only one irrigation at grand growth stage (2219 kg/ha) by sprinkler and was at par with only one sprinkler irrigation at flowering (2331 kg/ha) or pod formation stage (2443 kg/ha). Average GMR and NMR recorded from soyabean were 54710 and 31352 Rs/ha, respectively.In case of gram, significantly highest GMR and NMR was recorded with three sprinkler irrigations at grand growth + flowering + pod formation stage than rest of the irrigation treatments , however it was comparable with two sprinkler irrigations at flowering + pod formation stage. Highest water use efficiency was obtained with sprinkler irrigation at pod formation stage (194 kg/ha.cm) followed by sprinkler irrigation at flowering (185 kg/ha.cm). Lowest WUE was noted with three surface irrigations at grand growth + flowering + pod formation stage.

Another experiment on effect of mulching and drip irrigation on growth and yield of water melon.

Was carried out by the centre during the reporting period. During growth period of water melon, irrigation was applied through drip irrigation system having inline dripper of 2.4 lph discharge. The irrigation was applied daily on the basis of daily pan evaporation at 0.6 PE (I_1), 0.8 PE (I_2) and 1.0 PE (I_3). The depth of water applied at irrigation levels I_1, I_2 and I_3 was measured as 257.22, 342.96 and 428.70 mm respectively. The effective rainfall of 101.50 mm was received during crop growing season which was considered while scheduling irrigation.The growth parameters like length of longest vine and number of leaves on longest vine were recorded under different mulching treatments. All these growth parameters were affected by the various mulching treatments. Length of longest vine and number of leaves of longest vine were found maximum in case of black polythene mulch followed by transparent polythene mulch and soybean straw mulch. The minimum values of growth parameters were observed in un-mulched control plot.

Table2.27 : Yield of water melon as influenced by irrigation levels (Summer 2014)

Sr. No.	Treatment	Water melon yield (q ha^{-1})
1	I_1 – Irrigation at 0.6 PE	75.89
2	I_2 – Irrigation at 0.8 PE	96.51
3	I_3- Irrigation at 1.0 PE	94.67
	SE ±	3.02
	CD at 5%	8.97

From the above table it is revealed that water melon yield is affected by different irrigation levels. Irrigation at 0.6 PE (I_1) recorded lowest yield i.e. 75.89 q/ha whereas highest yield i.e. 96.51 q/ha was recorded when irrigation was applied at 0.8 PE. The application of irrigation at 1.0 PE recorded 94.67 q/ha. water melon yield. Results of the analysis of yield data further revealed that treatment I_2 (0.8 PE) recorded significantly higher yield over treatment I_1. However yield recorded in treatment I_3 (1.0 PE) was found to be at par with treatment I_2. Maximum water melon yield obtained in treatment I_2 indicates that water melon crop should be irrigated at 0.8 PE rather than at 0.6 PE and 1.0 PE. Lowest water melon yield was obtained in treatment I_1.

2.12.3 Effect of different mulches on yield of water melon.

Black polythene mulch, transparent polythene mulch and soybean straw mulch were used to study the effect of different mulches on yield of water melon. The thickness of black and transparent polythene mulch was 30 micron. The soybean straw mulch was applied at the rate of 5 t/ha. The water melon yield obtained from different mulching treatments and control plot is presented in Table.2.28

Table 2.28 : Yield of water melon as influenced by different mulching treatments

Sr. No.	Treatment	Water melon yield (q ha^{-1})
1	M_1 - Black polythene mulch	121.64
2	M_2 - Transparent polythene mulch	96.43
3	M_3 - Soybean straw mulch	75.53
4	M_4 - Control	62.49
	SE ±	3.45
	CD at 5%	10.24

Yield data recorded under different mulches indicated that black polythene mulch recorded maximum yield i.e. 121.64 q/ha which was followed by transparent polythene mulch, soybean straw mulch. Lowest yield i.e. 62.49 q/ha was recorded from the unmulched plot (M_4). It is thus concluded that black polythene mulch gave significantly higher yield over the rest of the treatments.

Table 2.29: Yield parameters as influenced by irrigation regimes and fertilizer levels under turmeric

Treatment	Weight of rhizomes (kg $plant^{-1}$)				Fresh yield(q ha^{-1})				Dry yield (q ha^{-1})			
	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled
a) Irrigation regimes												
1. Drip irrigation at 0.5 C.F.	1.66	0.61	0.67	0.98	229.92	225.00	298.28	245.51	45.98	45.17	59.66	50.27
2. Drip irrigation at 0.7 C.F.	3.60	0.90	0.89	1.80	274.80	251.38	347.61	291.27	54.96	50.02	69.52	58.17
3. Drip irrigation at 0.9 C.F.	2.49	0.60	0.94	1.34	251.03	244.80	325.72	273.85	50.21	48.96	65.14	54.77
SE±	0.14	0.019	0.03	0.08	8.31	2.47	9.26	9.10	1.66	0.53	1.85	1.47
CD at 5%	0.56	0.075	NS	0.26	32.42	9.72	3.36	28.05	6.48	2.11	7.27	4.52
b) Fertilizer levels												
1. 100% GRDF – Conventional fertilizer	2.51	0.71	0.82	1.35	251.37	229.88	323.89	268.38	50.27	45.98	64.78	53.68
2. 100%GRDF – P and K basal C.F & N through drip	2.74	0.74	0.87	1.45	262.25	242.89	339.67	277.90	52.45	48.58	67.93	56.32
3. 100% GRDF – through W.S.F.	3.93	0.88	1.16	1.99	300.93	281.00	387.44	319.42	60.19	56.20	77.49	64.62
4. 75% GRDF – through W.S.F.	3.25	0.77	1.01	1.68	274.75	278.19	364.78	302.20	54.95	55.47	72.96	61.12
5. 50% GRDF – through W.S.F	2.31	0.67	0.73	1.24	254.60	238.05	305.00	265.88	50.92	47.61	61.00	53.18
6. No fertilizers	0.76	0.45	0.42	0.55	167.62	172.36	222.44	187.48	33.52	34.47	44.49	37.50
SE±	0.090	0.08	0.05	0.07	5.15	2.41	11.41	8.13	1.03	0.51	2.28	1.47
CD at 5%	0.25	0.23	0.16	0.21	14.88	6.97	32.95	22.86	2.98	1.50	6.59	4.14
Surface irrigation- control	2.70	0.50	0.52	0.57	260.67	192.71	285.51	229.53	42.07	38.54	57.10	45.90
Interaction	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.
Mean	2.60	0.70	0.84	1.37	251.92	240.40	323.87	270.21	50.38	48.05	64.77	54.40

Table2.30 : Fertilizer use efficiency and Curcumin content in turmeric crop as influenced by irrigation regimes and fertilizer levels

Treatment	FUE (kg kg^{-1})				Curcumin (%)			
	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled
a) Irrigation regimes								
1. Drip irrigation at 0.5 C.F.	3.11	2.42	3.79	3.11	4.98	4.56	5.72	5.09
2. Drip irrigation at 0.7 C.F.	5.36	4.09	6.26	5.24	5.13	4.98	5.10	5.07
3. Drip irrigation at 0.9 C.F.	4.17	3.39	5.16	4.24	5.08	4.77	4.98	4.94
b) Fertilizer levels								
1. 100% GRDF – Conventional fertilizer	4.18	2.88	5.07	4.04	4.98	4.59	5.10	4.89
2. 100%GRDF – P and K basal C.F & N through drip	4.37	3.53	5.86	4.59	5.02	4.83	4.93	4.93
3. 100% GRDF – through W.S.F.	6.66	5.56	8.25	6.82	5.39	4.92	5.20	5.17
4. 75% GRDF – through W.S.F.	5.35	4.56	7.12	5.68	5.21	4.89	5.15	5.08
5. 50% GRDF – through W.S.F	4.35	3.29	4.12	3.92	5.14	4.79	5.10	5.01
6. No fertilizers	-	-	-	-	4.63	4.52	4.40	4.52
Surface irrigation- control	2.13	2.40	3.15	2.56	5.09	4.48	4.63	4.73

2.13. Rahuri

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

The pooled data on fresh yield of turmeric for three years (Table 2.29) concluded that the irrigation regime 0.7 C.F. recorded significantly highest yield (291.27 q ha^{-1}) being at par with the treatment 0.9 C.F. (273.85 q ha^{-1}) being higher than the surface irrigation (229.53 q ha^{1}). The fertilizer levels treatment with 100% GRDF through W.S.F. recorded significantly highest (319.42 q ha^{-1}) fresh yield, but was at par with the treatment 75% GRDF through W.S.F. (302.20 q ha^{-1}).The data on total water applied, WUE and saving are depicted in table 05 which revealed that the highest water was applied in surface irrigation treatment (227.43 cm) followed by the treatment with 0.9 C.F. (119.43 cm) through drip irrigation. The WUE was highest under the treatment with 0.5 C.F. (73.18 kg ha^{-1} cm) followed by 0.7 C.F. (70.12 kg ha^{-1} cm). The fertilizer level treatment with 100% GRDF through W.S.F. showed highest WUE (77.80 kg ha^{-1} cm) followed by the treatment with 75% GRDF through W.S.F. (71.95 kg ha^{-1} cm). The highest water saving was observed under the treatment with 0.5 C.F. followed by the treatment 0.7 C.F.The pooled data on curcumin content (Table 2.6.1b) revealed that the highest content was observed under the treatment 0.5 C.F. (5.09%) followed closely by the treatment 0.7 C.F. (5.07%). The treatment with 100% GRDF through W.S.F. recorded highest curcumin content (5.17%) followed by the treatment with 75% GRDF through W.S.F. (5.08%).

2.13.2 Effect of irrigation regimes on yield contributing characters, yield and monetary returns and water use efficiency of marigold.

It was noticed that significantly higher no. of flowers (56) and weight of flower plant^{-1} (0.26 g) was recorded when marigold crop was irrigated at 100% PE followed by irrigation at 80% PE it was at par with at 100% PE irrigation i.e. 55 no. of flower and 0.25 g weight of flower plant^{-1}, respectively.In case of yield, it was noticed that the marigold flower yield were significantly influenced due different irrigation regime. The irrigation given at 100% PE recorded the significantly higher flower yield (16.36 tha^{-1}) over other irrigation regime except irrigation given at 80% PE (15.42 tha^{-1}) was at par with 100% PE irrigation. The gross monetary return received from different irrigation regimes presented in (Table 2) from the table it is revealed that significantly higher gross monetary return were recorded (Rs. 5,29,962) when crop was irrigated

Table 2.31: Water applied and water use efficiency for summer marigold influenced by Various treatments

Treatment	Yield t ha^{-1})	Water applied (cm)	Effective rainfall (cm)	Total water applied (cm)	Water use efficiency (kg/ ha-cm)	Water saving (%)
A) Irrigation regimes (4)						
I_1 -Irrigation at 40 % PE	13.05	24.13	8.59	32.72	398.84	66.44
I_2 - Irrigation at 60 % PE	14.78	40.49	8.59	49.08	301.14	49.67
I_3 -Irrigation at 80 % PE	15.42	56.85	8.59	65.44	235.63	33.91
I_4- Irrigation at 100 % PE	16.36	73.20	8.59	81.79	199.29	16.12
B) Planting methods						
S_1 : 45 x 15 cm, lateral spacing 90 cm	14.54	51.54	8.59	60.13	241.80	38.33
S_2 : 30-60 x 15 cm, lateral spacing 90 cm	15.18	31.70	8.59	40.29	376.76	58.62
S_3 : 60x 10 cm, lateral spacing 120 cm	14.86	74.92	8.59	83.51	177.94	14.35
S_4 : 45-75 x10 cm, lateral spacing 120 cm	15.01	36.51	8.59	45.10	332.81	53.75
Control						
S_5 : 45 x 15 cm row spacing under surface irrigation (irrigation will be applied as critical growth stages)	12.30	88.91	8.59	97.50	125.56	-
S_6 : 45 x 15 cm row spacing under surface irrigation (Irrigation will be applied at 75 mm CPE at 7.5 cm depth)	12.45	88.91	8.59	97.50	127.69	-

at 100% PE irrigation regimes over other irrigation regimes. The next in order of sequence was treatment I_3 (Rs. 4,99,487ha^{-1}.). Same trend was observed in case of net monitory returns, it revealed from the table that significantly higher net monetary returns were recorded (Rs. 1,43,625ha^{-1}) when crop was irrigated at 100% PE irrigation regimes (I_4)over other regimes. Except treatment I_2, (irrigation at 60% PE) was at par (Rs. 1,31,301ha^{-1}) with treatment I_4. Incase B:C ratio it was observed that, significantly higher B:C ratio was recorded (1.37) when crop was irrigated at 100% PE over other treatment (I_4).Table 3 revealed that maximum water requirement was noticed (81.79 cm) when crop was irrigated with 100% PE. whereas minimum water requirement was noticed (32.72 cm) when crop was irrigated at 40% PE. The reverse trend was noticed in case of water use efficiency. Higher water use efficiency was noticed 398.84 kg/ha-cm when crop was irrigated at 40% PE and lowest was 199.29 kg/ha-cm when crop was irrigated at 100% PE. In case of water saving it was noticed that maximum water saving 66.44% at 40% PE irrigation regime and minimum at 16.12% at 100% PE irrigation regime.

2.13.3 Effect of irrigation regimes on sorghum growth, yield contributing characters, yield monetary returns and water use efficiency.

Sorghum grain (35.22 q ha^{-1}) and fodder yield (7.64 tha^{-1}) were recorded maximum when sorghum crop was irrigated at 100% ETc followed by 80% ETc in case of grain yield 33.99 q$ha^{-1}$and in case fodder yield 7.22 t ha^{-1} at 90% ETc.Interaction effect of planting method and irrigation regimes on fodder was found significant. The combination S_4 x I_4 i.e. paired planting at 45-75 x 10 cm x 100% ETc irrigation recorded significantly higher fodder yield i.e. 8.35 t/ha except $S_1 I_4$, S_3 x I_2, S_3 x I_3 and S_2 x I_4 combination were at par with S_4 x I_4 (i.e. 8.15, 7.57, 7.93 and 7.62 t/ha respectively). Same trend was observed in table 6 case of gross monetary returns and net monetary return (Rsha^{-1}) and B:C ratio also. Maximum and higher gross monetary returns (Rs. 1,04,917, net monetary returns Rs. 68,792ha^{-1}

Table 2.32 : Effect of irrigation regimes and planting methods on yield and monetary returns of rabi sorghum

Treatment	Grain yield (q/ha)	Fodder yield (t/ha)	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
A) Irrigation regimes (4)						
I_1- Irrigation at 70 % ETc	30.95	6.53	-	90964	52759	2.38
I_2- Irrigation at 80 % ETc	33.99	6.94	-	99074	60864	2.59
I_3 - Irrigation at 90 % ETc	33.90	7.22	-	98533	62408	2.72
I_4 - Irrigation at 100 % ETc	35.22	7.84	-	104917	68792	2.90
SE +	1.95	0.33	-	5243	5600	0.14
CD 5%	NS	NS	-	NS	NS	NS
B) Planting methods						
S_1 : 45 x 15 cm, lateral spacing 90 cm	32.04	7.16	38210	94893	56683	2.48
S_2 : 30-60 x 15 cm, lateral spacing 90 cm	35.95	6.97	38210	104171	65961	2.72
S_3 : 60x 10 cm, lateral spacing 120 cm	32.55	7.22	36125	96909	60784	2.68
S_4 : 45-75 x10 cm, lateral spacing 120 cm	32.91	7.17	36125	97519	61394	2.69
SE +	0.89	0.15	-	2178	2178	0.06
CD 5%	2.56	NS	-	6245	6245	0.16
Interaction	NS	Sig.	-	NS	NS	NS
Control						
S_5 : 45 x 15 cm row spacing under surface irrigation (irrigation will be applied as critical growth stages)	28.30	5.50	30983	81510	50527	2.63
S_6 : 45 x 15 cm row spacing under surface irrigation (Irrigation will be applied at 75 mm CPE at 7.5 cm depth)	29.10	5.60	30983	83620	52637	2.69

and B:C ratio 2.90) were recorded when sorghum crop was irrigated at 100% ETc irrigation followed by 80% ETc irrigation (Rs. 99,074ha^{-1}) but in case of net monetary returns and B:C ratio (Rs. 62408ha^{-1} and 2.72 respectively) at 90% ETc recorded maximum value.Data in respect of water study was presented in (Table 2.32). It was revealed from the table that maximum water requirement was noticed (20.97 cm) when crop was irrigated at 100% ETc regime where as minimum water requirement was noticed (14.67 cm) when crop was irrigated was 70% ETc regime. The reverse trend was observed in case of WUE in respect of both grain and fodder. The maximum WUE was noticed at 80% ETc irrigation level in case of grain 215.54 kg/ha-cm and in case of

Table 2.33 : Total water requirement of Bt. cotton as influenced by different treatments

Treatments	Water Requirement									
	Surface Irrigation					Drip irrigation				
	Yield ($Kgha^{-1}$)	Water applied (cm)	Effective rainfall (cm)	Total water applied (cm)	WUE ($Kgha^{-1}$ –cm)	Yield ($Kgha^{-1}$)	Water applied (cm)	Effective rainfall (cm)	Total water applied (cm)	WUE ($Kgha^{-1}$ –cm)
T_1: N application in 3 splits (33% at sowing, 33% 30 DAS and 34% 60 DAS)	36.34	75	10.64	85.64	42.43	41.52	38.55	17.2	55.75	74.48
T_2: N application in 3 splits (20% at sowing, 40% 30 DAS and 40% 60 DAS)	33.65	75	10.64	85.64	39.29	39.49	38.55	17.2	55.75	70.83
T_3: N application in 4 equal splits (at sowing, 30, 45 and 60 DAS)	42.09	75	10.64	85.64	49.15	40.77	38.55	17.2	55.75	73.13
T_4: N application in 5 equal splits (at sowing, 30, 45, 60 and 75 DAS)	44.32	75	10.64	85.64	51.75	47.19	38.55	17.2	55.75	84.65
T_5: N application in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS)	51.65	75	10.64	85.64	60.31	55.92	38.55	17.2	55.75	100.30
T_6: T_1 + foliar application of 2% urea at 60, 75 and 90 DAS	41.00	75	10.64	85.64	47.87	40.50	38.55	17.2	55.75	72.65
T_7: T_1 + foliar application of 2% KNO_3 at 60, 75 and 90 DAS	46.10	75	10.64	85.64	53.83	51.74	38.55	17.2	55.75	92.81
T_8: T_2 + foliar application of 2% urea at 60, 75 and 90 DAS	39.56	75	10.64	85.64	46.19	39.48	38.55	17.2	55.75	70.82
T_9: T_2 + foliar application of 2% KNO_3 at 60, 75 and 90 DAS	39.32	75	10.64	85.64	45.91	43.73	38.55	17.2	55.75	78.44
Total water saving of 35% was achieved due to drip irrigation over surface irrigation										

fodder it was maximum at 70% ETc irrigation required 445.10 kg/ha-cm. Further it was observed that maximum water saving was noticed at 70% ETc (67.40%) and minimum at 100% ETc 53.40%).

2.13.4 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 water saving of 35% could be achieved as well as the reddening intensity was also low. 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.

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

Regarding yield of bulbof onion, the treatment with drip irrigation at alternate day recorded highest fresh bulb yield of 36.67 t ha^{-1} compared to surface irrigation 25.56 t ha^{-1}. The INM treatment RDF + FYM has recorded the significantly highest fresh bulb yield of 41.24 t ha^{-1}, while lowest was recorded in the control treatment 16.57 tha^{-1}. The next treatment followed by RDF + FYM was RDF + Vermi compost which recorded 36.47 t ha^{-1} of fresh onion. The interactions are nonsignificant and the average yield of fresh onion is 31.31 t ha^{-1}.The data pertaining to water applied, WUE and saving is depicted in table 08, which revealed that the amount of total water applied was lowest under drip irrigation and alternate day on ETc (52.62 cm), followed by micrisprinkler treatment (58.48 cm), highest being recorded under the surface irrigation (100 cm). The WUE was recorded lowest in surface while highest in drip irrigation followed by microsprinkler irrigation. The saving of water was highest in the drip irrigation (47.37%) followed by microsprinkler (41.52%) under INM treatments the total water applied was 70.37 cm for all the treatments. The WUE was recorded highest by the treatment RDF + FYM followed by the treatment RDF + Vermi compost, lowest being recorded by control treatment. The overall water

Table 2.34 : Water applied and water use efficiency for onion crop as influenced by irrigation regimes and fertilizer levels

Treatment	Yield (tha^{-1})	Water Applied (cm)	Effective rainfall (cm)	Total water applied (cm)	Water use efficiency (kg ha^{-1} cm)	Water saving (%)
a) Irrigation methods						
I_1. Drip irrigation at alternate day as perETc	36.67	52.63	-	52.63	697	47.37
I_2. Micro sprinkler irrigation at alternateday as per ETc	31.87	58.48	-	58.48	545	41.52
I_3. Surface irrigation at 50 mm CPE	25.56	100.00	-	100.00	256	-
b) INM235						
S_1. Control	16.57	70.37	-	70.37	235	29.63
S_2. RDF through NPK	28.01	70.37	-	70.37	398	
S_3. AST (As per Soil Test)	33.91	70.37	-	70.37	482	
S_4. RDF through NPK + FYM @ 10 t ha^{-1}	41.24	70.37	-	70.37	586	
S_5. RDF through NPK + PMC (on the basis of N content of FYM)	32.02	70.37	-	70.37	455	
S_6. RDF through NPK + Vermicompost (onthe basis of N content of FYM)	36.46	70.37	-	70.37	518	

Table 2.35. Effect of different irrigation treatments on water use and expense efficiency (Average of 3 years)

Treatments	Effective rainfall (mm)	Irrigation water applied (mm)	Total water use (mm)	WUE (kg/ha mm)
0.5 IW/CPE (3)	137.97	260.00	397.97	133.53
0.7 IW/CPE (4)	137.97	320.00	457.97	140.03
0.9 IW/CPE (5)	137.97	380.00	517.97	143.02
1.1 IW/CPE (6)	137.97	460.00	597.97	129.91
Control (Surface irrigation) (4)	137.97	492.00***	629.97	101.63

*Including pre sowing irrigation (100 mm),
** Figures in parenthesis indicate the number of irrigations applied ,
*** including convinces losses (25%)

Table 2.36 Response of different treatments on Yield attributes of Sorghum

	Green fodder Yield (q/ha)			
Treatments	2012	2013	2014	Pooled
0.5 IW/CPE	625.50	350.42	618.33	531.42
0.7 IW/CPE	750.19	423.68	750.00	641.29
0.9 IW/CPE	850.36	493.19	878.89	740.81
1.1 IW/CPE	942.43	542.50	845.56	776.83
Control (Surface irrigation)	860.23	495.00	565.56	640.26
SED	43.58	31.04	30.52	44.25
CD	94.96	67.63	66.49	96.42
	Dry fodder Yield (q/ha)			
0.5 IW/CPE	111.87	75.36	155.82	114.35
0.7 IW/CPE	129.98	99.92	179.25	136.38
0.9 IW/CPE	147.44	122.99	168.75	146.39
1.1 IW/CPE	160.65	126.16	191.10	159.30
Control (Surface irrigation)	150.60	121.62	146.48	139.57
SED	7.146799	5.454703	7.404645	8.367658
CD	15.57287	11.8858	16.13472	18.23313
	Oven dry fodder Yield (q/ha)			
0.5 IW/CPE	106.43	73.93	148.25	109.54
0.7 IW/CPE	123.51	98.53	170.32	130.79
0.9 IW/CPE	140.01	121.78	160.24	140.68
1.1 IW/CPE	151.70	123.30	180.45	151.82
Control (Surface irrigation)	145.36	119.85	141.38	135.53
SED	6.781818	5.340689	7.074616	8.018244
CD	14.77758	11.63736	15.41559	17.47175

saving was to the tune of 29.63% in INM treatments. This gives us the idea that use of micro irrigation methods saves water as well as increases yield of the crops.

2.14 Sriganganagar

2.14.1 Optimum irrigation schedule for fodder sorghum under sprinkler irrigation system

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 (740.81 q/ha). Further increase in irrigation level increased fodder yield non-significantly. Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum.The water expense efficiency was higher in I_3 treatment (IW/CPE 0.9) followed by I_2 treatment (IW/CPE 0.7) as compared to rest of irrigation treatments tested in the study.Under sprinkler irrigation the highest B:C ratio 2.78 was observed when sprinkler irrigation was scheduled at IW/CPE 0.9 & 1.1. The maximum B:C ratio 3.84 was recorded under flood irrigation. The highest incremental benefit cost ratio was recorded when sprinkler irrigation was scheduled at IW/CPE 0.9.

2.14.2 Irrigation scheduling for fodder oat through sprinkler

The green forage yield of oat was influenced by the level of irrigation significantly during all the three years and in pooled data. The maximum green forage yield was recorded when irrigation was applied at IW/CPE 1.1 and it was at par with that recorded with IW/CPE 0.9 during 2011-12 but significantly superior to all treatments during

Table 2.37 : Response of different treatments on yield and yield attributes of oat (Pooled 2011-12 to 2013-14)

Treatments	Plant Height (cm)	Plant Population (1m length)	Green fodder yield (q/ha)	Dry fodder Yield (q/ha)	Oven dry fodder yield (q/ha)
IW/CPE 0.5	103.37	122.83	620.00	123.45	108.06
IW/CPE 0.7	109.77	122.00	648.33	130.76	110.34
IW/CPE 0.9	111.53	120.83	690.00	133.68	112.96
IW/CPE 1.1	117.23	123.50	757.50	148.37	123.41
Flood	109.95	121.08	640.83	127.03	104.05
S Ed	2.46	2.29	28.24	7.63	8.92
CD at 5%	5.67	NS	65.13	17.60	NS

Table 2.38: 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)
I1 = 0.6 ETc through drip (LT)	177.1	303.6	480.7	72.091
I2 = 0.8 ETc through drip (LT)	177.1	397.6	574.7	63.973
I3 = 1.0 ETc through drip (LT)	177.1	492.2	669.3	65.242
I4 = 1.2 ETc through drip (LT)	177.1	563.2	740.3	59.660
I5 = 1.0 ETc through drip (WLT	177.1	547.5	724.6	23.708
I6 = Control (Surface irrigation at IW/CPE 1.0)	177.1	940.0	1117.1	11.184

Table 2.39 : Effect of drip irrigation on the Yield attributes of chilli

Treatments	Initial Plant Population/ha	Final plant Population/ha	Fruit yield (kg/plant)	Fruit yield (Q/ha)
0.6Etc (LT)	21728.40	20925.93	1.66	346.54
0.8Etc(LT)	21666.67	20925.93	1.76	367.65
1.0Etc(LT)	21666.67	20925.93	2.09	436.67
1.2Etc(LT)	21296.30	20740.74	2.13	441.67
1.0Etc(WLT)	21481.48	20864.20	0.82	171.79
Control (LT)	21111.11	20802.47	0.60	124.94
SEd	275.54	327.92	0.14	27.03
CD	600.41	NS	0.30	58.90

2012-13, 2013-14 and in pooled data. Thus, sprinkler irrigation to oat at IW/CPE 1.1 was found optimum irrigation schedule. The maximum water use efficiency of 309.58 kg/ha mm was recorded with thetreatment IW/CPE 0.9. The highest benefit cost ratio of 3.35 was recorded when sprinkler irrigation was scheduled at IW/CPE 1.1 as against 3.19 in surface irrigation method. The incremental benefit cost ratio worth 5.56 was recorded in sprinkler irrigation at IW/CPE 1.1.

2.14.3. Irrigation scheduling in winter planted chilli under low tunnels in cotton based drip irrigation system

On the basis of experimentation, the water expense efficiency was higher in the drip-irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 72.091 kg/ha mm was recorded under I_1 (0.6 Etc by drip system), followed by 65.242 kg/ha mm under I_3 (1.0 Etc by drip system) treatment. (Table 2.38).On the basis of experimentation it may be concluded that, the fruit yield of chilli increased with increase in the level of applied water up to 1.2 ETc with low tunnel. The fruit yield of chilli (436.67 q/ha) was recorded with drip irrigation at 1.0 ETc (LT) was statistically at par with that of 1.2Etc (LT) (441.67 q/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 249.5 % higher fruit yield of chilli and saved 36.08 % irrigation water over conventional surface irrigation and 154.19 % higher fruit yield of chilli and saved 7.6 % irrigation water over 1.0 ETc without low tunnel.

2.14.4. Response of chilli to fertigation

Different fertilizer treatments significantly influenced chilli yield. The maximum chilli yield was recorded with 120 % RD and it out yielded rest of the treatments. The minimum chilli yield was recorded under flood irrigation treatment. Thus, 120 per cent recommended dose of fertilizer in 9 equal splits each at an interval of 15 days was found optimum dose for fertigation in chilli.

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

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.The maximum fruit yield of tomato (626.60 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). Thus drip irrigation at 0.8 Etc (LT) was found optimum irrigation schedule for tomato. It gave 51.24 % higher fruit yield and saved 25.72 % irrigation water over drip irrigation at 1.0 Etc (Without Low Tunnel) and 101.5 % higher fruit yield and saved 79.08% irrigation water over conventional surface irrigation.A post transplanting irrigation of 100 mm in surface method and in drip irrigation treatments the drip was operated for 5.5 hr in December to ensure good establishment of seedlings. Remaining irrigations were applied as per treatment.On the basis of three year of experimentation, it was observed that the maximum water (935.0 mm) was used in surface irrigation treatment and the least water (425.8 mm) was used in 0.6 ETc treatments.The water expense efficiency was higher in the drip-irrigated with low tunnel treatments as compared to flood irrigation and drip-irrigated without low tunnel treatments. The maximum water expense efficiency of 121.67 kg/ha mm was recorded under I_1 (0.60 Etc by drip system with low tunnel), followed by 115.5 kg/ha mm under I_2 (0.8 Etc by drip system with low tunnel).

Table 2.40: Plot wise fruit yield of tomato under different treatments

Treatments	Plot wise yield of tomato (kg / plot)			
	R_1	R_2	R_3	Total
0.6 Etc (LT)	113.50	106.40	101.10	321.00
0.8 Etc (LT)	146.80	106.90	111.00	364.70
1.0 Etc (LT)	148.40	140.30	129.60	418.30
1.2 Etc (LT)	142.40	152.10	125.50	420.00
1.0 Etc (WLT)	100.00	97.70	98.60	296.30
Control	102.10	88.90	84.40	275.40
Total	**753.20**	**692.30**	**650.20**	**2095.70**

Theme III

Management of rain water for judicious use and to develop and evaluate groundwater recharge technologies for augmenting groundwater availability under different hydrogeological conditions.

3.1 Ludhiana

3.1.1 Rainwater harvesting in agricultural fields

The feasibility study of rainwater harvesting through agricultural fields is continued by Ludhiana centre in three sites by modifying the abandoned wells. Two abandoned wells were selected for recharge through agricultural field and recharge structures were installed at different locations for rainwater harvesting. At third site, earthen channel was available where a pit was excavated upto 3 m depth. In all the three sites, water table decline sharply upto July then it start rising till December month. After that it again start declinig.It has been observed that rate of water fall is greater than the rate of rise.

Groundwater recharge

The recharge rate for all the sites were monitored during/after rainfall and represented in Fig. 3.1 to Fig. 3.2. The recharge rate varies with time. Initially the recharge rate was as high as 66.32 l/min where as it reduces to 10.72 l/min in six hours and 30 minutes duration with the average head difference of 3.87 m at site 1. At site 2, the recharge rate in the abandon well varied from 121.9 l/min to 54.18 l/min for first one hour, 39.99 l/min to 19.35 l/min for second hour and 16.77 l/min to 3.87 l/min thereafter for next five hours with the average head difference of 1.40 m. At site 2, the recharge rate in cemented pit varied from 42.57 l/min to 5.80 l/min for six hours duration with the head difference of 2.55 m. At site 3, the recharge rate varied from 19.27 l/min to 1.91 l/min in four hour duration with the head difference of 1.49 m. Watertable fluctuation at all the three sites is presented in Fig. 3.3.

The groundwater and soil sample quality were tested for pre monsoon, during monsoon and post-monsoon for insecticides namely organochlorines, organophosphates and synthetic pyrethroids and also for the herbicides and found to be below determination limit. The EC and RSC were also observed at all the three sites for all the three seasons i.e. pre monsoon, monsoon and post monsoon. It has been found that EC at Site 1, Site 2 and Site 3 varied from 0.60 to 1.273, 0.50 to 1.400 and 0.54 to 1.015 dS/m whereas for soil samples in abundant dry wells in Site 1 and Site 2 varied from 0.278 to 0.875 and 0.188 to 0.920 dS/m, respectively. So in all three seasons the salinity remains within permissible limit. The trend in RSC values found erratic which need to be monitored closely for next monsoon season.

The recharge rate for all the sites were monitored during/after rainfall and represented in Fig. 3.1 to Fig. 3.3.The recharge rate varies with time. Initially the recharge rate was as high as 66.32 l/min where as it reduces to 10.72 l/min in six hours and 30 minutes duration with the average head difference of 3.87 m at site 1. At site 2, the recharge rate in the abandon well varied from 121.9 l/min to 54.18 l/min for first one hour, 39.99 l/min to 19.35 l/min for second hour and 16.77 l/min to 3.87 l/min thereafter for next five hours with the average head difference of 1.40 m. At site 2, the recharge rate in cemented pit varied from 42.57 l/min to 5.80 l/min for six hours duration with the head difference of 2.55 m.At site 3, the recharge rate varied from 19.27 l/min to 1.91 l/min in four hour duration with the head difference of 1.49 m.

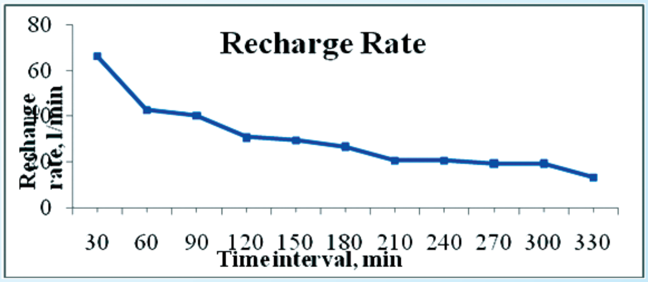


Fig 3.1. Recharge rate at Site 1 on 28.07.15 fore noon

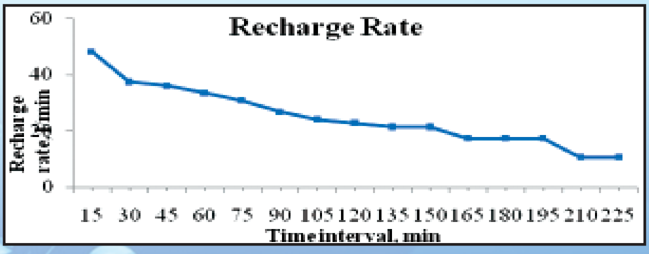


Fig 3.2 Recharge rate at Site 1 on 28.07.15 after noon

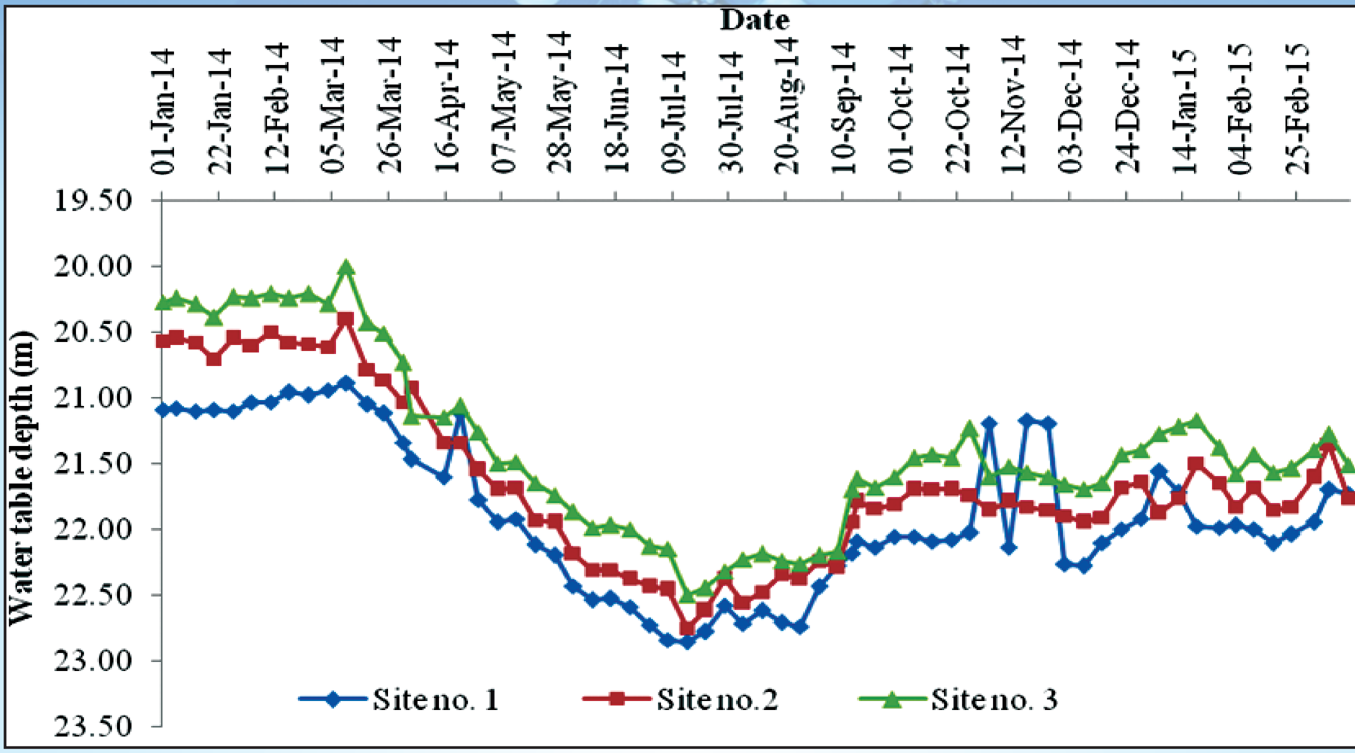


Fig. 3.3. Water Table depth at different sites during 2014-15

The recharge structures were improved and observation wells were developed to increase the porosity and permeability of the water bearing formation in the vicinity of the well by removing finer material of aquifer.

3.2 Coimbatore

3.2.1 Groundwater balance to assess the quantity of water available for development in the Amaravathy basin

Amaravathy basin has a catchment area of 8280 square kilometer constituting four districts viz., Coimbatore, Dindigul, Karur and Tiruppur in Tamil Nadu. Thematic maps of the basin (Soil, geology, Lineament density, drainage density, Geomorphologic, slope, land use and land cover map) (Fig .3.4, 5.5 and 3.6) were generated and the information are used for decision making process of identification of potential zones of ground water recharge and development. About 24 rain gauge stations were available and the rainfall data of forty years were analyzed and the average annual rainfall of the basin is 1009.8 mm and more number of normal years was observed at the head end of basin and number of deficit years was high in the tail end. The recharge was estimated using the empirical formulas range from 17 to 30 %. The number of blocks in the basin is 33, out of which 16 were over exploited, 2-critical, 12- semi critical and remaining blocks are safe.

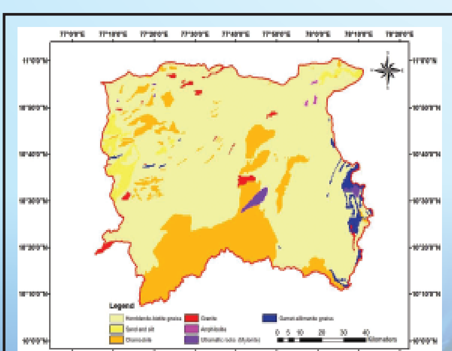


Fig 3.4. Geological map of Amaravathy basin

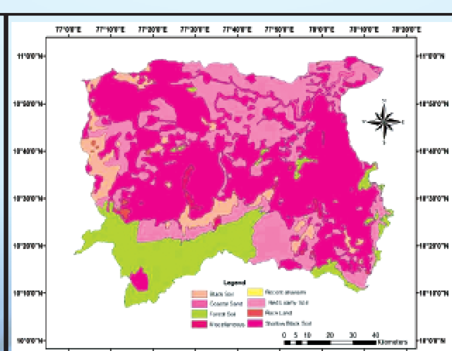


Fig 3.5. Soil map of the basin

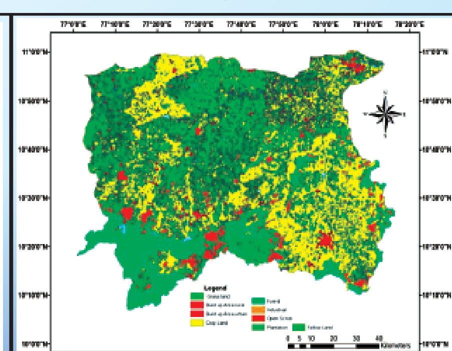


Fig 3.6. Landuse and Land cover map

3.2.2 Augmentation of ground water resources by artificial recharge structures and to identify the potential recharge zone using remote sensing and GIS in selected watershed of Amaravathi river basin

The potential recharge zones for Uppar Odai watershed south (4B2A7a2) of Amaravathi basin were identified .Thematic maps such as geology, geomorphology, land use/land cover, soil and slope map were prepared using Remote Sensing and GIS. Detail characteristics of each theme were studied in accordance with their response to artificial recharge process. After detailed study and criteria, ranking and weightage applied for suitable site selection for artificial recharge process, weighted overlay analysis was carried out. From the recharge zone map, five different rechargeable zones were identified, namely 'very good', 'good' 'moderate', 'poor', 'very poor' (Fig 3.7). The average annually exploitable groundwater reserve in the very good and good zone was estimated to be 15.7 %, whereas it is 61.7 % for the moderate zone and 22.62 % for the poor and very poor zone.

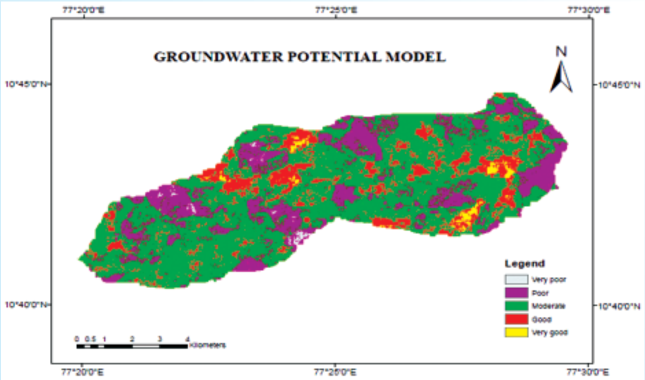


Fig 3.7. Groundwater Potential zone of Uppar Odai watershed

3.3. Udaipur

3.3.1 Impact assessment of low cost groundwater recharge structures constructed in hard rock regions of Southern Rajasthan

The designed and developed low cost structure has been constructed and assessed in terms of its effectiveness on groundwater recharging by AICRP Udaipur centre. The low cost groundwater recharging structures are very effective for augmenting groundwater table of hard rock aquifers. It is widely accepted among the community because of its cost effectiveness, easy in construction and high recharging potential as per the test conducted by AICRP Udaipur centre. This study is being conducted to assess the impact of low cost structures constructed by Govt. and NGOs under MGNREGA and watershed development programme in various districts of southern Rajasthan.

The low cost water harvesting structures constructed in Girwa block of Udaipur, Asapur block of Dungarpur and Kushalgarh block of Banswara have been identified to conduct the impact assessment study. The rainfall pattern of these districts shows almost similar pattern but the amount of rainfall is highest in Banswara followed by Dungarpur and Udaipur. The rainfall at 75% dependence level for Udaipur, Dungarpur and Banswara was found to be 455.6 mm, 500 mm and 574.6 mm respectively. The depth capacity curve of these identified structures will be prepared after conducting the topographical survey of the submergence area. The volume of recharge and recharge rate along with amount of harvested water used for providing life saving irrigation to the kharif crops will be determined.

3.3.2 Augmentation of groundwater resources through dugout ponds in Haroti Region of Rajasthan

In Haroti region of Rajasthan namely Bundi, Kota, Baran and Jhalawar district lot of percolation ponds (about 800) were constructed by the Department of Agriculture, Govt. of Rajasthan for augmenting groundwater table and also for providing life saving irrigation to the crop during longer dry spells The study is being conducted to standardize the size and also to determine the recharge rate and volume as well as increase in irrigation potential in the area.

Runoff generating capacity of catchment was calculated by SCS curve number method. The total catchment areas of three selected farm ponds were 4.6, 6.35 and 8.7 ha; in which clay loam soil was found in varying depths. The hydrologic conditions of these catchments were found to be good. The highest annual rainfall was recorded to be 1114 mm in 2013 which produced runoff of 293.27 mm whereas lowest rainfall was observed 323 mm in 2009 for which runoff was estimated to be 63.16 mm. The average rainfall and runoff estimation on the basis of ten years data was found to be 614.35 mm and 134.12 mm, respectively. The estimated annual runoff volume using curve number method on the basis of 10 years data for three selected ponds was found to be 6169.52 m^3, 8516.62 m^3 and 11668.44 m^3 respectively (Fig 3.8).

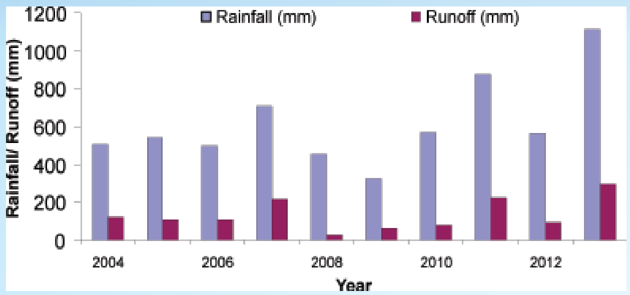


Fig 3.8. Rainfall-Runoff relationship for the area

The ponds constructed in the area do not have any relationship of runoff and catchment area and in each case; the runoff yield is quite high. The study reveals that there is need to design optimum size of farm pond after establishing the relationship between catchment size and runoff yield for black soils of Bundi district. A study was conducted to find out percolation through constructed farm pond of size 32 m x 32 m at top, 24 m x 24 m bottom and depth of 3 m. The groundwater recharge through dugout farm pond was determined. The average recharge rate was found to be 47 mm/day whereas net recharge volume was 2905 m^3.

3.4 Junagarh

3.4.1 Evaluation of groundwater recharge techniques for Junagadh region

Three groundwater recharge techniques namely check dam, recharge basin, groundwater recharge by roof water harvesting were evaluated by Junagadh centre during last monsoon season. Rainfall data analysis of Junagadh shows average annual rainfall of Junagadh is 937 mm, highest 2794 mm, lowest 146 mm and rainfall of 20, 15 and 10 years return periods are 1595 mm, 1533 mm and 1427 mm respectively. Also maximum, average, minimum and 15 years return period of rainy days are 76, 40, 13 and 54 recorded respectively.

Check dam at Instructional farm, college of Agricultural Engineering and Technology was considered for the evaluation of recharge. Resultant vertical flow velocity of geological formation below check dam after pounding was estimated at 0.0058 m/day. The occurrence of annual average runoff from catchment of check dam was determined 13094 cu.m, which occurs at two years return period so, that once in every two years run off excess was 2339 cu.m as recharge cum storage capacity of check dam was estimated 10755 cu.m, against run off 13094 cu.m, for more than two years return period there will always be excess runoff. Maximum and minimum runoff may occurs at 58 and 1 year return period, which may 122835 and 0 cu.m respectvely also runoff excess during these events were 112080 and 0 cu.m respectively. Runoff and excess runoff at 20 years return which is equal to efective life of checkdam were estimted 35664 cu.m and 24909 cu.m respectively. It is observed on the basis of daily water balance in year 2014, total recharge was 14420 cu.m, runoff escaped from check dam was 12582 cu.m, total runoff from catchment was 19997 cu.m. Total Water resource available from rainfall in hydrological unit (check dam catchment) was estimated 88017 cu.m. Structure cost on current rate basis was estimated Rs. 95000, so recharge cost goes to Rs. 0.33 per cu.m of recharge volume @ 20 years effective service of structure. Recharge per sq.m of catchment was observed 0.19 cu.m. Evaporation loss excluding stream flowing period was found 834 cu.m and during stream flowing period it was 3123 cu.m.

The recharge basin structure constructed at Instructional farm, College of Agricultural Engineering & Technology, Junagadh Agricultural University, Junagadh. The curve number technique was adopted for the estimation of annual runoff from catchment area of recharge basin. The maximum, average, minimum and 15 years return period of runoff were found 1830 mm, 253 mm, 0 mm, 516 mm respectively. The highest, average, lowest and 15 years return period of per day runoff were found 976 mm, 107 mm, 0 mm, 190 mm respectively. Recharge basin maximum storage capacity and maximum water spread area were estimated 3181 cu.m and 7057 sq. m respectively. During monsoon season total 33381 cu.m of runoff volume was generated from catchment area of recharge basin, out of that 15510 cu. m was trapped in to the basin and 17870 cu.m was escaped from the basin. Evaporation loss from the water storage of recharge basin was estimated as 657 cu.m. So, net recharge was 14853 cu.m. (water collected – evaporation loss). Cost of recharging is Rs. 0.12 per m^3 in Junagadh region under recharge basin technique, considering 15 years effective life of structure, where as cost of recharge basin was Rs.25500.

Plate 1. Water storage area of recharge basin during summer

Plate 2. Recharge Basin Structure functioning during storm

The roof water harvesting system installed at South part of Department of Soil and Water Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh. Nearby tube wells were used for recharging as well as observation wells. Estimated cost harvesting roof water runoff of 1 to 5 consecutive days maximum rainfall for 10 years return period in sump varies from Rs. 50 to 94 per sq.m of roof respectively. Also estimated runoff of 1 to 5 consecutive days maximum rainfall for 10 years return period varies from 0.22 to 0.42 cu.m per sq.m of roof respectively in Junagadh region. The capacity of buffer storage tank for collection of excess roof water then real time tube well intake capacity of 1 to 5 consecutive days maximum rainfall for 10 years return period was determined, only in case of 1 day maximum rainfall buffer storage sump of 0.057 cu.m per sq. m. of roof area is required. In remaining days intake is more than roof water for given time duration.

The roof water runoff for annual average, lowest, highest and 10 years return period of rainfall was determined as 0.62, 0.1, 1.86 and 0.95 cu.m per sq. m roof respectively. The rainy days for average, lowest, highest and 10 years return period of rainfall were recorded 33, 13, 52 and 41 respectively. Tube well intakes for annual average, lowest, highest and 10 years return period of rainfall years were determined considering intake duration equal to their respective rainy days and roof water runoff was compared with intake of tube well yearly intakes for all the cases were found higher as compare to yearly roof water runoff. But roof water runoff and tube well intake is not always matching therefore temporary roof pounding may occurs in case system without buffer storage tank so buffer storage tank is advisable.

Determination of safest buffer storage sump in combination of groundwater recharge through tube well were determined considering 1 to 5 consecutive days maximum rainfall, suppose occurs at highest rainfall intensity of 10 years return period and time of concentration equal to 20 min, it means it generates peak rate of runoff for all five days rainfall duration. Day wise duration of rainfall occurrence was used to calculate the tube well recharge capacity. For one day maximum raifall roof weater runoff was found 0.207 cu.m per sq.m of roof and for remaining days it was 0.081, 0.060, 0.038 and 0.003 cu. m per sq.m of roof for 2, 3, 4 and 5 days maximum rainfall respectively. Cost of system per sq. m of roof was found Rs. 79.87, 51.67, 46.89, 41.97 and 34.16 for 1 to 5 consecutive days maximum rainfall respectively. It was found total intake during 5 consecutive days maximum rainfall is higher as compare to roof water runoff. However 0.207 cu.m of buffer storage sump is recommended for safest combination of buffer storage sump with groundwater recharge in Junagadh region.

The observations of groundwater recharge and roof water runoff collected in the sump were recorded, It was found that out of total runoff 0.87 cu.m per square meter of roof, 0.26 cu.m of runoff per square meter of roof was contributed as ground water recharge and 0.61 cu.m of runoff per square meter of roof was collected in to sump (Fig 3.9). Cost of system was determined Rs.172 per square meter.

Annual roof water runoff coefficient was estimated 0.7 for concreate roof for Junagadh region.It was found that out of total runoff 0.87 cu.m per square meter of roof, 0.26 cu.m of runoff per square meter of roof was contributed as ground water recharge and 0.61 cu.m of runoff per square meter of roof was collected in to sump. Cost of system was determined Rs.172 per square meter.

3.5 Raipur

3.5.1 Groundwater recharge planning for Bilaspur district using remote sensing and GIS

Groundwater recharge planning for Bilaspur district using remote sensing and GIS has been conducted by Raipur centre. Out of 146 blocks in the state, 15 have been categorized as semi-critical as the stage of groundwater development in these area is more than 70% but less than or equal to 90%. Various thematic maps including drainage map, slope map, district and block boundary maps, soil texture and lineament maps were generated using available data. The pixel based classification of the satellite imagery will be used for the planning of artificial groundwater recharge plan (Fig 3.10).

Plate 3. Submersible Pumping system with flow control valve and water meter arrangement

Plate 4. Tube well recharging at full recharge head condition

Plate 5. Spill over flow during tube well recharging

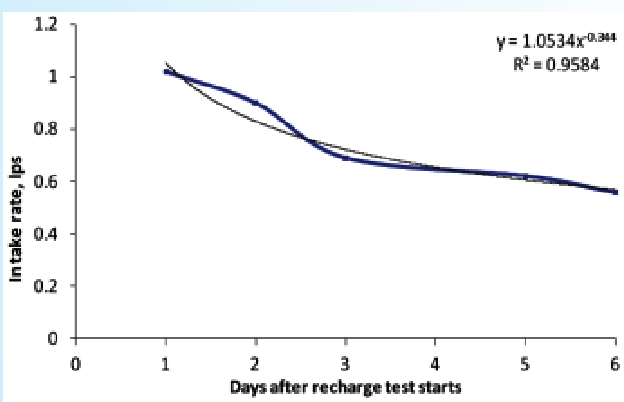


Fig 3.9: Recharge rate at various testing days

S. No.	Land Class	Area (ha)
1	Agriculture upland	5453.9
2.	Agriculture lowland	16997.2
3.	Fallow land	5493.0
4.	Barren land	2137.5
5.	Shallow water body	863.0
6.	Deep Water Body	584.3
7.	Settlements	4617.2
	Total	**36146.1**

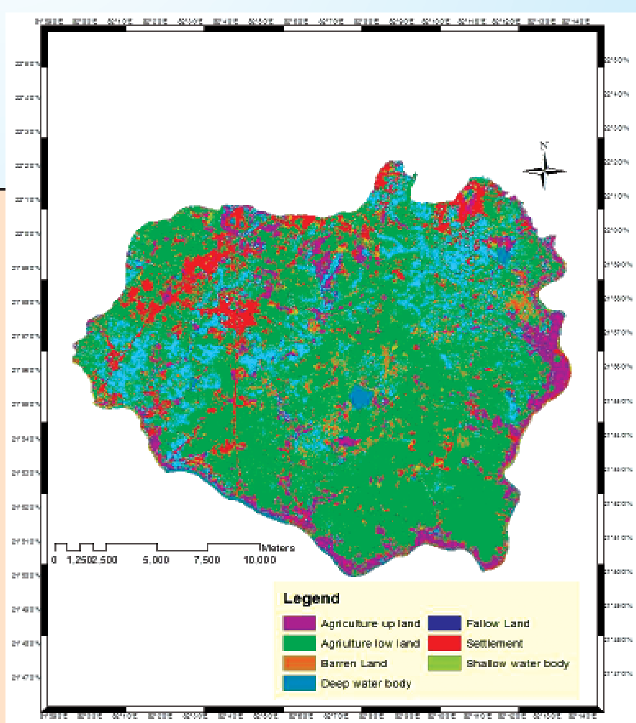


Fig. 3.10 – Classified image of Bilha Block, Bilaspur District

3.6 Rahuri

3.6.1 Development of the technique for recharge of bore well

Artificial groundwater recharge technique for recharge of bore well is developed to tackle the problem of declining groundwater table. The experiment was conducted at the Instructional Farm and the tests were conducted during the period from July, 2014 to October 2014. The filter unit consisted of inlet tank (sediment mixing tank), filter tank and an outlet tank (observation tank) of sizes 1.5 m^3, 1 m^3 and 0.2 m^3, respectively. Suspended load from silt and clay was prepared in sediment mixing tank (inlet tank) having known volume of water, which was then passed through the filter. Filter tank with perforated casing pipe, cover with mesh, which were used to prevent the blockages of casing pipe. These casing pipes fixed at bottom of filter tank, diameter of casing pipe was 16 cm (6.2") and length was 1.75 m. Filter materials such as brick flakes, angular gravel, pea gravel, sand were used in single layer, two layer, three layer and four layer filter in combination. A tapped outlet for sediment mixing tank was provided in the form of PVC gate valve and water was directed towards the filter. The known weight of suspended load material was mixed with water in the sediment mixing tank and turbidity of this influent water was measured with Digital Nephelometer CL-52 D of ELICO make, which was compared further with the turbidity of outflow leaving the filter material. The constant suspended load concentration of 200 NTU was passed through each filter by mixing known 1.19 kg of Silt in 1500 lit water. Flow from the tank was controlled by using gate valve to maintain constant filtration rate throughout the filter column. The time required passing the water through filter and time of filtration was noted. The elevation of inlet tank was 0.5 m above filter tank for allowing free flow under gravity to the filter unit. The experimental layout is shown in fig.3.11.

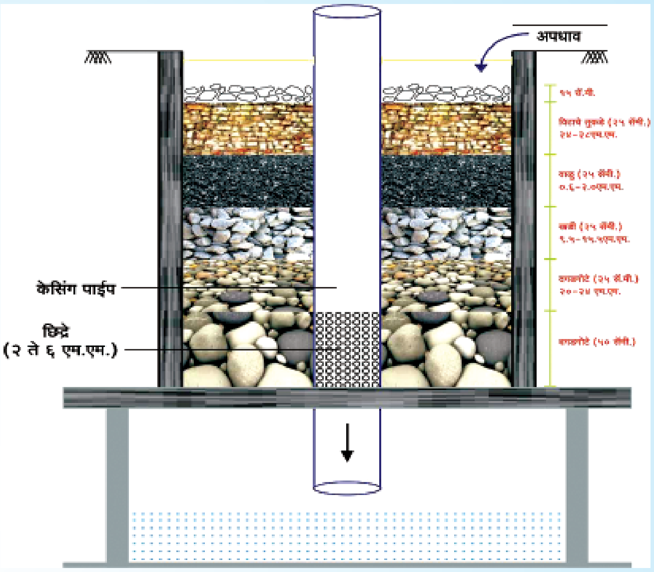


Fig. 3.11 Experimental layout of the filter unit

The filters made from various locally available materials were tested for the constant suspended load concentration of 200 NTU. The filter developed in single layer, two layer, three layer

Table 3.1. Comparison of best treatments obtained in single layer, two layer, three layer and four layer filters

Treatment No.	Filter material	Filter material thickness (cm)	Inlet (NTU)	Outlet (NTU)	Discharge (lps)	F.E. (%)
T1,2	SG-I	100	200	38.0	1.098	81.0
T2,1	BF-I SG-I	25 75	200	25.6	1.108	87.2
T3,1	BF-I SG-I AG-I	25 37.5 37.5	200	22.06	1.072	89.0
T4,2	BF-I SG-I AG-I PG-I	25 25 25 25	200	15.4	1.156	92.3
S.E					0.0229	0.5545
C.D. (0.05)					NS	1.6624

and four layer with combination of filter material viz. sand- I (0.6-0.2mm), angular gravel- I (9.5-15.5mm), angular gravel- II (15.5-21.5), pea gravel –I (20-24mm), pea gravel –I (24-28), brick flacks (24-28mm). The layer thickness in single layer was 100 cm, in two layer was 25cm, 75cm, in three layer was 25cm, 37.5cm, 37.5cm and in four layers 25cm, 25cm, 25cm and 25cm. The four layer filter has performed better in terms of filtration efficiency (92.3%) and discharge (1.156 lps) amongst all other filters (Table 3.1).

The cost of the four layer filter according to the current price is Rs.4000 /- as per DSR rates. The four layer filter is recommended for recharge of bore wells to obtain more filtration efficiency.

3.7 Almora

Water storage dynamics revealed that the lowest volume water was reached in Julian day 159. The runoff started flowing in tank during June 2014; from Julian day 164 days onwards and it became full by Julian day 200 and it maintained up to 228 and later on water was 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 42.0 per cent higher wheat yield obtained with supplementary irrigation in comparison to rain fed (22.6 q/ha). 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. 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.

3.7.1 Artificial-recharge techniques for hill springs

The comparative study revealed that the five year mean annual discharge of the spring was higher 73.2, 100.7,114.2,135.9 and 148.8 per cent during 2006-2010, 2007-2011, 2008-2012 and 2009-2013, and 2010-2014 respectively in comparison to annual discharge recorded during 2000 before the inception of recharge treatments. Although five yearly mean annual rainfall was below by -19.4, 13.5, -15.5,-13.6 and -12.5 percent in 2006-2010, 2007-2011, 2008-2012, 2009-2013 and 2010-2014 respectively in comparison to year 2000. The annual discharge was 129.1 percent higher during 2014 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 shows 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.

3.8 Jammu

3.8.1 Conjunctive use of water at basin level within the canal commands of Jammu

Modeling studies for planning the conjunctive use of water at basin level within the canal commands of Jammu showed that during the second year (2014-15), distributary No. 12 (D-12) emerging from Chak - Harni link road, as a representative of deficit irrigation scenario area, has been selected for determining the cropping intensity, crop productivity and water productivity for devising the matching interventions in the shape of conjunctive use of water to cater the production system demand (Table 3.2).

Table 3.2 Water supply v/s water requirement scenario during kharif within D-12 having command area of 783 ha

Stages of Kharif crop (rice)	WR per day (ha-m/day)	Total WR (ha-m)	IWS per day (ha -m/day)	Total WS on (7) days rotation basis within different stages of rice crop (ha-m)
Nursery (1-23rd June)	0.17	3.91	8.98	82.0
Field bed preparation (24th-30thJune)	25.1	175.7	8.98	41.0
Planting to PI (1st July -8th Sept)	2.21	154.7	8.98	205.1
PI to flowering (9th Sept-30thSept)	16	352	8.98	82.0
Flowering to Maturity (1st Oct-9thNov.)	2.74	109.6	8.98	53.8
Total water requirement stage wise during kharif (ha-m)		795.91	Total water supply stage wise during kharif (ha-m)	463.9

WR: Water requirement, IWS: Irrigation water supply

3.9 Jorhat

3.9.1 Effect of tillage and legume mulching on soil moisture conservation and productivity of baby corn - rapeseed system

Mulching with cowpea recorded the highest baby corn yield followed by mulching with dhaincha. No mulch treatment recorded the lowest yield. However, differences among the treatments were not significant (Table 3.3). Different yield attributing characters and biomass yield were also not significantly influenced by different mulching treatments. Similarly, there had been no much

Table 3.3 Effect of tillage and legume mulching on growth, yield attributes and yield of baby corn

Treatments	Plant Height at harvest (cm)	No of cobs /m²	Corn yield (q/ha)	Biomass yield (q/ha)
Legume mulch				
M_1	202.0	11.0	15.3	327.6
M_2	203.8	11.1	16.3	354.3
M_3	202.8	11.1	15.9	344.6
SEm $\pm$	6.3	0.3	0.4	9.5
CD (0.05)	NS	NS	NS	NS
Tillage		0.0		
T_1	200.3	11.1	15.6	334.0
T_2	202.1	11.1	15.8	341.9
T_3	203.6	11.2	16.2	353.2
T_4	201.8	10.9	15.7	339.6
SEm $\pm$	6.9	0.4	0.3	7.2
CD (0.05)	NS	NS	NS	NS
Interaction	NS	NS	NS	NS

differences among the different treatments with respect to water use and water use efficiency (Table 3.3).

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 (123.1 kg/ha-cm) followed by conventional tillage + irrigation at flowering (104.3 kg/ha-cm).

Table 3.4 Effect of different treatments on water use efficiency of baby corn

Treatments	Water used (cm)	Corn yield (q/ha)	WUEkg/ ha-cm)
M_1	15.7	15.3	97.5
M_2	16.2	16.3	99.4
M_3	16.1	15.9	98.8

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 ploughing 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 (156.5 kg/ha-cm).

3.9.2 Effectct of rain water harvesting with ridge and furrow on yield of sugarcane with different methods of planting

Results of the experiment revealed that different methods of planting had no significant effects on growth, yield attributes and cane yield of sugarcane. However, different water harvesting techniques significantly influenced the cane yield of sugarcane. Ridge mulch by plastic film and furrow with sugarcane trash/weed (H_4) being at par ridge mulch by plastic film and furrow (H_3) recorded significantly higher cane yield than ridge

Table 3.5 Effect of tillage and legume mulching on seed and stover yield and water use of rapeseed

Treatments	Seed Yield (q/ha)	Stover yield (q/ha)	Water used (cm)	WUE (kg/ ha-cm)	Rapeseed eq.yield (q/ha)	Water used by the system (cm)	WUE of the system (q/ha-cm)
Legume mulch							
M_1	7.77	12.73	7.92	98.1	38.37	23.62	162.4
M_2	8.31	13.59	8.14	102.1	40.91	24.34	168.1
M_3	8.07	13.24	7.97	101.2	39.87	24.07	165.6
SEm ±	0.12	0.19	-	-	0.79	-	-
CD (0.05)	NS		-	-	NS	-	-
Tillage							
T_1	6.32	10.38	6.94	91.1	37.52	22.94	146.1
T_2	5.99	9.79	7.41	80.8	37.59	23.41	143.1
T_3	9.31	15.24	7.56	123.1	41.71	23.56	156.5
T_4	10.57	17.32	10.13	104.3	41.97	26.13	144.1
SEm ±	0.35	0.58	-	-	0.68	-	-
CD (0.05)	1.05	1.71	-	-	2.03	-	-
Interaction	NS	-	-	-	-	-	-

and furrow (H_1) and ridge and furrow with sugarcane trash/weed biomass (H_2). Similar trend was observed in case of cane diameter, single cane weight, millable cane and plant height.

Considering Assam lemon plants susceptibility to water logging and root zone depth within 45 cm water table draw down of 300 mm/day has been selected. Therefore drain spacing is 6 m. Assam Lemon plants are planted at 3m spacing. Therefore drains are to be located in middle of alternate rows of plants at 6 m spacing. In humid areas drainage coefficient depends largely on rainfall but it is difficult to correlate rainfall with drainage coefficient. The drainage coefficient for the design has been chosen after ASAE 1988 (Table 3.6).

Table 3.6 Drainage coefficient (for orchard crops)

Crop and degree of surface drainage	Drainage Coefficient Mineral soil (Clay & silt) mm/day	Organic soil mm/day
Normal	13-19	19-38
With blind inlets	19-25	38-51
With surface inlets	25-38	51-102

For Assam lemon the subsurface drain has been designed with blind inlet (no loss of land) and soil is organic therefore design drainage coefficient is 38-51 mm/day. As per ASAE 1988 a grade of 0.81 is selected. Net size available 76 mm chosen. PVC pipe of 76 mm dia was punctured with 0.5 cm dia hole at 2 cm spacingin one half portion. Bamboo of same dia was split and internodes were removed. One half of the split bamboo was punctured with same dia and spacing. Envelope material (rough sand (0.5-1mm dia) and rice husk) was laid to a depth of 10 cm on the trenches dug upto 60 cm. Each of the perforated pipes (both PVC and Bamboo) were then wrapped with 40 mesh size plastic net and laid at 1:100 slopes. Backfilling was done with envelope material upto 10 cm depth overlaid by dug soil.

3.10 Bhavanisagar

3.10.1 Evaluation of water productivity in integrated farming system in different situations for Western Zone in Tamil Nadu

Water Productivity of different components were evaluated in Integrated Farming Systems. Among the crop components, the water use efficiency (WUE) was higher in CO4 CN hybrid grass which was 179.4 kg. ha^{-1} mm. This might be due to higher yield potential and perennial type. Among the other annual crops, bhendi resulted in higher WUE (45.4 kg ha^{-1} mm). Among the crop components, bhendi resulted in higher water productivity and income. Among the dairy unit, milching cows resulted in higher water productivity and CO4(CN) hybrid grass gave higher income. Regarding the other livestocks, the physical water productivity was higher in duck followed by pigeon and economic productivity was higher in pigeon followed by duck. However higher income was recorded in fishery unit followed by ducks.

Table 3.7 :Integrated Farming System components (1 ha) – Wetland (I year)

Components	Area
Rice - Rice – pulses	2000 m^2
Sugarcane	2000 m^2
Maize	2000 m^2
Vegetables (Bhendi)	400 m^2
CO(CN) 4 grass	1400 m^2
Velimasal	1000 m^2
Fish pond	1000 m^2 (Catla, Roghu & Mrigal)
Dairy unit	2 cows (Jersy)
Poultry unit	30 desi birds
Pigeon unit	10 pairs
Duck	30 birds (Khaki Campbell)
Total area	**10,000 m^2 (1 ha)**

3.10.2 Water productivity in rainfed areas with different land configurations in Lower Bhavani basin

Among the various land configurations, formation of broadbed furrows recorded highest moisture content during vegetative (20.52%), flowering (23.22 %) and harvest stages (5.64%) under rainfed groundnut and compartmental bunding was on par with broadbed furrows. Among different soil moisture conservation practices compartmental bunding recorded the significantly highest pod yield and it was comparable with broad bed & furrows.Among different soil moisture conservation practices, during vegetative stage random tie ridging recorded the highest plant

Table 3.8 : Water productivity of crop and livestock components

Crops	Irrigation water used (mm)	Total water used (mm)	Water consumed in litres/ day/ animal	Total water consumed in litres	Yield kg/ha	WP (kg/ litre of water)
A. Crop component						
Rice (IW Ponni)	525	546	-	5460000	8500	0.00156
Rice (Anna 4)	500	469	-	4690000	6150	0.00131
sugarcane	900	1277.3	-	12773000	-	-
Maize (CO6)	550	571	-	5710000	5350	0.00094
Bhendi (ArkaAnamika)	250	271	-	2710000	12300	0.00454
B. Dairy unit						
CO4(CN) grass	1450	1783.5	-	17835000	320000	0.01794
Velimasal	550	748.8	-	7488000	75200	0.01004
Dairy (2) (Jersy)	-	-	136.47*	99620	4726 litres	0.04744
C. Other Livestock						
Fish	-	-	-	1224000**	1000	0.00082
Poultry (30)	-	-	0.29	3178	77	0.02423
Duck (30) Khaki campbell	-	-	0.62	6738	355	0.05269
Pigeon (20)	-	-	0.05	347	15	0.04323

* Water consumption for cow includes drinking, washing and shed cleaning

** Water is allowed through inlet @ 0.38 litre per sec and the outflow is also maintained at the same rate

Table 3.9: Water productivity and Economics of IFS components

Enterprises	Area(ha)/ No.	Water sage (m^3)	Yield (kg/ha)	Income (Rs.)	Physical WP (kg/m^3)	Economic WP (Rs./m^3)
A. Crop components						
Rice	0.2	5460	8500	85000	1.56	15.6
Rice	-	4690	6150	61500	1.31	13.1
Sugarcane	0.2	12773	-	-	-	-
Maize	0.2	5710	5350	69550	0.94	12.2
Bhendi	0.04	2710	12300	98400	4.54	36.3
B. Dairy unit						
CO4(CN) grass	0.14	17835	320000	480000	17.94	26.9
Velimasal	0.1	7488	75200	150400	10.04	20.1
Dairy	2 Nos.	99.62	4726 litres	113424	47.44* litres	1138.6
C. Other Livestock						
Fish	0.1	1224	1000 kg	50000	0.82	40.8
Poultry	30 Nos.	3.178	77 kg	4320	24.23	1359.3
Duck	30 Nos.	6.738	355 kg	30234	52.69	4487.1
Pigeon	20 Nos.	0.347	15 kg	3000	43.23	8645.5

* Litres of milk

height and number of branches and it was at par with T3, and T2.

Table 3.10: Effect of treatments on Pod yield of rainfed groundnut (kg/ha)

Treatments	Yield / ha (kg)
T_1 - Summer ploughing	1558
T_2 - Broadbed and furrows	1713
T_3 - Ridges and furrows	1703
T_4 - Comparmentalbunding	1752
T_5 - Contour bunding	1572
T_6 - Random tie ridging	1705
T_7 - Control	1572
SEd	19.4
CD (p=0.05)	42.0

Groundwater Table

Watertable fluctuation at all the three sites is presented in Fig. 3.12. In all the three sites watertable decline sharply upto July then it start rising till December month. After that it again start declining. It has ben observed that rate of water fall is greater than the rate of rise. It has been also observed that the water table is rising in first half of January 2015 and declining thereafter till the end of month and again rising in the month of February which may be due to rainy days in the third week of January 2015.

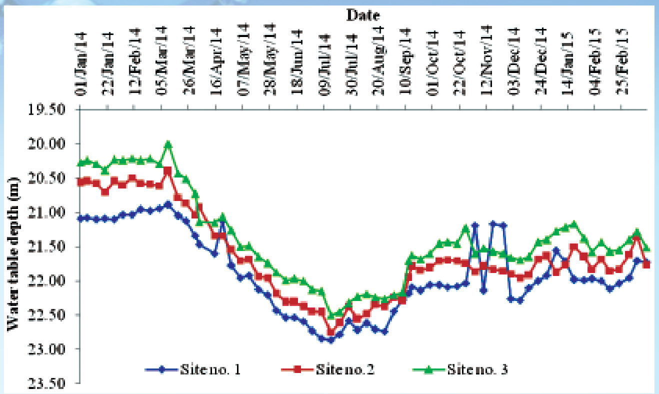


Fig. 3.12 Water Table depth at different sites during 2014-15

Improvement in Recharge structures

There was deficit rainfall during 2014 as it evident from the rainfall data but recharge rate in the abundant wells were quite low in spite of high head. This was due to the soil column present in the well and some compaction. So this soil layer was removed from the wells at both the sites. At Site 1, there was barren land and runoff generated from this land contain silt load so the grass was grown in that land to reduce the silt load entering in the well as shown in plate. Also the direction of runoff generated from the adjoining fields is given toward abundant well by constructing small pits as shown in Plate. At Site 2, the adjoining pit was covered with better quality PVC sheet and the well was deepened till sandy strata are available. Also at Site 1 and Site 2 both the abundant wells were covered with iron lead to avoid any accident. At Site 3, the pits were lined with brick wall because

Table 3.11: Effect of treatments on growth parameters during vegetative stage

Treatments	Plant height (cm)	Number of branches	Number of leaves	Leaf length (cm)	Leaf breadth (cm)
T_1 - Summer ploughing	16.67	4.33	16.20	3.50	2.27
T_2 - Broadbed and furrows	18.43	5.43	23.57	4.30	2.27
T_3 - Ridges and furrows	20.47	5.33	28.43	4.13	2.07
T_4 - Comparmentalbunding	18.00	5.00	19.13	5.00	2.67
T_5 - Contour bunding	17.00	4.57	16.33	4.47	2.40
T_6 - Random tie ridging	20.60	5.80	23.57	5.20	2.70
T_7 - Control	17.00	4.67	16.67	4.50	2.43
SEd	**0.98**	**0.32**	**2.58**	**0.56**	**0.27**
CD (p=0.05)	**2.14**	**0.70**	**5.63**	**1.21**	**0.59**

at this site soil was light and huge runoff is generated from the wide channel. Also another pit was dug out before the drainage point to enhance the recharge capacity. In this pits RCC pipe were placed.

3.11. Navasari

3.11.1 Management of rain water for judicious use to develop and evaluate groundwater recharge technologies for augmenting GW availability under different hydro geological conditions cluster based MIS demonstration in tribal area

Navsaricentre 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. The results of the demonstrations are given in table 3.11.During the year under report,out of twelve (12) farmers three each grown bitter gourd and brinjal, two grown cowpea and one each grown little gourd, pointed gourd, rose and maize. Among the different crops, higher net income of Rs. 30,000 to 36,200 from 0.2 ha was realized with bitter gourd and brinjal crop and the lowest net income of Rs. 6500 from 0.21 ha area was realized with rose and cowpea (Table 3.12).

Selling price:Bitter gourd, brinjal, cowpea and BhindiRs. 8/kg, little gourd Rs. 10 /kg and Rose cut flower Rs.0.25, Pointed gourd Rs.20/kg

3.11.2 Rain water harvesting and it efficient utilization in tribal area Rubber dam site selection

A reconnaissance survey for selecting suitable site for installation of rubber dam in Gujarat at Ranifalia / Vanarashi village of VansdaTaluka of Navsari district was carried out by the scientists from WTC, Bhubaneswar in collaboration with AICRP on Water Management, NAU, Navsari. Accordingly, necessary civil work for the installation of rubber dam at selected site has been completed. During the monsoon water harvested and stored in rubber dam area. Further, for efficient utilization of rain water stored in rubber dam, given input of MIS for demonstrations (Table 3.12) in dam site areas on different vegetable crops. The Micro Irrigation System (MIS) was laid on the farmer's field and the farmers sown different vegetable crops and it is in progress. The results will be reported in next year.

3.12. Palampur

3.12.1 Management of soil moisture in summer crop of brinjal in high rainfall areas of Himachal Pradesh

Mulch sources had significant effect on brinjal

Table 3.12: The details regarding MIS demonstration (2014)

SN	Name of farmer	Area (ha)	Crop	Yield (kg)	Crop duration (months)	Net Profit (Rs.)
1	ShankarbhaiManjibhai	0.12	Bhindi	3000	6	19200
		0.12	Cowpea	1500	3	10200
2	RamubhaiChhotubhai	0.21	Bittergourd	3820	6	33200
3	SumanbhaiBhangyabhai	0.26	Rose(local)	22000	Cont.	6500
4	ManekbhaiGandabhai	0.25	Bittergourd	4230	6	36200
5	RanjitbhaiLallubhai	0.18	Brinjal	4820	7	33560
6	LaljibhaiSonubhai	0.17	Bittergourd	3500	6	30000
7	IshawarbhaiPrabhubhai	0.30	Maize	570	4	11750
8	RamanbhaiBhangyabhai	0.21	Brinjal	3840	7	33400
9	DalubhaiChhanabhaiv	0.21	Littlegourd	2200	Cont.	15500
10	GulabbhaiChhaganbha	0.17	Bhindi	3100	6	18000
11	KanubhaiPrabhubhai	0.11	Brinjal	1100	7	6150
		0.10	Cowpea	700	3	2600
12	RameshbhaiPrabhubhai	0.11	Pointedgourd	680	Cont.	10600
		0.11	Bhindi	1720	6	6760
	Total area	**2.63**				

Table 3.13 : MIS on farmers field under TSP (at Ranifalia / Vanarashi village of Vansda Taluka of Navsari district)

SN	Name of farmers	Survey No.	Area(acre)	Remarks
1	AmrutbhaiLimji Patel	281	3.50	Crop sow during *rabi*season and condition is good
2	MadarbhaiRumshibhai Patel	122	1.12	
3	KanubhaiJivanbhai Patel	141	2.50	
4	IshwarbhaiRanchhodbhai Patel	-	1.00	
5	BabubhaiKarsanbhai Patel	123	1.50	
6	Gulabbhai L. Patel	132	2.33	
7	NaginbhaiLimjibhai Patel	133	2.33	
8	RamanbhaiLimjibhai Patel	133	1.50	
9	NarotamParbhubhai Patel	119	1.50	
10	SagnatabenKanjibhai Patel	126	2.00	
Total			**19.28**	**(8.0ha)**

yield, gross returns and water use efficiency. The crop planted after application of plastic mulch result in significantly higher brinjal yield and gross returns than crop grown with organic mulch application (7.70 % & 7.67 %) after planting and crop planted without mulching (22.25 & 22.23 %). Organic mulch resulted in significantly higher brinjal yield and gross returns (13.51 and 13.53 %) than application of no mulch. Similarly water use efficiency were significantly higher in crop grown under plastic mulch than crop grown with organic (14.15 %) or no mulch (46.69 %) due to lower water use under plastic mulch than under organic (5.01 %) or no mulch (16.21 %) . Application of organic mulch resulted in significantly higher (28.51 %) water use efficiency than application of no mulch due to 11.79 per cent lower water use in the former treatment. Mulch sources had no effect on net returns and B: C ratio .FYM levels had significant effect on

Table 3.14 : Effect of different treatments on productivity, water use and economics of brinjal

Treatment	Brinjal yield ($Mgha^{-1}$)	TWU (m^3ha^{-1})	WUE (Mgm^{-3})	GR ($Rs.ha^{-1}$)	NR ($Rs.ha^{-1}$)	B:C ratio
Mulch sources						
Organic mulch	10.00	1197(9)	8.34	150000	94628	1.71
Plastic mulch	10.77	1137(7)	9.52	161500	98120	1.55
No mulch	8.81	1357(15)	6.49	132125	84761	1.79
CD (P = 0.05)	0.74		0.62	11100	NS	NS
FYM levels (t ha^{-1})						
5.0	9.47	1230(10)	7.81	142042	87961	1.64
10.0	10.25	1230(10)	8.42	153708	97045	1.73
CD (P = 0.05)	0.60		0.51	9063	9063	NS
Irrigation levels (cm)						
2	9.34	1134(10)	8.32	140042	84670	1.52
4	10.38	1327(10)	7.91	155708	100336	1.84
CD (P = 0.05)	0.60		NS	9063	9063	0.16

* Value in the parenthesis indicate number of irrigations

brinjal yield, gross returns, net returns and water use efficiency. The crop planted after application of FYM @ 10 t ha^{-1} resulted in significantly higher yield of brinjal, gross returns, net returns and water use efficiency than crop planted after application of FYM @ 5 t ha^{-1} (8.24, 8.21, 10.33 & 7.81 %). FYM levels had no effect on B: C ratio. Irrigation levels had significant effect on brinjal yield, gross returns, net returns and B: C ratio. The crop irrigated with 4 cm of water depth resulted in significantly higher brinjal yield, gross returns, net returns and B: C ratio than crop irrigated with 2 cm of water depth (11.14 %, 11.19 %, 18.50 % & 21.05 %). Irrigation levels had no effect on water use efficiency.

For saving irrigation water and increasing WUE, brinjal crop should be planted after incorporation of FYM @ 10 t ha^{-1} and application of plastic mulch and irrigated either with 2 or 4 cm of water depth. It also maximizes production and gross/net returns.

3.13. Shillong

3.13.1Residue management and conservation tillage in Rice-based system.

Data presented in Table 3.17, revealed that the grain yield of rabi crops (Buckwheat and Pea) following rice was increased significantly due to tillage practices. Yield of buckwheat and pea was significantly higher under zero tillage for all crops along with residue retention as compared to other tillage practices. Straw yield of buckwheat only was highest under zero tillage for all crops along with residue retention followed by reduced tillage (residue incorporation). The water use efficiency (WUE) of succeeding rabi crops was greatly influenced by tillage practices. The highest WUE for pea was recorded under zero tillage for rabi crops (residue retention) (9.38 kg ha^{-1} mm^{-1}) which is 18.14% more as compared to conventional tillage. Higher WUE in mustard was recorded under zero tillage for all crops (residue

Table 3.15: Interaction effect of mulch source and irrigation on productivity and water use efficiency of brinjal

Mulch source	Brinjal yield (Mg ha^{-1})		Water use efficiency (kg ha-mm^{-1})	
	Irrigation level		Irrigation level	
	2 cm	4 cm	2 cm	4 cm
Organic mulch	9.08	10.93	8.20	8.49
Plastic mulch	10.99	10.54	10.30	8.73
No mulch	7.94	9.68	6.47	6.51
CD (P = 0.05)	1.05		0.88	

Table 3.16. Interaction effect of mulch source and irrigation on productivity economics of brinjal

Mulch sources	Gross returns (Rs.ha^{-1})		Net Returns (Rs.ha^{-1})		B:C Ratio	
	Irrigation Level		Irrigation Level		Irrigation Level	
	2 cm	4 cm	2 cm	4 cm	2 cm	4 cm
Organic mulch	136125	163875	80753	108503	1.46	1.96
Plastic mulch	164875	158125	101495	94745	1.60	1.49
No mulch	119125	145125	71761	97761	1.51	2.06
CD (P = 0.05)	15698		15698		0.28	

retention) (3.24 kg ha^{-1} mm^{-1}) which was 4.85% higher than conventional tillage.

Seasonal soil profile moisture status:

The soil moisture content at 0-45 cm depth was marginally higher under Zero tillage for all crops along with residue retention compared to other tillage practices. However, the moisture content at 60 and 90 DAS was almost at par under the tillage systems.

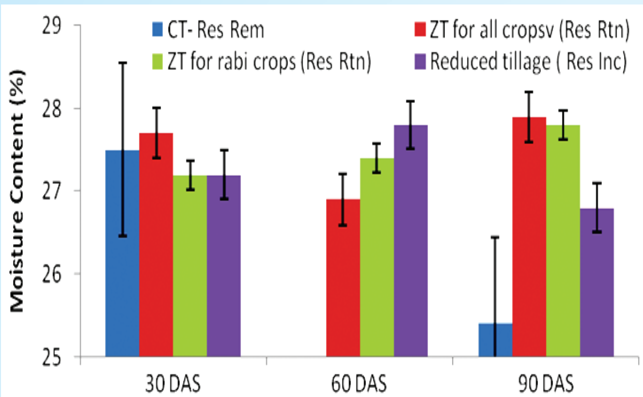


Fig. 3.13 Moisture content (%) at 0-45 cm under various treatments.

Yield attributes and yield:

Data presented in Table 3.18, revealed that the different tillage practices had significant influence on yield and yield attributes of rice except for panicle length and 100 seed weight. The grain yield of rice was significantly higher under zero tillage for both the crops with residue retention (6550.0 kg ha^{-1}) followed by zero tillage for rabi crops only with residue retention (6266.7 kg ha^{1}). The lowest grain yield of rice was recorded under reduced tillage with residue incorporation (5666.7 kg ha^{-1}). Thus it is seen that there was an increase of 15% yield under zero tillage for all crops with residue retention as compared to conventional tillage. The straw yield was also significantly influenced by various tillage practices. The highest straw yield was recorded under zero tillage for all crops with residue retention as compared to other tillage practices.

Tillage practices significantly influenced the weed population and dry weight in rice. Zero tillage for all crops with residue retention recorded the highest weed population while, conventional tillage residue removal recorded the lowest weed population. Weed dry weight followed the similar trend as that of weed population.

3.13.2 Effect of manures and straw mulching on turmeric under terrace condition.

The evaluation for micro and macro-nutrients in the soil revealed that the highest amount of nitrogen was observed under FYM +Mulching (271.2 kg ha^{-1}) at 0-15 depth followed by FYM +Mulching (227.3 kg ha^{-1}) at 15-30 cm depth while lowest was recorded at 15-30 cm depth(101.9 kg ha^{-1}), under paddy straw mulching. Highest amount of phosphorous was recorded at 31.2 kg ha^{-1} at 0-15 depth under FYM +Mulching practice

Table 3.17: Effect of mulching, and conservation tillage on yield and WUE of rabi crops

Treatments	Buckwheat			Pea		Mustard		
	Grain yield (kg ha^{-1})	yield ($kgha^{-1}$)	yield ($kgha^{-1}$)	yield ($kgha^{-1}$)	($kgha^{-1}$) mm^{-1}	yield ($kgha^{-1}$)	yield ($kgha^{-1}$)	($kgha^{-1}$) mm^{-1}
CT - Residue removal	588.5	1156.8	1783.9	1489.7	7.94	899.8	899.8	3.09
ZT for all crops (Res. Rtn.)	723.6	1342.6	1878.5	1618	8.36	943.1	943.1	3.24
ZT for rabi crops (Res. Rtn.)	493.3	1061.7	2108.4	1676.1	9.38	816.7	816.7	2.80
Reduced tillage (Res. Inc.)	708.4	1267.6	1939.7	1536.3	8.63	901.1	901.1	3.09
SEm	**9.3**	**56**	**71.3**	**61.2**	**-**	**46.5**	**46.5**	**-**
CD *(P =0.05)*	**32.3**	**193.9**	**246.8**	**NS**	**-**	**NS**	**NS**	**-**

Table 3.18. Yield attributes and yield of rice as influenced by various tillage practices

Treatments	Plant height (cm)	Panicle length (cm)	Grain panicle⁻¹ (cm)	Chaffy grain panicle⁻¹	Plant dry wt. (g)	Root dry wt. (g)	100 speed wt. (g)	No. of paniclem⁻²	No. of tillers m⁻²	No. of yield (kg ha⁻¹)	Straw yield (kg ha⁻¹)
CT - Residue removal	98.0	23.5	107.9	27.2	75.5	23.9	30.2	364.7	379.7	5700.0	7300.0
ZT for all crops (Res. Rtn.)	104.4	24.3	151.3	35.4	56.6	24.6	30.1	391.3	427.3	6550.0	6766.7
ZT for rabi crops (Res. Rtn.)	99.1	23.1	132.4	14.3	51.1	18.5	29.7	348.3	379.7	6266.7	7453.3
Reduced tillage (Res. Inc.)	94.3	23.3	110.0	15.7	47.6	17.2	30.1	306.0	341.0	5666.7	7266.7
SEm	**0.9**	**0.5**	**0.9**	**1.2**	**0.6**	**0.7**	**0.2**	**4.6**	**7.9**	**125.4**	**87.7**
CD *(P= 0.05)*	**3.3**	**NS**	**3.3**	**4.1**	**1.9**	**2.5**	**NS**	**15.8**	**27.5**	**433.8**	**303.4**

while the lowest was recorded at 16.2 kg ha^{-1} 15-30 cm depth under control. For potassium the highest amount was recorded poultry manure + Mulching (159.9 kg ha^{-1}), 0-15 cm depth followed by Paddy straw mulching (136.2 kg ha^{-1}) at 15-30 cm depth while control recorded the lowest at 57.1 kg ha^{-1} at 15-30 cm depth. Organic carbon percentage was recorded lowest under control practices (1.1% 15-30 cm depth) while highest percentage of Organic carbon was observed under Biowaste + Mulching practice at 2.6 %, at 0-15cm depth. Little variation was recorded for ph under the various practices performed as it was observed that FYM + Mulching and control practice had the highest ph at 4.6 while practices under Poultry manure + Mulching, Biowaste + Mulching and Farmer's practice recorded the lowest at 4.2 at 15-30 cm depth

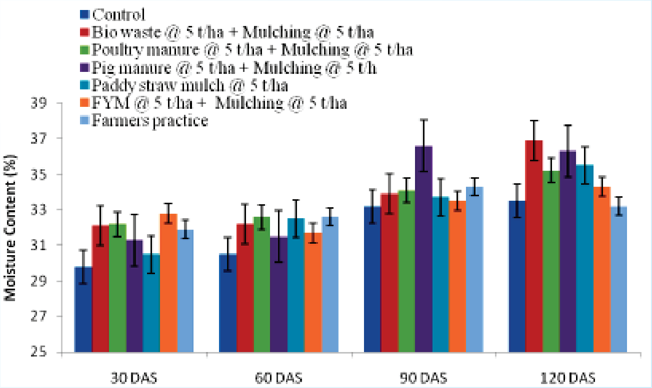


Fig 3.14 : Soil moisture content at 0-45 cm during the crop period

Table 3.19: Effect of manures and straw mulch on weed population and density

Treatment	Total weed population m⁻²		Total dry wt. (g) m⁻²	
	30 DAS	60 DAS	30 DAS	60 DAS
Control	180ab	271a	65.5a	33.1b
Bio waste + mulching	216a	272a	33.7c	29.9abc
Poultry manure + mulching	229a	187ab	29.5c	26.7cd
Pig manure + mulching	128b	236a	27.5c	24.4d
Paddy straw mulch	177ab	180ab	44.4b	27.1abc
FYM + mulching	117b	133b	34.0c	31.0bc
Farmers practice	164ab	177ab	52.8b	42.2a

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

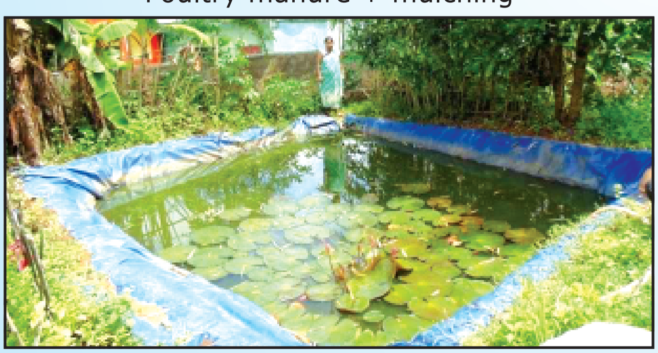
The demonstration on low cost micro rain water harvesting structure and their efficient utilization undertaken at different farmer's field viz; Umroi village (Fig.1.1.), Kyrdem (Fig.1.2.) and Mawlasnai village (Fig.1.4.) at Ri-Bhoi District. The harvested water is being used for growing vegetable crops; rearing livestock and poultry etc. the technology is getting immense popularity in different states of N.E. hill region.

Control

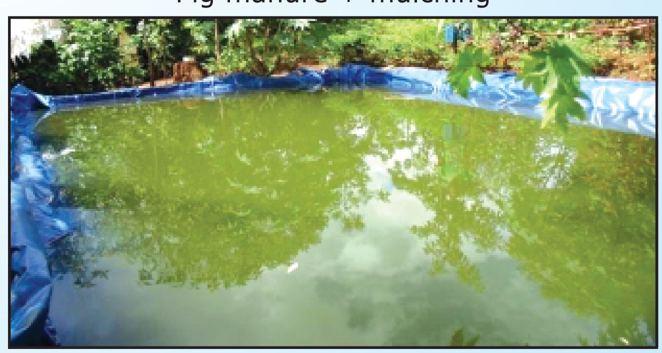
FYM + mulching

Poultry manure + mulching

Pig manure + mulching



Jalkund at Umroi village



Jalkund at Kyrdem village

Jalkund at Water Management farm

Jalkund at Mawlasnai village

Theme IV

Basic studies on soil-water-plant-environment relationship under changing scenarios of irrigation water management including wastewater irrigation.

4. 1. Pantnagar

4.1.1 Development of Water Production Functions for Rice-Mustard-Cowpea Rotation

Rice experiment was conducted during kharif season 2014 in 36 lysimeters under controlled conditions with irrigation schedule as 7.5 cm of irrigation water 3 days after its disappearance of ponded water since one week after seedling establishment. Daily loss of water as ET was measured in Lysimeters using Hook Gauge during the crop season.

The average yield of 46.47 q/ ha of rice was obtained with an average water requirement of 701.3 mm, having average WUE as 6.68 kg/ha-mm during the kharif season of 2014 in lysimeters (Table 4.1. and Fig. 4.1.). During the month of June 2014, a total of 114.6 mm rainfall was received. There was well distribution of rainfall during kharif season 2014 in all months except in August & September 2014. The rainfall distribution in various months was 114.6 mm (June), 427.2 mm (July), 90.2 mm (August), 37.0 mm (September) and 45.4 mm (October). Rice yield was observed during kharif season 2014. More number of irrigation was required in August & September 2014.

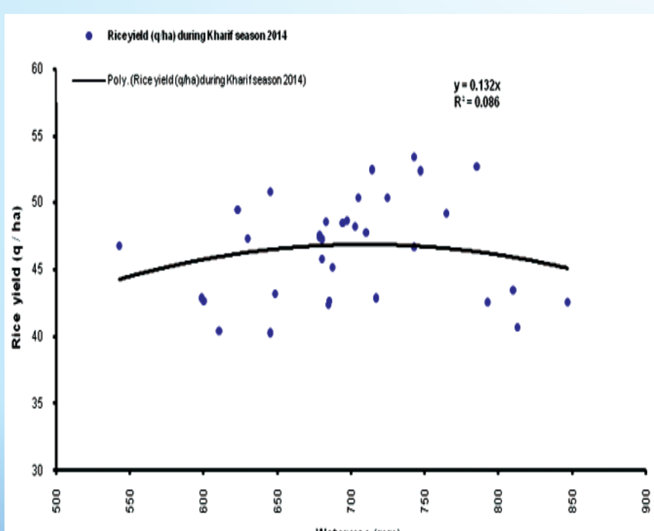


Fig. 4.1 Rice yield (q/ha) and total water use (mm) during kharif season 2014

Table 4.1. Water use, yield and water use efficiency in Lysimeter experiment during Kharif season 2014

Lysi. No.	ET (mm)	Rice yield (q/ha)	WUE (kg/ ha-mm)
1.	680.2	45.8	6.73
2	684.9	42.7	6.23
3	785.6	52.7	6.71
4	742.4	53.4	7.19
5	724.6	50.4	6.96
6	682.7	48.6	7.12
7	600.4	42.7	7.11
8	764.5	49.2	6.44
9	598.6	42.8	7.15
10	623.4	49.5	7.94
11	629.8	47.3	7.51
12	645.1	50.8	7.87
13	746.8	52.3	7.00
14	704.8	50.4	7.15
15	697.2	48.7	6.99
16	714.3	52.4	7.34
17	678.4	47.6	7.02
18	702.4	48.2	6.86
19	846.7	42.6	5.03
20	792.5	42.6	5.38
21	687.4	45.2	6.58
22	810.2	43.5	5.37
23	792.4	42.6	5.38
24	645.2	40.2	6.23
25	710.5	47.8	6.73
26	678.4	47.4	6.99
27	694.7	48.5	6.98
28	812.5	40.7	5.01
29	742.6	46.7	6.29
30	684.5	42.4	6.19
31	648.2	43.2	6.66
32	742.6	46.7	6.29
33	680.3	47.2	6.94
34	542.8	46.8	8.62
35	610.8	40.4	6.61
36	716.9	42.8	5.97
Average of 36 Lysimeters	**701.26**	**46.5**	**6.68**

Table 4.2. Water use, seed yield and water use efficiency of yellow Mustard during Rabi season

Irrigation Treatment & Water Table depth		Ground water contribution (mm)	Total water (irrigation+ rainfall (mm)	Total Water use (mm)	Seed yield (kg/ha)	Water use efficiency (kg/ha -mm)
IW: CPE 0.5 (I_1 F)	30 cm	478	174.6	653	996	1.53
	60 cm	353	174.6	527	844	1.60
	90 cm	210	174.6	384	431	1.12
IW: CPE ratio 0.5 (I_1 S),	30 cm	343	154.6	497	1287	2.59
	60 cm	246	154.6	401	860	2.15
	90 cm	203	154.6	358	847	2.37
IW: CPE ratio 0.75 (I_2 F),	30 cm	246	174.6	421	924	2.20
	60 cm	162	174.6	337	689	2.04
	90 cm	122	174.6	297	616	2.08
IW: CPE ratio 0.75 (I_2 S),	30 cm	204	184.6	389	1212	3.12
	60 cm	172	184.6	357	1087	3.04
	90 cm	162	184.6	347	840	2.42
IW: CPE ratio 1.00 (I_3 F),	30 cm	248	224.6	473	981	2.07
	60 cm	142	224.6	367	791	2.15
	90 cm	103	224.6	328	657	2.00
IW: CPE ratio 1.00 (I_3 S),	30 cm	244	244.6	489	1125	2.30
	60 cm	186	244.6	431	957	2.22
	90 cm	120	244.6	365	667	1.83

Table 4.3. Water use parameters of yellow Mustard under different treatments during rabiseason 2013-14

Treatments	Ground Water contributon (mm)	Total Water use (mm)	Mustard seed yield (kg/ha)	Water use efficiency (kg/ha-mm)
Water table depth (cm)				
30	307	526	1088	2.25
60	210	403	871	2.20
90	154	347	676	1.97
Irrigation method				
Flood	230	421	770	1.87
Sprinkler	218	413	987	2.41
Irrigation schedule				
IW:CPE 0.50	305	470	877	1.89
IW:CPE 0.75	178	358	895	2.48
IW:CPE 1.00	188	422	863	2.04

The results pertaining to water use and seed yield of yellow Mustard are given in Table 4.2.. The maximum seed yield of yellow mustard (1287 kg /ha) was obtained in IW/CPE ratio 0.50 irrigation associated with 30 cm water table (only one irrigation by sprinkler) and minimum seed yield of 431kg /ha was obtained under 90 cm water table (only one irrigation by flood method). In general seed yields were more under 30 cm water table and were decreased as the water table depth was increased upto 90 cm. At deeper water table depths, the decrease in grain yield was better arrested by sprinkler irrigation (less depth but more frequency) than the flood method. The ground water contribution and total water use decreased with increase in water table depth. The ground water contribution was relatively higher in flood method than sprinkler method. Among irrigation schedules, IW:CPE 0.50 had the highest ground water contribution and other two ratios were close to each other.

depths under various irrigation schedules consisted of 3 irrigation treatments with two methods of irrigation with two replications during Summerseason of 2014.

The number of irrigations required at 100, 150 & 200 mm CPE was 5, 3 & 2, respectively. To maintain ground water table at 30 cm, the highest 1378 mm water was needed in 200 mm CPE schedule with sprinkler irrigation. It was 1261 mm at 100 mm, with same method. It suggests that under relatively drier treatments 117 mm, more water was needed to maintain the same water table depth. In deeper water table level i.e. 90 cm, the ground water contribution did not vary much over the irrigation levels. Total crop water use was the highest (1500 mm) in 100 mm CPE, 30 cm water table with sprinkler method and minimum (936 mm) at 200 mm CPE at 90 cm water table depth with sprinkler method.

Table 4.4. Seed yield (kg/ha) of yellow Mustard under different treatments

Water table depth (cm)	IW:CPE 0.50		IW:CPE 0.75		IW:CPE 1.00	
	Flood	Sprinkler	Flood	Sprinkler	Flood	Sprinkler
30	996	1287	924	1212	981	1125
60	843	860	689	1087	791	957
90	431	847	616	840	657	667

From interactive effect of different factors tested on grain yield of mustard (Table 4.4), it is observed that Mustard performed better under shallow water table (30 cm) at both the methods of irrigation. Sprinkler irrigation system maintained the grain yield in a better way than flood when water table depth got deeper. It can be concluded that for higher grain yield, mustard should be taken under shallow water table with sprinkler irrigation method. Even under deep water table situations, mustard should be grown with sprinkler method. Flood method was inferior to sprinkler as it produced lower mean grain yield by a margin of 217 kg/ha than sprinkler method. The mean increase in WUE due to sprinkler method was 0.54 kg/ha-mm over the flood method (1.87 kg/ha-mm).

Cowpea (Vigna unguiculata)

After the harvesting of Mustard in the month of February 2014, Lysimeter experiment was conducted in an available battery of 36 lysimeters associated with 30, 60 and 90 cm water table

The mean ground water contribution decreased as the water table depth was increased. It did not vary much between two irrigation methods and among irrigation levels. Total crop water use decreased as the ground water table depth was increased. Between two irrigation methods, flood method had 30 mm higher water use than sprinkler. Total crop water use was considerable higher at 100 mm CPE schedule than 150 and 200 mm CPE levels, but did not vary much between the later two levels. The grain yield followed almost the similar trend that of total water use. The WUE was the highest at 60 cm water table depth, with sprinkler method and 150 mm CPE ratio. The cross table data on grain yield of cowpea indicates that 60 cm water table was optimum irrespective of the irrigation method and irrigation levels.

It can be concluded that summer cowpea needs to be irrigated at CPE loss of 150 mm with sprinkler and 200 mm CPE loss with flood method. Overall sprinkler method of irrigation was superior to flood

Table 4.5. Water use, grain yield and water use efficiency of Lobia cv Pant Lobia -1

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)
100 mm CPE, Flood 30 cm	1285	214.8	1500	1187	0.79
60 cm	1126	214.8	1341	1323	0.99
90 cm	948	214.8	1163	998	0.86
100 mm CPE, Sprinkler 30 cm	1261	164.8	1426	1347	0.94
60 cm	1086	164.8	1251	1478	1.18
90 cm	868	164.8	1033	1077	1.04
150 mm CPE, Flood 30 cm	1226	154.8	1381	1233	0.89
60 cm	1149	154.8	1304	1300	1.00
90 cm	825	154.8	980	943	0.96
150 mm CPE, Sprinkler 30 cm	1172	124.8	1297	1248	0.96
60 cm	1024	124.8	1149	1513	1.32
90 cm	910	124.8	1035	1124	1.09
200 mm CPE , Flood 30 cm	1237	124.8	1362	1246	0.91
60 cm	1033	124.8	1158	1343	1.16
90 cm	811	124.8	936	1024	1.09
200 mm CPE, Sprinkler 30 cm	1378	104.8	1483	1233	0.83
60 cm	1149	104.8	1160	1148	0.99
90 cm	919	104.8	1024	845	0.83

*(Irrigation + rainfall)

Table 4.6. Grain yield and water useparameters of cowpea during 2014

Treatment	Ground water contribution (mm)	Total water use (mm)	Grain yield (kg/ha)	WUE (kg/ ha–mm)
Water table depth (cm)				
30	1260	1408	1438	0.89
60	1095	1227	1273	1.11
90	881	1028	1059	0.98
Irrigation method				
Flood	1071	1236	1266	0.96
Sprinkler	1085	1206	1247	1.02
Irrigation schedule				
100 mm CPE	1096	1285	1316	0.97
150 mm CPE	1051	1191	1221	1.04
200 mm CPE	1088	1187	1233	0.97

Table 4.7. Grain yield (kg/ha) of cowpea under different treatments during 2014

Water table depth (cm)	100 mm CPE		150 mm CPE		200 mm CPE	
	Flood	Sprinkler	Flood	Sprinkler	Flood	Sprinkler
30	1187	1347	1233	1248	1246	1233
60	1323	1478	1300	1513	1343	1148
90	998	1077	943	1124	1024	845

Table 4.8. WUE (kg/ha-mm) of cowpea under different treatments during 2014

Water table depth (cm)	100 mm CPE		150 mm CPE		200 mm CPE	
	Flood	Sprinkler	Flood	Sprinkler	Flood	Sprinkler
30	0.79	0.94	0.89	0.96	0.91	0.83
60	0.99	1.18	1.00	1.32	1.16	0.99
90	0.86	1.04	0.96	1.09	1.09	0.83

and had higher WUE. Both the methods performed better at 60 cm water table depth.

4.1.2 Determination of Crop Coefficients for Mustard

Evapotranspiration and crop coefficients are the keys to irrigation management decision. Their determination requires lysimeters and meteorological data. Crop coefficients of major crops like Rice, Wheat, Chickpea, Fieldpea, Lentil, Spring Maize, Toria and Sugarcane crops have been worked out earlier and have been published in the form of Research Bulletin No. 150 of Directorate of Experiment Station in May 2005 (Tripathi & Kushwaha, 2005). However, the crop coefficients for other crops like, European dill (Anethum graveolens Linn.) and Vegetable pea grown earlier in Lysimeters have been worked out during 2013-14 using Evapotranspiration data taken through lysimeters. For this purpose reference crop evapotranspiration was calculated using Jensen-Haise (1963) using required weather data as has been done earlier for other crops. The evaporative demand was often expressed as reference evapotranspiration (ET_0), which represents the ET rate of an extended surface of an 0.08 – 0.15 m tall green grass cover, actively growing, completely shading the ground and not short of water. The reference crop evapotranspiration (ET_0) will be calculated using meteorological data, and is related with actual crop ET as determin4ed by lysimeters by the relation

$$ET = Kc \cdot ET_0 \qquad ...(1)$$

Where, ET is actual ET of a healthy crop well supplied with water, mm d^{-1}, ET_0 is reference crop ET or potential ET, mm d^{-1}, and Kcis crop growth stage coefficient. The Kcvaries with crop, development stage of the crop, and method used to determine ET_0. Kcincreases from planting to full development of the crop, and declines thereafter until maturity. Crop ET determined using lysimeters (Tripathi et al., 1987), and ET_0 estimated from Jensen and Haise (1963) method have been used to calculate Kcfor important crops of this region.

Computation of Reference crop evapotranspiration, ET_0

The Jensen – Haise method (1963), method will be utilized for computation of ET_0, mm d^{-1} by

$$ET_0 = C_T (T - T_X) Rs \times 0.0171 \qquad ...(2)$$

Where T is mean daily air temperature, ^{0}C, and Rsis daily solar radiation, cal cm^{-2} d^{-1}. The factor 0.0171 converts Rsinto equivalent depth of evaporation in mm. C_T is air temperature coefficient, $degree^{-1}$, calculated as

$$C_T = \frac{1}{C_1 + C_2 C_H} \qquad ...(3)$$

in which,

$C_1 = 38 - (2^0C.\ \text{elevation in m}/305)$ ...(4a)

$C_2 = 7.6^0C$, and $C_H = \frac{50\,mb}{e_2 - e_1}$ ...(4b)

where e_2 and e_1 are saturation vapour pressures in mb at mean maximum and mean minimum air temperatures, respectively, during the warmest month in the area based on long-term monthly temperature records. The T_X is calculated as

$T_X = -2.5 - 0.14\,(e_2 - e_1)\ ^0C/mb - \text{elev. in m}/550$ ...(5)

Both C_T and T_X are constants for the area. Daily maximum and minimum temperatures, and Rscan be taken from the meteorological observatory. Daily Rs can also be estimated for Pantnagar situations from bright sunshine hour, n, as (Tripathi, 1992)

$Rs = 34.98\,n + 155.83, \quad R^2 = 0.73$

Results: Values of crop coefficients for Yellow Mustard var. Pant Pili Serson-1 computed based on ETp calculated and ET determined by Lysimeters for two consecutive years 2012-13 and 2013-14 are given in Table 4.9

Table 4.9 Crop Coefficients (Kc) for Yellow Mustard var. Pant Pili Serson-1 at Pantnagar

Weeks after sowing	Kc	Weeks after sowing	Kc
1	0.17	10	0.68
2	0.43	11	1.02
3	0.60	12	0.60
4	0.56	13	0.40
5	0.65	14	0.55
6	0.50	15	0.48
7	0.60	16	0.33
8	0.60	17	0.38
9	0.93	Av.	0.56

The average Kc (crop coefficient) for Mustard cv. Pant Pili Serson-1 is 0.56. It ranges from 0.17 (sowing time) to 1.02 at flowering & pod formation stage. The Kc values increased till 11th week after sowing and decreased thereafter. It remained below 1.0 at all the stages except flowering and pod formation stage.

4.1.3 Pollution of water resources due to industries in Kashipur industrial cluster of Uttarakhand state

In the study of pollution of water resources due to industries in Kashipur Industrial cluster of Uttarakhand State it was found that the turbidity, the total suspended solids, the BOD and the COD values in the effluent at all the sampling sites were out of permissible limits (BIS norms). The ground water at Parmanandpur I and Parmanandpur II located on downstream side of effluent channel-II (towards Kosi river) from Cheema Paper Ltd. and Multiwal Paper & Board Factory sites was found in C3-S2 class which indicated that the ground water at these two locations was moderately alkaline in nature and cannot be used for irrigation on all type of soils without proper drainage practices.It was concluded that effluents of both the effluent channels were affecting the ground water resources in the area.

Contour maps of concentration of the total dissolve solids and the alkalinity show that the higher concentrations of these parameters were present near Petrol pump, Parmanandpur I, Parmanandpur II (Fig 4.2 and 4.3). These observation points were at downstream side of effluent channel-II (toward Kosi river) from Cheema Paper Mill, Multiwal Paper & Board Factory. Therefore, it was concluded that there industrial cluster was polluting the ground water of the region and the concentration of the several parameters were increasing near the factories/industries.

Different parameters viz. Mg: Ca ratio, Percent Na, ESP, SAR and SSP were estimated for the assessment of the quality of the effluents from

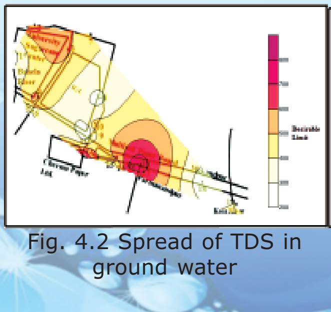


Fig. 4.2 Spread of TDS in ground water

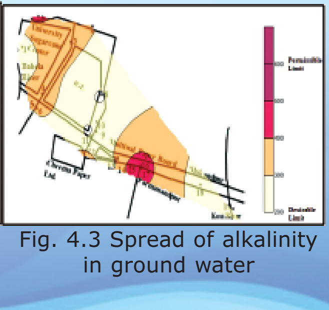


Fig. 4.3 Spread of alkalinity in ground water

Indian Glycol Ltd., Multiwal Paper & Board Factory, Cheema Paper Mill, water quality of Kosi river and ground water of nearby study area. The categorization, for their suitability for irrigation, was done on the basis of criteria given by Richard (1954), Wilcox's (1955) and Wescot and Ayers (1984). The values of different parameters estimated for the assessment of water quality for irrigation are given in table 2. The Mg:Ca ratio is an important parameter for the assessment of water quality for irrigation, when its value is higher than 4. Therefore, in addition to salinity and SAR, Mg: Ca ratio was considered while judging the suitability of water for irrigation. The Mg: Ca ratio values were found to be less than 4 in all the effluent and Kosi river water as well as ground water samples. As Mg: Ca ratio was found less than 4 in all of the samples of surface water and ground water, therefore it can be concluded that the effect of Mg: Ca ratio will be very less on the quality of water for irrigation.

Table 4.10. Irrigation suitability Categorization of water on the basis of criteria given by Wescot and Ayers (1984)

Problem	Parameter	Class	Limits	Locations
Salinity (affects the availability of crop water)	EC (ds/m)	None	<0.70	Kosi river, Artesian well at Sugarcane Research Center, DhouriPratha II, DhouriPratha (D.H.P.), Sangam sweets, Punjabi Dhaba, Glyscol material gate (D.H.P.), Jaishankar tea stall, Railway crossing (D.H.P.), Mazar and Multiwal gate (D.H.P.)
		Slight to moderate	0.70-3.0	IGL effluent, DhouriPratha culvert, Sugarcane Research Center site I, Sugarcane Research Center culvert, Railway bridge, Cheema Paper Mill outlet, Multiwal outlet, Multiwal after mixing with Cheema Paper Mill effluent, Jindal farm, Mazar effluent, Mukandpur, Kosi bank, Sugarcane Research Ccenter gate, Glycol gate no.1, DhouriPratha I, Tea stall at Cheema Paper Mill, Multiwal Gate, Petrol pump, Parmanandpur I and Parmanandpur II
		Severe	> 3.0	-
	TDS (mg/l)	None	< 450	Kosi river, Artesian well at Sugarcane Center, DhouriPratha II, DhouriPratha (D.H.P.), Sangam sweets, Punjabi Dhaba, Glycol material gate (D.H.P.), Jaishankar tea stall, Railway crossing (D.H.P.), Multiwal gate, Multiwal gate (D.H.P.) and Mazar
		Slight to moderate	450-2000	IGL effluent, DhouriPratha culvert, Sugarcane Research Center site I , Sugarcane Research Center culvert, Railway bridge, Cheema Paper Mill outlet, Multiwal outlet, Multiwal after mixing with Cheema Paper Mill efflunt, Jindal farm, Mazar effluent,

Problem	Parameter	Class	Limits	Locations
				Mukandpur, Kosi bank, Sugarcane Research Center gate, Glycol gate no.1, DhouriPratha I, Tea stall at Cheema Paper Mill, Parmanandpur I, Petrol pump and Parmanandpur II
		Severe	>2000	
Specific ion toxicity (affects the sensitivity of the crops)	Sodium absorption ratio (SAR)	None	< 3.0	Kosi river, Artesian well at Sugarcane Research Center, DhouriPratha I, DhouriPratha II, DhouriPratha (D.H.P.), Punjabi Dhaba, Glycol material gate (D.H.P.), Railway crossing (D.H.P.), Mazar, Sangam sweets and Multiwal gate (D.H.P.)
		Slight to moderate	3.0-9.0	IGL effluent, Cheema Paper Mill outlet, Multiwal outlet, Multiwal after mixing with Cheema Paper Mill effluent, Jindal farm, Mazar,Mukandpur, Kosi bank, Sugarcane Research Center gate, Glycol gate no.1, Jaishankar tea stall, Tea stall at Cheema Paper Mill and Multiwal gate,
		Severe	>9.0	DhouriPratha culvert, Sugarcane Research Center site I, Sugarcane Research Center culvert, Railway bridge, Petrol pump, Parmanandpur I, andParmanandpur II
Permeability (affects the infiltration rates of water in to soil)	SAR and EC (ds/m)	None	0-3 & > 0.7	DhouriPratha I
			3-6 & > 1.2	-
			6-12 & > 1.9	-
			12-20 & > 2.9	-
		Slight to moderate	0-3 & 0.7-0.2	Artesian well at Sugarcane Research Center, DhouriPratha II, DhouriPratha (D.H.P.), Sangam sweets, Punjabi Dhaba, Glycol material gate (D.H.P.), Railway crossing (D.H.P.), Mazar and Kosi river and Multiwal gate (D.H.P.)
			3-6 & 1.2 -0.3	Sugarcane Research Center gate, Glycol gate no.1, Tea stall at Cheema Paper Mill, Jaishankar tea stall, Multiwal gate, Multiwal outlet and Mazar effluent

Problem	Parameter	Class	Limits	Locations
			6-12 & 1.9-0.5	Jindal farm, IGL effluent, DhouriPratha culvert, Sugarcane Research Center site I, Sugarcane Research Center culvert, Railway bridge, Cheema Paper Mill outlet, Multiwal after mixing with Cheema Paper Mill effluent, Mukandpur, Kosi bank, Petrol pump, Parmanandpur I and Parmanandpur II
			12-20 & 2.9-1.3	-
		Severe	0-3 & <0.2	-
			3-6 & <0.3	-
			6-12 & < 0.5	-
			12-20 & <1.3	-

4.2 Belvatagi

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

In Malaprabha command area, water released in to the canal at the end of Aug and Sept first week every year for irrigation. Adopting different land configuration like 120 cm width raised bed recorded significantly higher maize yield in all years and in pooled analysis over normal sowing. The irrigation at 0.6 IW/CPE ratios recorded significantly higher yield over other treatments. It also recorded higher gross returns (Rs. 60,337), net returns (Rs.42, 837) and B: C ratio (3.1) and WUE (14.2 ha mm) (Table 4.10). The interaction between irrigation levels and land configuration showed that, irrigating the crop at 0.6 IW/CPE ratio with 120 cm width raised bed recorded higher yield (64.49 q/ha) over 0.8 IW/CPE ratio and normal sowing (I_1L_1), 0.8 IW/CPE ratio and 60 cm width raised bed (I_1L_2), 0.6 IW/CPE ratio and 60 cm width raised bed (I_2L_2) and 0.8 IW/CPE ratio and 60 cm width raised bed (I_1L_2) Table (4.11-4.12).

The chickpea grown after maize also responded to the application of water at different IW/CPE ratio levels. Irrespective of land configuration and irrigating the crop at 0.6 IW / CPE ratio recorded higher yield (13.35 q/ha in pooled analysis) compare to other treatments in all the years except during 2011-12 and 2012-13. Among the different land configurations 120 cm width of raised bed recorded higher yield (13.94 q/ha) over 60 cm width raised bed (11.90 q/ha) and normal sowing (12.2 q/ha). The interaction between irrigation and land configuration shows that , an irrigation at 0.6 IW/ CPE ratio with 120 cm width raised bed recorded higher yield over irrigation at 0.8 and 0.4 IW/CPE ratio with normal or 60 cm width raised bed. The former treatment in pooled analysis also recorded higher gross income (Rs.35, 500), net income (Rs.15,823) and B:C ratio (2.21) and water use efficiency (5.15 kg/ha mm) (Table 4.11).

Table 4.11 Effect of irrigation levels and land configurations on Net income for maize crop

TREATMENTS	Net income (Rs/ ha)			
	2011-12	2013-13	2014-15	Pooled
Irrigation levels (I)				
I_1 = 0.8 IW/CPE	22036	34625	53737	36799
I_2 = 0.6 IW/CPE	24135	31862	60219	38739
I_3 = 0.4 IW/CPE	26459	34803	59754	40339
SEm±	630	350	415	465
CD(0.05)	954	1052	1439	1148
Land configurations (L)				
L_1 = Normal sowing	34038	24650	49570	36086
L_2 = 60cm width raised bed	33605	22007	57543	37718
L_3 = 120 cm width raised bed	35942	25973	66597	42837
SEm±	449	7068	991	2836
CD(0.05)	1335	9684	2944	4654
Interaction effect (IXL)				
I_1L_1	36801	23441	45043	35095
I_1L_2	28896	21747	54249	34964
$I_1 L_3$	45054	20920	61918	42630
I_2L_1	32534	25157	52663	36784
I_2L_2	26779	20935	59730	35814
$I_2 L_3$	36274	26314	68264	43617
I_3L_1	32789	25352	51004	36381
I_3L_2	45139	23339	58649	42375
$I_3 L_3$	26490	30686	69610	42262
SEm±	778	768	717	754
M X S CD(0.05)	2312	2355	2156	2274

Table 4.12 Effect of irrigation levels and land configuration on water use efficiency (WUE) for chick pea crop

TREATMENTS	WUE, Kg / ha.mm					
	2009-10	2010-11	2011-12	2012-13	2013-14	Pooled
Irrigation levels (I)						
I_1 = 0.8 IW/CPE	2.38	4.57	3.79	6.03	3.79	4.19
I_2 = 0.6 IW/CPE	2.67	3.97	4.45	6.5	4.45	4.39
I_3 = 0.4 IW/CPE	3.3	4.27	4.88	7.36	4.88	4.95
SEm±	0.12	0.42	0.13	0.26	0.129	0.21
CD(0.05)	0.44	1.45	0.32	0.91	0.316	0.68
land configurations (L)						
L_1 = Normal sowing	2.53	3.78	3.79	4.28	3.79	4.22
L_2 = 60cm width raised bed	2.76	2.92	3.25	5.97	3.25	3.87
L_3 = 120cm width raised bed	3.26	6.11	5.07	7.14	5.07	5.34
SEm±	0.15	0.24	0.12	0.21	0.12	0.16
CD(0.05)	0.47	0.73	0.25	0.86	0.25	0.51
Interaction effect (I XL)						
I_1L_1	2.22	3.99	3.1	6	3.10	3.68
I_1L_2	2.26	3.22	3.65	5.62	3.65	3.68
I_1L_3	2.66	6.5	4.62	6.47	4.62	4.97
I_2L_1	2.29	3.58	3.9	6.75	3.90	4.08
I_2L_2	2.77	2.77	4.32	5.75	4.32	3.98
I_2L_3	2.96	5.58	5.12	7	5.12	5.15
I_3L_1	3.07	3.67	4.37	7.6	4.37	4.61
I_3L_2	3.26	2.79	4.8	6.55	4.60	4.44
I_3L_3	3.58	8.05	5.47	7.95	4.87	6.26
SEm±	0.25	0.54	0.21	0.39	0.10	0.34
M X S CD(0.05)	0.76	1.62	0.6	1.18	0.32	1.03

4.3. Gayeshpur

4.3.1 Integrated nutrient-water management for sunflower

The changes in simulated moisture situations brought significant changes in plant height, basal girth, CGR, NAR, seed yield, harvest index and water use efficiency and better seed yield, harvest index and water use efficiencies were supported under 50% depletion of soil moisture in sun flower. Integrated management of nutrients influenced the plant height, basal girth, dry matter accumulation, seed yield, harvest index and water use efficiencies significantly over chemical fertilizers where boron fertilization (F3) and bacterial fertilizers (Azotobacter and PSB) along with boron supported highest values. The nutrient-moisture interactions also showed remarkable promise in improving water use efficiencies, yield attributing parameters and augmenting yields. Crops grown under 50% depletion of available soil moisture, supported by integrated fertilizer NPK supplemented with bacterial fertilizers and substantiated with boronated fertilizers (I_2F_5) turned up with highest seed yield manifested through best efficiency of water use.

Total N, P, K uptake (kg/ha) by hybrid sunflower at harvesting stages as affected by irrigation at varying ASMD level and INM Simulation of the moisture situations failed to exert any significant influence on NPK uptake by sunflower while integrated management of nutrient brought significant changes in N, P uptake by sunflower although effect of their interactions (moisture x INM) were significant in K uptake only. Sunflower internal efficiencies (IE) to recover NPK from soils were also derived from the uptake database and effects of simulated moisture situations and INM packages were assessed. The INM treatments and moisture x INM interaction significantly influenced the IE_k while IE_N values were significantly influenced by moisture situations. Precisely, total NPK uptake and sunflower IE_{NPK} were facilitated at 50% ASMD of ASW (I_2) and also supported by F_5 (NPK+ FYM + azotobacter + PSB + boronated fertilizer) and F_4 (NPK+ FYM + azotobacter + PSB) respectively.

The recoveries of available NPK from post harvest soils were observed to decrease with depth of sampling. Moisture situations and INM packages alone and in combination brought significant changes in NPK availabilities in post-harvest soils of sunflower. Increasing moisture stresses (70% MAD of ASW>50% MAD of ASW>30%MSD of ASW) significantly and progressively reduced NPK availabilities at all depth of sampling. Recommended doses of chemical NPK administration ($N:P_2O_5:K_2O$::80:60:40 kg/ha) recovered highest available NPK from 30 cm of sunflower post-harvest soils while chemical NPK supplemented with bacterial azotobacter, PSB and boronated fertilizer (F_5) restored higher available NPK at 60 and 90 cm soil depths. The effect of nutrient-moisture interaction on NPK availabilities in sunflower post-harvest soils did not follow a definite pattern although plants receiving NPK + bacterial fertilizers + boronated fertilizer at 30% ASMD of ASW (I_1F_5) supported highest soil nutrient recoveries in major occasions

Water use and its efficiency by sunflower varied with variation of irrigation water applied to soil. Relative water content (RWC) of leaf was directly related to irrigation. RWC was observed maximum (79.085%) at I1. Highest water use in the profile up to 0-90cm was maximum in case of I1 i.e. at 30 % ASMD level followed by I2 (50% ASMD) and I3 (70 % ASMD). Depletion of available moisture was found maximum in I3 (70 % ASMD). But the highest water use efficiency was found maximum in case of I2 (50% ASMD). Interaction effect of available soil moisture and INM showed a significant increase in water use efficiency. Depletion of available soil moisture decreased with increasing irrigation. Amount of available soil moisture gradually decreased with decrease in amount of irrigation I1>I2>I3.

4.4 Jorhat

4.4.1 Integrated approach using remote sensing and GIS techniques for mapping of groundwater prospects in Jorhat district, Assam

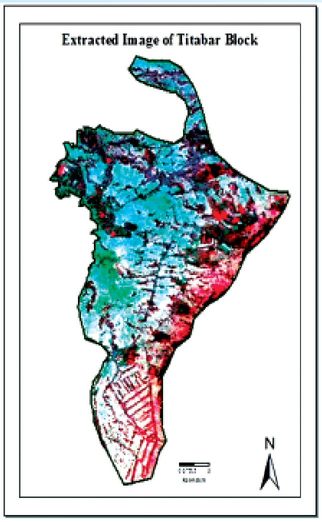
Out of the 336 numbers of geo-referenced observations recorded from 56 villages of Jorhat district covering all eight blocks, pre-monsoon ground water table depths ranged from 2.22 to 17.58 m bgl. Area (in sq.km) under each category of pre-monsoon ground water potential zone is furnished below:

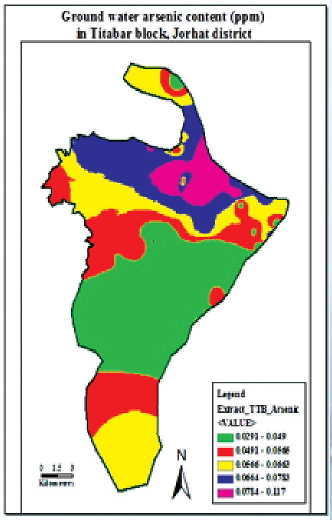
Groundwater prospect mapping using Remote sensing and Geographic Information System (GIS) as tool for demarcating the potential ground water resource during pre-monsoon season for the entire Jorhat district covering 2852 sq.km was completed highlighting with area-wise groundwater potential information in the form of map. Maximum area (739.50 sq. km) was observed in groundwater table depth of 6.16 – 6.82 m bgl and minimum (78.34 sq. km) in groundwater table depth of 4.20-4.95 m bgl. Based on the depth of groundwater resource, selection of pump suitable for lifting water and possibility of using such pump to irrigate unit area were prepared in the form of map. Post-monsoon groundwater potential zone mapping is in progress.

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

Forty-two (42) water samples were collected from different locations of Titabar subdivision covering 7 villages viz. Nagajanka, Bacha bihari, Garmuria, Katoni, Kathpar, Borera and Deka gaon. The sources of the water samples were PHE outlet, STW, Hand tube well etc. Tube wells were operated at least 10 minutes before collection to flash out the stagnant water inside the tube and to get fresh ground water.

Two sets of water samples from each location were collected in clean 500 ml Poly-propylene bottles. In one set, the samples were collected directly in the rinsed bottles without using any preservatives for immediate analysis of Arsenic while, in the other, samples were collected similarly with addition of preservative (HNO_3 @ 1%). Analysis for the samples with preservative may be delayed for a maximum period of 6 months. Immediately after collection of water samples, the bottles were sealed and transported to the laboratory under ambient temperature. Samples were collected during January-February' 2013 and analyses for As were done in the month of March 2013.





Water samples collected from three villages viz. Nagajanka, Bacha bihari and Garmuria gaon, showed Arsenic contamination in 67% samples based on the bench mark value of National Drinking Water Standard. The remaining four villages viz. Katoni, Kathpar, Borera and Deka gaon had only 50% samples contaminated with Arsenic.

Table 4.13. Arsenic content in groundwater

GW Arsenic content (ìg/ml)	Area (Sq.km)	Total Arsenic content(ìg/g) in soil	Area (Sq.km)
0.029-0.049	183.12	0.428-0.667	195.98
0.049-0.056	132.47	0.667-0.755	122.55
0.056-0.066	130.44	0.755-0.892	96.36
0.066-0.078	104.43	0.892-1.025	119.23
0.078-0.117	82.43	1.025-1.33	98.77

GW arsenic content in most of the paddy soils ranged from 0.029 to 0.117ìg/ml resembling with 29 to 117 ppb, which showed far above the critical value of 10 ppb set by WHO. Maximum area of 183.12 sq. km was seen in the category of 0.029 – 0.049 ìg As/ml and minimum area of 82.43 sq. km was noticed in the category of 0.078 to 0.117 ìg As/ml. Interestingly, total arsenic content in most of the paddy soils ranged from 0.428 to 1.33 ìg/g which did not show any residual toxicity of arsenic so far. Maximum area of 195.98 sq. km was observed with arsenic content of 0.428 to 0.667 ìg/g and minimum area (98.77 sq. km) was noticed in the category of 1.025 – 1.33 ìg/g. Highest concentration was noticed towards north-western part of Titabar and comparatively lowest value was recorded in eastern part of central Titabar.

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

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. In respect of Arsenic concentration of the study area, data revealed that nearly 44% samples had their arsenic content less than 30 ppb while, 34%

samples showed 30-40ppb showing maximum concentration of 40-50 ppb in 17% samples. Both arsenic and fluoride content in the soils as well as in rice plants are in the verge of analytical phase. 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. Nearly, 80% samples had fluoride concentration of less than 0.15 mg/L while, 7% had more than 0.2 mg/L. Of the total sample analyzed, 7.3% samples had more than 0.5 mg/L fluoride concentration which showed comparatively higher value in comparison to the rest of the samples. Regarding arsenic concentration of the study area, data revealed that nearly 44% samples had their arsenic content less than 30 ppb while, 34% samples showed 30-40ppb highlighting maximum concentration of 40-50 ppb in 17% samples. Both arsenic and fluoride content in the soils as well as in rice plants are in the verge of analytical phase.

4.4.4 Sustainability of water resources of Brahmaputra basin

Scarcity of fresh water in the face of increasing demand to sustain agricultural and industrial growth in India is a major concern for policy planers, scientists and water professionals. Brahmaputra is an important river system having highest amount of unutilized water resources. However growing demand for water in the basin requires an in depth study. This work is an attempt to study the Brahmaputra river water system through a system dynamics model. The model has been tested with time series data of Brahmaputra basin for 30 years. Test scenario generation using the model suggests that water consumption pattern for Brahmaputra Basin has showed a rising trend during years 2025- 2050. The water availability in the River Basin has showed wide seasonal variation. The water supply remained more or less same whereas the consumption has been rising; therefore water availability status for the basin has been going down over the years. With the present consumption pattern the basin will face water scarcity during the lean season (December to February) before the year 2050. Flood storage reservoir to store excess water during high flood and augment flow during lean season may be a viable option

4.5 Bhavanisagar

4.5.1 Evaluation of alternate wetting and drying irrigation (AWDI) in transplanted rice in western zone of Tamil Nadu

Among the different irrigation levels,irrigation after 20 cm drop in ponded water in field water tubes (DPW) upto maximum tillering stage (30-35DAT) (from seven days after transplanting) received lowest quantum of irrigation water as compared to other treatments. The results revealed that, irrigation after 15 cm drop in ponded water in field water tubes (DPW) upto maximum tillering stage (30- 35DAT) (from seven days after transplanting) was recorded highest water use efficiency of 5.38 and which is followed by Irri. after 15 cm DPW - upto PI stage (45DAT – 50 DAT) and afterwards irrigation 10 cm DPW upto 10 days prior to harvest.The results revealed that, irrigation after 15 cm drop in ponded water in field water tubes (DPW) upto maximum tillering stage (30- 35DAT) (from seven days after transplanting) and after that 10 cm DPW up to 10 days prior to harvest was found to be the best treatment in terms of grain yield and B C ratio. However, the highest WUE was recorded in the treatment of

4.5.2 Alternate wetting and drying irrigation regimes management through field water tube device in rice in western zone of Tamil Nadu

The grain yield of rice was significantly influenced by the irrigation treatments. Significantly higher grain yield of 5972 kg ha^{-1} was registered under the conventional irrigation practice of recouping 5 cm submergence one day after disappearance of ponded water (T_8) followed by irrigation after 15 cm DPW uptomaximum tilleringand continuous submergenceupto 10 days prior to harvest (T_5) recorded grain yield of 5855 kg ha^{-1} and it was on par with T_8. This was followed by scheduling irrigation after 15 cm DPW uptopanicle initiation and continuous submergence upto 10 days prior to harvest (T_7), irrigation after 10 cm DPW from 7 DAT to 10 days prior to harvest (T_1) and irrigation after 15 cm DPW from 7 DAT to 10 days prior to harvest (T_2) in registering comparable yields of 5726, 5650 and 5455 kg ha^{-1}, respectively and the treatments were statistically on par with T_8 and T_5.

Scheduling irrigation after 20 cm DPW from 7 DAT to 10 days prior to harvest (T_3) recorded lower

Table 4.14: Effect of treatments on Water use and water use efficiency

Treatments		Irrigation water applied (cm)	Effectve Rainfall (mm)	Total water used (mm)	Yield (kgha^{-1})	WUE (kg/ ha.mm)
T_1 -	Irri. after 10 cm DPW - from transplanting to 10 days prior to harvest	1250	141	1391	4131	2.97
T_2 -	Irri. after 15 cm DPW – from transplanting to 10 days prior to harvest	800	141	941	5061	5.38
T_3 -	Irri. after 20 cm DPW – from transplanting to 10 days prior to harvest	700	141	841	4237	5.04
T_4 -	Irri. after 15 cm DPW – upto max tillering (30- 35DAT) and afterwards irri. after 10 cm DPW upto 10 days prior to harvest	stage 1050	141	1191	5201	4.37
T_5 -	Irri. after 15 cm DPW - upto max tillering stage (30-35DAT) and continuous submergence upto 10 days prior to harvest	1200	141	1341	4558	3.86
T_6 -	Irri. after 15 cm DPW - upto PI stage (45DAT – 50 DAT) and afterwards irri. after10 cm DPW upto 10 days prior to harvest	900	141	1041	4798	5.19
T_7 -	Irri. after 15 cm DPW - upto PI (45 DAT- 50 DAT) and afterwards continuous submergence upto 10 days prior to harvest.	1100	141	1241	4808	4.16
T_8 -	Farmers practice - Irrigation to 5 cm depth one day after disappearance of ponded water	1550	141	1691	4611	2.73

Table 4.15 : Economics of treatments

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross income (Rs.)	Expenditure (Rs.)	Net income (Rs.)	B:C ratio
T_1	4131	5649	58257	36187	22070	1.61
T_2	5061	5564	67302	36187	31115	1.86
T_3	4237	6331	61363	36187	25176	1.70
T_4	5201	6413	71249	36187	35062	1.97
T_5	4558	6561	65263	36187	29076	1.80
T_6	4798	6501	67483	36187	31296	1.86
T_7	4808	6805	68495	36187	32308	1.89
T_8	4611	6664	66102	36187	29915	1.83

grain yield of 4819 kg ha^{-1} and was significantly inferior to the rest of the treatments. The cost of cultivation under various treatments ranged from ₹28,638 to 29,793 ha^{-1}. The highest gross return of 78,269 ha^{-1} and net income of 48,476 ha^{-1} were realised under conventional irrigation practice (T_8) followed by irrigaion after 15 cm DPWuptomaximum tillering and continuous submergenceupto 10 days prior to harvest (T_5) and both the treatments recorded the maximum B: C ratio of 2.62. Lower monetary returns with minimum B: C ratio of 2.19 was realized under irrigation at 20cm DPW from 7 DAT to 10 days prior to harvest (T_3).

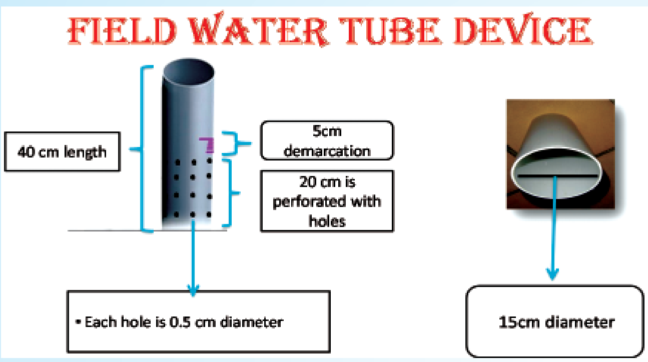


Fig.4.1 Field water tube device

Table 4.16 :Effect of AWDI on grain yield and straw yield

Treat-ments	Cost of cultivation (ha^{-1})	Gross income (ha^{-1})	Net income (ha^{-1})	B:C ratio
T_1	29133	74117	44984	2.54
T_2	28803	71595	42792	2.48
T_3	28638	62830	34192	2.19
T_4	28968	66443	37475	2.29
T_5	29298	76781	47483	2.62
T_6	28968	69365	40395	2.39
T_7	29298	74730	45405	2.55
T_8	29793	78269	48476	2.62

4.5.3 Alternate wetting and drying irrigation regimes management through field water tube device in rice

Similarly, the net return and the BC ratio were higher with the treatment adopted with irrigation after 15 cm drop below ground in the water level

Table 4.17 Economics of Alternate Wetting and Drying Irrigation

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_{1}- Irrigation after 10 cm DPW	5650	6328
T_{2} - Irrigation after 15 cm DPW	5455	6130
T_{3}- Irrigation after 20 cm DPW	4819	5461
T_{4}- Irrigation after 15 cm DPW upto maximum tillering and 10 cm DPW there after	5410	5569
T_{5}- Irrigation after 15 cm DPW upto maximum tillering and continuous submergence thereafter	5855	6481
T_{6}- Irrigation after 15 cm DPW upto panicle initiation and 10 cm DPW thereafter	5317	5916
T_{7}- Irrigation after 15 cm DPW upto panicle initiation stage and continuous submergence thereafter	5726	6349
T_{8}- Conventional irrigation practice (recouping 5 cm submergence one day after disappearance of ponded water)	5972	6581
S E_d 261	302	
CD (p= 0.05)	546	631

of the field tube continuously (T2- Rs.93,305; 2.33)followed by irrigation after 15 cm drop below ground in the water level of the field water tube upto panicle initiation (50 DAT) and 10 cm drop there after (T6 –Rs.90,337; 2.29). The higher water use efficiency of 9.0 kg/ha/mm and water productivity of 184.27Rs./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). It was closely followed by the irrigation after 15 cm drop below ground in the water level of the field water tube upto panicle initiation (50 DAT) and 10 cm drop there after (T6 – 8.3; 169.73) and irrigation adopted after 10 cm drop below ground in the water level of the field water tube upto 10 days prior to harvest (T2 – 8.3; 169.21).

4.6 Ludhiana

4.6.1 Impact of climate change on irrigation energy requirements and crop production in Ludhiana district

In the previous year, simulations for crop duration and water- balance were run using CropSyst model by Stockleet al (1994). In the CropSyst model, daily weather files were prepared from the observed data. The soil files for Ludhiana district were made using the data reported by Sharma (2004). Irrigation events were calculated based

Table 4.18 Effect of irrigation regimes on Grain yield (kg/ha), Straw yield (kg/ha), Harvest Index and Economics

Treatments	Grain yield (kg/ha)	Harvest index	Gross return Rs./ha	Cost of cultiva-tion Rs./ha	Net return Rs./ha	BC ratio	WUE kh/ ha/ mm
T_1 Water level 10cm below ground upto 10 days prior to harvest	7677	0.45	1,57,310	70,135	87,175	2.24	8.3
T_2 Water level 15cm below ground upto 10 days prior to harvest	7946	0.44	1,63,230	69,925	93,305	2.33	9.0
T_3 Water level 20cm below ground upto 10 days prior to harvest	6599	0.42	1,36,830	70,135	66,695	2.05	7.8
T_4 Water level 15cm below ground upto AT stage (30 - 35DAT) and at 10cm below ground upto 10 days prior to harvest.	7407	0.46	1,51,104	70,135	80,969	2.15	7.9
T_5 Water level 15cm below ground upto AT stage (30 -35 DAT) and continuous submergence upto 10 days prior to harvest.	7273	0.45	1,48,962	70,135	78,827	2.12	7.2
T_6 Water level 15cm below ground upto PI stage (45DAT – 50 DAT) and at 10cm below ground upto 10 days prior to harvest.	7811	0.44	1,60,262	69,925	90,337	2.29	8.3
T_7 Water level 15cm below ground upto PI stage (45 DAT-50 DAT) and continuous submergence upto 10 days prior to harvest.	7138	0.44	1,46,800	70,135	76,665	2.09	7.0
T_8 Farmer's Practice	6465	0.43	1,33,610	70,555	63,055	1.89	5.6
SEd	447						
CD (P=0.05)	960						

on IW/CPE ratio and were added to management file of CropSyst. The soil water balance model, used to assess the percolation losses from fields, incorporates several features to facilitate estimation of percolation losses on daily basis. The population projections for 2021, 2031, 2041 and 2051 were found to be 3675400, 4210480, 4745560 and 5280640 respectively and accordingly the projected built-up land was computed as 43844.93, 47790.97, 58782.9 and 72302.97 hectares respectively. Thus, area under built-up which is presently 10 per cent of district area would increase to 12, 13, 16 and 20 per cent by 2021, 2031, 2041 and 2051 consequently causing reduction in agriculture area from 85 to 75 per cent by 2050.

Climate projections

The Hadley Centre of United Kingdom has developed PRECIS, a regional climate model (RCM) system which has been adopted in this research for generating projections of some specific climatic parameters, such as total monthly precipitation and temperature. The PRECIS RCM is based on the atmospheric component of the HadCM3 climate model and is extensively described in Jones et al. (2004). Simulated climate outputs from PRECIS RCM for the present (1961–1990, baseline) near term (2021–2050, midcentury) and long term (2071–2100, end-century) for A1B IPCC SRES socioeconomic scenario (characterized by a future world of rapid economic growth, global population that peaks in the mid-century and declines thereafter, and rapid introduction of new and more efficient technologies, with the development balanced across energy sources) were used to study the Ludhiana district of Punjab. Bias correction of the temperature data was carried out using Leander &Buishand (2007)and rainfall data were corrected using a daily difference approach. The data for 5 years were averaged for each of the time slices and were computed to nullify the effect of yearly variability. A perusal of the figures reveals that by the end of this century, the maximum and minimum temperature will increase by 5.5° C and 6° C, respectively, indicating that warming will be pronounced in the region. There will be variation in rainfall trends i.einterdecadal variability will be prominent in rainfall trends but overall it shows an increasing trend. The model results also indicated an increase of by 37 per cent by the end of century (Fig. 4.2.). Monthly trends (averaged over years in each time slice) showed that change in RF would be positive in all the months of MC and EC compared to that of the PTS, except in months of June and September (Figure 4.2). The highest positive change in RF would be in the month of July, which was computed as 104 mm in MC and 193 mm in EC.

On seasonal basis, in MC and EC, T_{max} would increase by 3.6° C and 6.7° C during kharif season; and 2.4° C and 4.8° C in rabi season, respectively. In MC, the change in T_{max} would be positive in all months except in February, March and April. Highest positive change would be of 5.8°C in the month of June and negative change of 1.3° C in the month of March. In EC, the change in T_{max} would be positive in all the months and the maximum positive would be 8.1° C in the month of October. Similarly, the increase in T_{min} would be 3.5° C and 7.1° C in kharifseason; and 2.2° C and 4.3° C in MC and EC in rabi season, respectively. On monthly basis, in MC there would

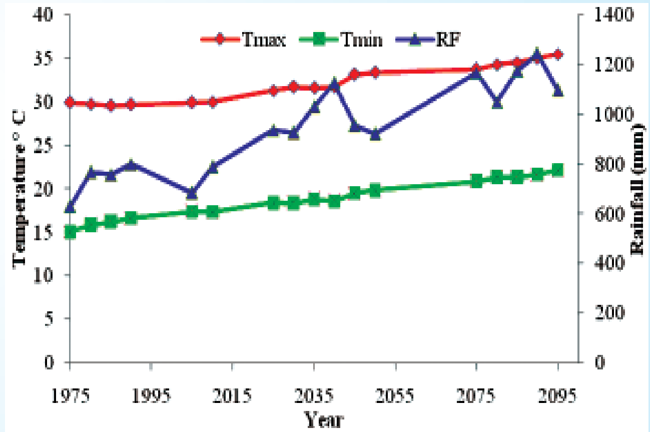


Fig. 4.2. Monthly variation in rainfall in different years in past and under A1B Scenario

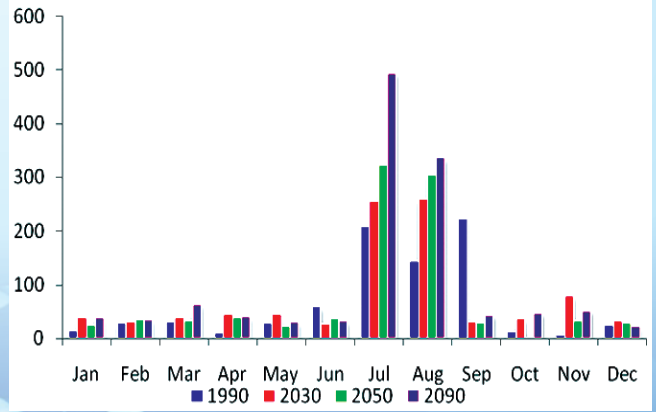


Fig. 4.3 Monthly variation in rainfall in different years in past and under A1B Scenario

be positive change in T_{min} in 11 months with highest of 4.8°C in the month of August; and negative in one month (April) by 0.4°C. In EC, the change would be positive in all the months with highest of 9.1°C in the month of August.

Crop yield

Simulated crop yields of rice-wheat cropping system in the PTS, MC and EC for four soil series are presented in Table 4.18. Averaged across soil series, yield of rice in MC and EC would be reduced by 701 kg/ ha (10.6%) and 1355 kg/ ha (20.5%), respectively from 6606 kg/ha in the PTS. Yield of wheat in MC would be almost identical to that in PTS (5642 kg/ ha) but in the EC it would be reduced by 708 kg/ ha (12.5%).

Due to increase in built up area in future, the agricultural area under different soil types would decrease as computed in Table 4.19.

may marginally increase to1460.9 thousand metric ton (0.2%) in MC and reduced to 1274.8 thousand metric tons (12.5%) in EC.

Crop duration

Reduction in yields of rice and wheat crops in climate change scenarios was found to be directly related to increased T_{max} and T_{min}. The increase in temperature would shorten the crop duration. In MC and EC (averaged over soil series), crop duration would be shortened by 17 days (16.3%) and 24 days (23.1%) in rice; and 8 days (5%) and 22 days (13.4%) in wheat, respectively. Rice yield in MC and EC would decrease almost in all the years compared to that of the PTS. Yield of wheat would decrease in 7 out of 30 years in MC and 13 out of 28 years in EC. Though wheat yield would decrease in less number of years but the magnitude of decrease would be more than rice, especially in EC.

Table 4.19. Yield (kg/ha) of rice-wheat cropping system as influenced by different time slices of the century and soil type

Crop	Time Slice	Soil type				
		Loamy sand	Sandy loam	Loam	Silt loam	Average
Rice	Present time slice	4971	6050	7358	8045	6606
	Mid century	5422	5754	6198	6248	5905
	End century	5019	5200	5383	5403	5251
Wheat	Present time slice	5043	5177	6068	6281	5642
	Mid century	5158	5303	6056	6097	5654
	End century	4522	4701	5249	5263	4934

Table 4.20. Present and Projected agricultural area (thousand ha) under different soil types

Soil Type	2005	2011	2021	2031	2041	2051
Loamy sand	27.6	27.5	27.2	27.0	26.6	25.9
Sandy loam	101.3	100.4	98.2	96.8	93.0	88.3
Loam	158.1	156.8	153.6	151.5	145.7	138.5
Silt loam	29.0	28.8	28.2	27.9	27.1	26.1
Total	**316**	**313.5**	**307.2**	**303.2**	**292.4**	**278.8**

Therefore on spatial scale, the average yield of adequately irrigated and fertilized rice for Ludhiana district in the PTS is 2117 thousand metric tons, which may reduce to 1803 thousand metric ton (14.8%) in MC and 1473 thousand metric ton (30.4%) in EC during kharif season (Table 3 and Fig. 3). However, in rabi, wheat yield in PTS is 1457.8 thousand metric ton which

Irrigation water requirements

The irrigation water requirement for different type of soils and time slices is presented in Fig. 5.Averaged over four soil types, there is 45 per cent reduction in irrigation water requirement by mid and end century during kharif season. In Rabi season the irrigation water requirement is decreased by 22 per cent and 34 per cent by the mid and end century respectively. On annual basis, about 40 per cent reduction in irrigation water requirement of Ludhiana district is expected under A1B scenario, in both MC and EC in comparison to PTS. The maximum irrigation requirement, in kharif season, would decrease from 1240.9 (2002-03) to 716.7 mm during MC (2035-36) and 785 mm in EC (2076-77), and correspondingly the minimum irrigation requirement of 721.4 mm (2003-04) in PTS would reduce to 335.0 (2034-35) and 275.0 (2095-96) mm in MC and EC respectively. In rabi season, maximum irrigation requirement would reduce from 481.6 to 431.1 and 332.0 mm in MC (2028-29) and EC respectively, and correspondingly the minimum irrigation requirement of 331.6 mm (2004-05) in PTS would be decreased to 205.6 (2034-35) and 175.0 (2073-74) in MC and EC respectively.

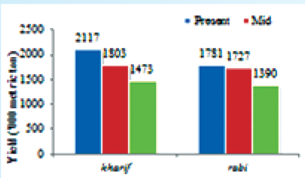


Fig.3 Effect of A1B Scenario on crop yield ('000 metric ton) of Ludhiana district

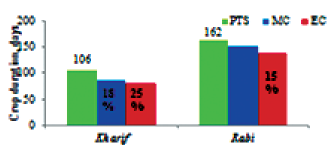


Fig. 4 Effect of A1B Scenario on crop duration (days)of rice – wheat cropping system

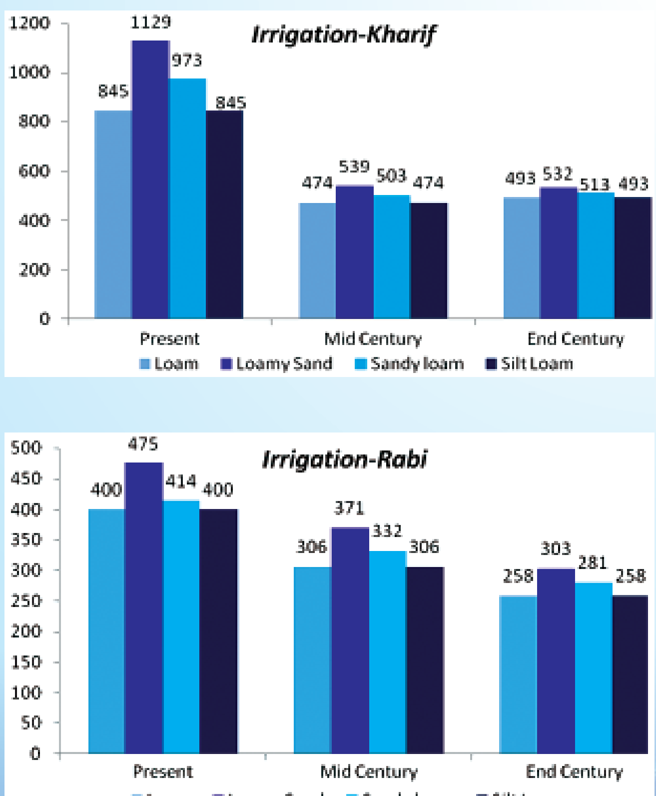


Fig.4.4 Irrigation water requirement under A1B scenario in different soil types

The spatial variability of irrigation requirement blockwise in kharif and rabiare given in Table 4. The average annual irrigation requirement was computed as 415.8, 243.6 and 215.6 thousand ha-m for PTS, MC and EC. The irrigation requirement ranged from 14.8 to 37.2, 7.6 to 19.6 and 7.0 to 19.4 thousand ha-m during kharif and 6.8 to 16.7, 5.0 to 12.8 and 3.7 to 10.4 thousand ha-m during rabi in PTS, MC and EC in various blocks of the districts. This variation was mainly due to spatial variation in area under agriculture, soil profile that has been accounted. Overall, the irrigation requirement in MC and EC would decrease by 139.5 thousand ha-m(48.7%) and 146.4 thousand ha-m (51.0%) during the kharifseason; and 32.7 thousand ha-m (25.3%) and 53.8 thousand ha-m (41.7%) in rabiseason, respectively .

4.7 Navasari

4.7.1 Feasibility of drip irrigation in summer paddy

The results of grain yield of paddy influenced by different treatments reported in table 4.20 revealed that individual effect of variety (V) and spacing(L) as well as their interactive effect (V x L) were conspicuous on grain yield of paddy. Variety V_1 (GNR-3) (between two varieties) and treatment L_2 (among three lateral spacing) levels recorded significantly higher grain yield of paddy in comparison to their respective other levels. Treatment V_1L_2 out yielded than rest of the treatments by recording significantly higher yield of paddy i.e., 6263 kg/ha. With respect to control v/s rest analysis, only treatment V_1L_2 (GNR-3 at 20x20x40 cm spacing) recorded significantly higher grain yield as compared to control-1 (GRN-3-Flood irrigation), while rest of the treatments were recorded significantly lower yield as compared to control-1. In case of control-2 (NAUR-1) v/s rest analysis, almost similar trend was observed, except treatment V_1L_3 (GNR-3 at 20x20-60 cm spacing) which recorded significantly higher yield in comparison to control-2 and treatments V_1L_1 and treatment V_2L_2 remained at par with control-2. In case of control V/ L treatment mean analysis both the controls were significantly superior over treatment mean.

4.7.2 Drainage demonstrations on farmers' fields in UKC

Since completion of Indo-Dutch Net work project in 2003, about 62 farmers have installed CSSD/

Table 4.21: Grain yield (kg/ha) of summer paddy as influenced by different treatments

Treatment/ Variety	Lateral Spacing (cm) L_1 (40)	L_2 (60)	L_3 (80)	Mean (V)
V_1 – GNR-3	4287	6263	4477	5009
V_2 – NAUR-1	1741	4188	1538	3749
Mean(S)	3014	5225	3007	
Control-1 (GNR-3) mean	4876	Cont-2 (NAUR-2) mean	4116	
Source	V	L	V x L	
SEm±	83	68	117	
CD @5%	240	196	339	
	Cont.-1/Rest	Cont-2/Rest	Cont-1 / treatment mean	Cont-2/ treatment mean
SEm±	130	93	171	211
CD at 5%	376	266	492	349
CV %	11.17			

OSSD system covering about 56.09, 28.57 and 42.70 ha area with drain spacing of 30-40, 40-50 and 50-60 m, respectively in Surat(Tapi), Bharuch and Navsari district of South Gujarat under only technical guidance of this unit. Whole cost of the system was borne by the farmers. These farmers are cultivating array of crops in CSSD/OSSD installed fields. On overall basis, they have reported about 40-50 per cent increase in crop yields (Table 4.22). Apart from yield increase, they also experienced early vapsa condition in fields which facilitate timely interculturing and thereby minimize weed and disease infestation.

4.8 Palampur

4.8.1 Soil–plant water dynamics under protected conditions in relation to drip based irrigation & fertigation scheduling in cucumber.

Table 4.22: Details of SSD demonstrations completed on farmers' fields (2003 to 2014)

SN	District	Drain spacing (m)	Name of farmers	Crop taken	Area covered (ha) CSSD	OSSD	Total	Increase in yield over pre drainage yield(%)
1	Surat	30-40	16	S'cane Cotton	36.84	-	36.84	25-40
	Bharuch		4	S'cane, Cotton	12.10	-	12.10	20-25
	Navsari		2	S'cane Banana Mango Vegetables Rose	5.40	-	5.40	30.35
	Tapi		1	Sugarcane	1.75	-	1.75	-
	Sub total	**23**		**56.09**		**56.09**		

2	Surat	40-50	19	S'cane Cotton Wheat Vetetable	25.47	1.50	26.97	15-40
	Bharuch		-	-	-	-	-	-
	Navsari		1	S'cane Vegetables Rose	1.60	-	1.60	30-40
	Sub total	**20**		**22.07**	**1.50**	**28.57**		
3	Surat	50-60	12	S'cane Cotton Wheat Mango Vegetable Sapota	20.40	2.0	22.40	20-50
	Bharuch		5	S'cane	7.80	10	17.80	30-40
	Navsari		2	Mango Sapota	2.50		2.50	15-20
	Sub total	**19**		**30.70**	**12.0**	**42.70**		
	Gross total	**62**		**113.86**	**13.50**	**127.36**		

Application of 200 per cent RDF (50 % through conventional and 50 % through fertigation in 7 splits at 10 days interval) resulted in significantly higher marketable yield of cucumber than that obtained at all other levels of fertigation. Application of 200 per cent RDF (50 % through conventional and 50 % through fertigation in 7 splits at 10 days interval) resulted in 33.94 per cent higher marketable yield, 33.45 per cent higher B: C ratio and 33.95 per cent higher water use efficiency than that obtained by the application of 100 per cent RDF (25 % applied as basal and 75 % through fertigation in 7 splits at 10 day interval).Fertigation schedulinginteracted significantly with irrigation scheduling in respect of marketable yield, water use efficiency and economics of cucumber (Table 4.23). A progressive increase in marketable yield of cucumber was recorded with increase in fertigation scheduling from 50 to 150 per cent at both levels of irrigation scheduling. However, increase in marketable yield was not significant when fertigation was increased from 100 to 150 per cent under irrigation schedule of 0.4 CPE. Application of 200 per cent RDF (50 % through conventional and 50 % through fertigation in 7 splits at 10 days interval) resulted in significantly higher marketable yield of cucumber than that obtained at any other levels of fertigation under irrigation schedule of 0.4 CPE as well as under irrigation schedule of 0.8 CPE. Irrigation scheduling had no effect on marketable yield of cucumber when the crop was fertigated with 50 per cent RDF (25 % applied as basal and 75 % through fertigation in 5 splits at fortnightly interval) or 200 per cent RDF (25 % applied as basal and 75 % through fertigation in 20 splits at 3 day interval). Irrigation scheduled at 0.8 CPE resulted in significantly higher marketable yield of cucumber than that obtained at 0.4 CPE when it was fertigated with any other levels of fertigation. The application of 200 per cent RDF (50 % through conventional and 50 % through fertigation in 7 splits at 10 days intervals) and drip irrigation at 0.8 CPE resulted in significantly higher cucumber yield (7.97 kg m^{-2}) compared to all other combinations of fertigation and irrigation scheduling.

Table 4.23 : Effect of different treatments on productivity, water use and economics of cucumber under protected condition

Treatment	Marketable yield (kg m^{-2})	TWU ($m^3 m^{-2}$)	WUE (kg m^{-3})	B.C ratio
Irrigation scheduling				
0.4 CPE	3.92	0.068	57.65	1.61
0.8 CPE	4.36	0.136	32.06	1.91
CD (P = 0.05)	0.43			
Fertigation scheduling				
50 % RDF	4.05	0.102	39.71	2.12
100 % RDF	5.54	0.102	54.31	2.96
150 % RDF	6.08	0.102	59.61	3.05
200 % RDF	5.03	0.102	49.31	2.14
200 % RDF (50 % Conventional & 50 % fertigation)	7.42	0.102	72.75	3.95
CD (P = 0.05)	0.68			
Control vs others				
Control	4.87	0.156	31.22	4.84
Others	5.82	0.102	57.06	2.88
CD (P = 0.05)	0.71			
Farmers' Practice vsfertigation				
Farmers' Practice	5.63	0.156	36.09	2.38
Fertigation	5.62	0.102	55.10	2.75
CD (P = 0.05)	NS			

Table 4.24. Interaction effect of fertigation scheduling and irrigation scheduling on marketable yield (kg m^{-2}) of cucumber

Fertigation scheduling	Irrigation scheduling	
	0.4 CPE	0.8 CPE
50% RDF	4.03	4.07
100 % RDF	5.00	6.13
150 % RDF	5.73	6.42
200 % RDF	4.90	5.17
200 % RDF (50 % Conventional & 50 % fertigation)	6.87	7.97
CD (P = 0.05)	0.33	

4.9 Ludhiana

4.9.1 Impact of climate change on irrigation energy requirements and crop production in Ludhiana district

The study was continued to understand the impact of climate change on irrigation water requirement and agricultural production at local scale in Ludhiana district. Simulated CropSyst model was used to estimate the impact of climate change on crop yield, crop duration and irrigation requirements. Simulated climate outputs from PRECIS RCM for the present (1961–1990, baseline) near term (2021–2050, midcentury) and long term (2071–2100, end-century) for A1B IPCC SRES socioeconomic scenario (characterized by a future world of rapid economic growth, global population that peaks in the mid-century and declines thereafter, and rapid introduction of new and more efficient technologies, with the development balanced across energy sources) were used to study the Ludhiana district of Punjab. Bias correction of the temperature data was carried out and rainfall data were corrected using a daily difference approach.

A perusal of the data reveals that by the end of this century, the maximum and minimum temperature will increase by 5.5° C and 6° C, respectively, indicating that warming will be pronounced in the region. There will be variation in rainfall trends i.e interdecadal variability will be prominent in rainfall trends but overall it shows an increasing trend. The model results also indicated an increase of by 37 per cent by the end of century (Fig4.5).

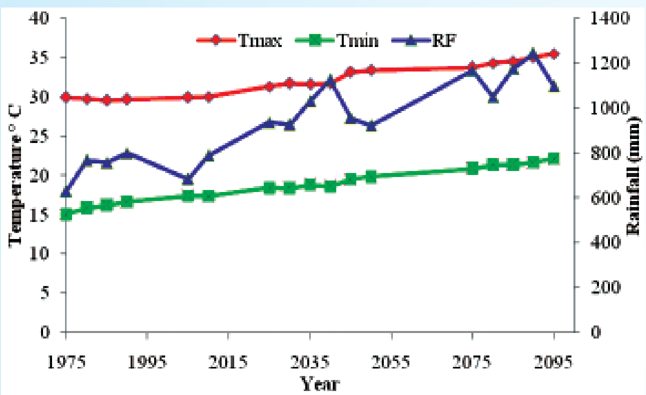


Fig. 4.5 Monthly variation in rainfall in different years in past and under A1B Scenario

Crop yield

Simulated crop yields of rice-wheat cropping system in the PTS, MC and EC for four soil series are presented in Table 1. Averaged across soil series, yield of rice in MC and EC would be reduced by 701 kg/ ha (10.6%) and 1355 kg/ ha (20.5%), respectively from 6606 kg/ha in the PTS. Yield of wheat in MC would be almost identical to that in PTS (5642 kg/ ha) but in the EC it would be reduced by 708 kg/ ha (12.5%). It was predicted that the average yield of adequately irrigated and fertilized rice for Ludhiana district may reduce by 14.8% in MC and by 30.4% in EC during kharif season. However, in rabi, wheat may marginally increase by 0.2% in MC and reduced by 12.5% in EC. In MC and EC (averaged over soil series), crop duration would be shortened by 17 days (16.3%) and 24 days (23.1%) in rice; and 8 days (5%) and 22 days (13.4%) in wheat, respectively. Rice yield in MC and EC would decrease almost in all the years compared to that of the PTS.

Irrigation water requirements

The irrigation water requirement for different type of soils and time slices is presented in Fig. 4.6. The maximum irrigation requirement, in kharif season, would decrease from 1240.9 (2002-03) to 716.7 mm during MC (2035-36) and 785 mm in EC (2076-77), and correspondingly the minimum irrigation requirement of 721.4 mm (2003-04) in PTS would reduce to 335.0 (2034-35) and 275.0 (2095-96) mm in MC and EC respectively. In rabi season, maximum irrigation requirement would reduce from 481.6 to 431.1 and 332.0 mm in MC (2028-29) and EC respectively, and correspondingly the minimum irrigation requirement of 331.6 mm (2004-05) in PTS would be decreased to 205.6 (2034-35) and 175.0 (2073-74) in MC and EC respectively. The irrigation requirement in MC and EC would decrease by 48.7% and by 51.0% during the kharif season; and 25.3% and 41.7% in rabi season, respectively.

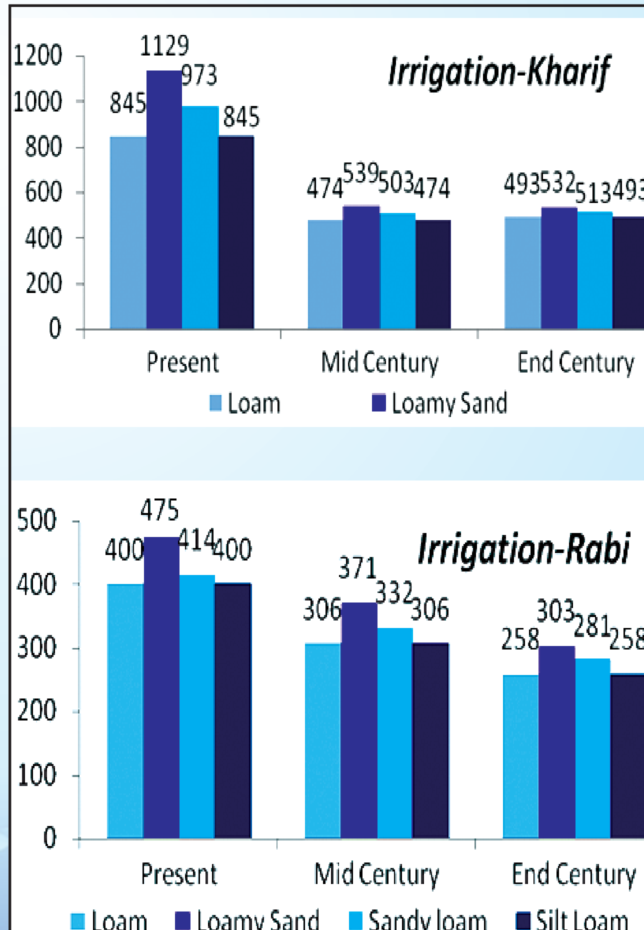


Fig.4.6 Irrigation water requirement under A1B scenario in different soil types

4.10. Coimabatore

4.10.1 Assessment of surface and groundwater quality and waste water reuse in Amaravathy basin and developing management strategies for agriculture

Amaravathi river basin at the downstream of Karur Town in Tamil Nadu is severely polluted due to discharge of partially treated effluent by the textile bleaching and dyeing units. The values on electrical conductivity showed an increasing trend during various season and the values ranged from 0.29 – 2.46 dsm^{-1}.The sodium ions in the groundwater samples collected from the various seasons was found to vary between 1.58 – 9.22 me L^{-1}. The groundwater in the tail end of the Amaravathy river basin near Aravakurichi, Nagampalli and Karur areas showed deviation from water quality standards recording 65.7 and 28.5 per cent samples under high and medium salinity class indicating groundwater contamination. Regarding irrigation suitability based on EC and Sodium Absorption Ratio (SAR - >10), the groundwater in the tail end of the basin is under high salinity hazard when used for irrigation. Proper soil management strategies are to be adopted in the major part of the Karur district while using groundwater for irrigation. The result of the field experiment conducted is presented in table.4.25.

The yield increase in gypsum application treatment was 17 % more than without gypsum application and the yield increase due to vermicompost application was 34 % more than control.

Other management practices recommended are

- Artificial recharge structures such as percolation pond, check dams, recharge pit, recharge shaft, contour trench, shall be constructed in

Table 4.25. Effect of different management strategies on yield attributes and yield of bhendi in Amaravathy basin

Treatments	No. of seeds/fruit			100 seeds weight (g)			Yield/plot (kg $plot^1$)			Yield ha (t ha^{-1})		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1 Control	35.4	32.1	33.7	5.80	5.10	5.45	18.2	15.8	17.0	9.10	8.25	8.67
S_2 RDF	38.6	35.5	38.0	6.72	5.71	6.21	21.4	16.3	18.8	10.70	8.88	9.79
S_3 RDF+FYM 12.5 t/ha	41.5	32.8	37.1	7.22	6.22	6.72	24.2	17.5	20.8	12.60	10.10	11.35
S_4 RDF+ Vermicompost 5t/ha	42.8	34.6	38.7	7.85	6.75	7.30	26.4	18.9	22.6	13.80	11.20	12.50
S_5 RDF+ Biocompost 5t/ha	42.6	33.2	37.9	7.57	6.56	7.06	25.3	18.1	21.7	13.10	11.30	12.20
S_6 RDF + Green Leaf Manure 6.25 t/ha	40.6	31.7	36.1	7.15	6.12	6.63	22.6	16.8	19.7	11.30	10.14	10.72
Mean	40.4	33.4	36.9	7.05	6.07	6.56	23.0	17.2	20.1	11.76	9.98	10.87
	SEd	CD (0,05)		SEd	CD (0,05)		SEd	CD (0,05)		SEd	CD (0,05)	
S	0.87	1.94		0.15	0.34		0.46	1.04		0.25	0.56	
M	0.26	0.56		0.05	0.10		0.14	0.31		0.08	0.17	
S x M	0.98	2.17		0.17	NS		0.53	1.17		0.28	0.63	
M x S	0.63	1.38		0.11	NS		0.35	0.77		0.19	0.41	

M_1 - with gypsum and M_2 - without gypsum

Amaravathi river basin area so as to augment the ground water recharge by way of rain water harvesting.

- Indiscriminate sand mining in the river bed had depleted the aquifer recharge rate. Sand mining in the river bed should be banned atleast for 5 years.
- Existing ponds / tanks should be cleaned, protected and properly managed and dumping of municipal solid waste in the tanks / ponds should be banned
- The application of chemical fertilizers and pesticides should be gradually reduced and replaced by biodegradable compost and other substitutes.
- Farmers should be educated for optimum use of groundwater for irrigation and to go for drip and sprinkler type irrigation.

4.11. Rahuri

4.11.1 Development of crop coefficients for sweet corn

The study was undertaken to develop the crop coefficient values of important different crops of the region, from the locally available measurements on crop evapotranspiration from lysimetric experiments and corresponding estimates of reference crop evapotranspiration; and develop the crop coefficient equations. Accordingly Sweet Corn was considered.

Methodology

Crop coefficient (Kc) is the ratio of crop evapotranspiration (ETc) to reference crop evapotranspiration (ETr) as given by following equation

$$Kc = \frac{ETc}{ETr}$$

The weekly values of crop coefficients were computed for sweet corn as the ratio of weekly crop evapotranspiration and weekly reference evapotranspiration. Weekly sweet corn evapotranspiration data were available from the lysimeters installed on the Experimental Farms of the AICRP on Water Management, MPKV, Rahuri for three years years 2010, 2011 and 2013. As the crop evapotranspiration values were available for two lysimeters, the ETc values were averaged over both the lysimeters to compute the crop coefficient values and deleting some erroneous measurements.

Finding

The crop coefficient curves were developed for the reference crop evapotranspiration estimated by Penman Monteith. 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 two three years (2011 and 2013). These equations are presented below. The results from the year 2010 were not consistent and hence ignored.It is seen that the polynomial equation of 5th order is the best fit as it gives the maximum value of regression coefficient for the three years. The average Kc values were obtained from the Kc polynomial equations of fifth order of two years. These Kc curve for the polynomial equations of 5th order is presented in Figure 7.1.

The proposed Kc equation is

$$Kc_t = -8.523(t/T)^5 + 31.21(t/T)^4 - 38.39(t/T)^3 + 17.82(t/T)^2 - 2.174(t/T) + 0.659 \quad R^2 = 0.99$$

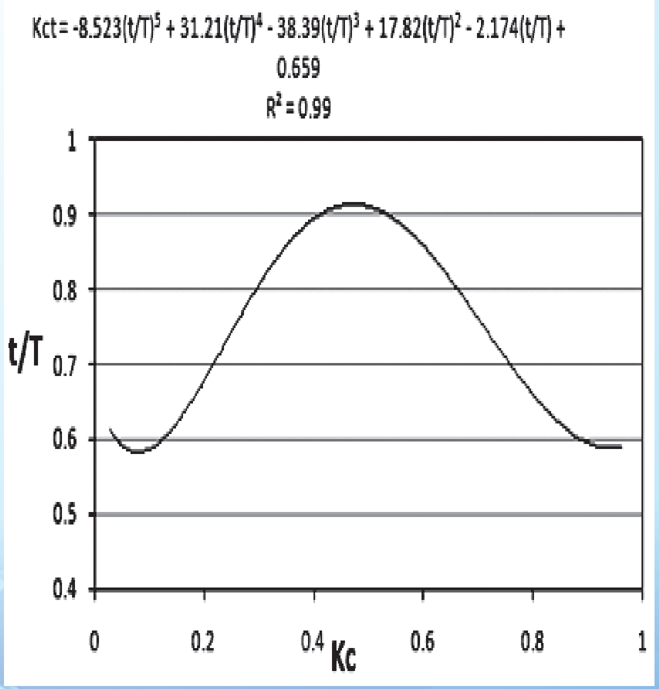


Figure 5.6.1: Kc curves for sweet corn for ETr estimated by Penman Monteith method

Table 4.26. Average weekly crop coefficient values for sweet corn

Week since sowing	Kc
1	0.61
2	0.58
3	0.63
4	0.71
5	0.80
6	0.87
7	0.91
8	0.91
9	0.89
10	0.83
11	0.77
12	0.70
13	0.63
14	0.60
15	0.59

4.11.2 Estimation of consumptive use of water by 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 presented in Table 4.27. The onion bulb and stalk yield both from lysimeter and field were 2.60, 0.75, 11300 and 3200 kg, respectively. The harvest index of lysimeter and field were 0.77 and 0.77 respectively. The moisture depletion was monitored daily and data in respect of ET, EP of crop were 458.8, 711.6 mm respectively. The irrigation water applied after considering moisture depletion at 50 mm CPE. The average ET was 4.12 and EP was 6.58. The average ET/EP ratio was 0.62. The maximum ET/EP ratio was 0.8 at bulb development stage. There by slightly declining upto bulb enlargement stage. The lowest ET/EP was noticed at maturity stage 0.5.From the table 1 (b) the ET and EP during entire growth period of onion was 458.8 and 711.6 mm respectively. The ET/EP ratio was maximum 0.8 bulb development stage and lowest was at maturity stage 0.5.

Table 4.27. Yield and WUE of Onion and other climatological parameters rabi 2014-15

Sr. No.	Particulars	Values	
1.	Crop and Variety	Onion (N-2-4-1) seed to bulb production	
2.	Season	Rabi	
3.	Duration	113 days	
4.	Total ET	458.8 mm	
5.	Total EP	711.6 mm	
6.	Average ET	4.1 mm	
7.	Average EP	6.3 mm	
8.	ET / EP Ratio	0.65 mm	
9.	Yield	**Tank (Kg)**	**Field (t/ha)**
	Main produce (bulb)	2.60	11.30
	Stalk	0.75	3.20
	Total bio mass	3.35	14.50
10.	Harvest index	0.77	0.77
11.	WUE (kg/ha cm)	**Tank**	**Field**
	Seed yield	269.05	
	Stalk	76.18	
12.	No. of irrigation applied	6	
13.	Total depth of irrigation water applied	42	
14.	Total rainfall received during the growth period	37.8 mm	

4.11.3 Effect of polluted groundwater due to sugar factory effluent on yield of wheat crop and soil properties

The untreated effluents from sugar factory and distillery and paper mill are dumped into lagoons and Nag Odha, respectively. These effluents seep into the adjacent wells and thus the well water is being polluted day by day. The water of the wells in the area adjoining the lagoon is highly polluted and lowly polluted away from the lagoon. Depending on the concentration of different anions and cations in the effluents, the crop yield grown in the area is influenced. Due to the irrigation

Table 4.28. ET/ EP, at various growth stage of Onion - Variety (N-2-4-1) rabi 2014-15

Physiological growth stage	Duration (days)	ET (mm)	EP (mm)	Average ET(mm)	Average EP (mm)	ET/ EP ratio
Transplanting to vegetative	43	139.3	211.1	3.2	4.9	0.6
Bulb development	20	86.9	101.3	4.3	5.1	0.8
Bulb enlargement	33	162.1	251.2	4.9	7.6	0.6
Maturity	17	70.5	148.0	4.1	8.7	0.5
Total / Average	113	458.8	711.6	4.12	6.58	0.62

with well water the soil adjoining to the lagoon is also polluted. The experiment is therefore, undertaken to know the influence of the application of different combination of low, medium and high polluted well water and normal well water on the yield in the polluted soil. The experiment was conducted on the farmer's field (Shri.Gunjal Mohan Vitthal) in Survey No. 508 of village Deolali Pravara for low polluted well water, Shri.Pansambal Karbhari Tukaram in Survey No. 101 of village Chinchvihire for medium polluted well water and Shri.Deshmukh Ganesh Madhukar in Survey No. 79 of village Chinchvihire for highly polluted well water located near Rahuri sugar factory area. The Wheat crop of Varity Trimbak (NIAW-301) was sown on 02.12.2013. Fertilizer dose was applied as per the recommendation. The crop is in the field observations are being taken and reporting will be done after harvest of the crop.

Theme V

To evolve management strategies for conjunctive use of surface water, groundwater and wastewater resources for sustainable crop production.

5.1 Almora

5.1.1. Soil moisture and nutrient dynamics in wheat-soybean rotation

Soil moisture and nutrient dynamics in wheat-soybean rotation under irrigated conditions showed that grain yield of wheat was affected significantly due to treatments. The significantly higher grain yield was recorded in all the treatment in comparison to control. Application of recommended NPK+ 10 t FYM /ha recorded significantly highest grain yield (55.4 q/ha) followed by 120 kg N + 10 t FYM /ha (50.2 q/ha). The significantly higher yield of 28.7 q/ha was recorded by the application of FYM in comparison to N alone (23.8 q/ha). The gross returns and gross returns per mm applied water followed the same trend. There was a significant higher net return observed by the application of NPK+FYM, N+FYM, NPK, and NPK in both the season in comparison to application of alone FYM, or alone N and control. The loss was observed in control (no application of FYM or fertilizer). The average profile moisture was higher in FYM consisting treatments in comparison to control and alone application of fertilizer. The WEE and WUE followed the same trend as of grain yield. During the crop season 236.2 mm rainfall was received and 2 irrigations of each 50 mm were applied. The experiment results revealed that the higher water use efficiency and higher returns per mm applied water can be achieved by application of balanced fertilizer.

Soybean: The seed yield of soybean was affected significantly due to the residual effect of fertilization .The highest seed yield (23.1 q/ha) was recorded in NPK+FYM whereas minimum in control (14.0 q/ha). The highest residual effect on soybean seed yield was recorded with NPK + FYM. The residual affect was in the order of NPK + FYM (9.1 q/ha), N+FYM (8.0 q/ha), FYM (7.1 q/ha) NPK (3.6 q/ha) and N effect was negative (-1.9 q/ha) over the control. The residual effect of NPK +FYM, N+ FYM, FYM was higher than direct effect of NPK +NPK (4.8 q/ha). The values of water expense efficiency ranged from 2.7 to 4.6 kg/ha/

Table5.1 Bulb yield and water use of onion as influenced by irrigation levels

Treatments	Bulb yield (q/ha)	PMC (±)	Irrig (mm)	WE (mm)	WEE (kg/ha mm)	WUE (kg/ha mm)	Gross returns (ooo Rs/ha	Gross returns (per mm applied water in 000 Rs/ha)
Drip								
IW: CPE 0.6	138.8	-52.6	41.4	334.0	41.6	47.8	155.5	3.75
IW: CPE 0.8	146.6	-52.1	60.0	352.1	41.6	47.5	164.2	2.74
IW: CPE 1.0	169.1	-49.0	81.0	370.0	45.7	51.8	189.4	2.34
IW:CPE 1.2	149.8	-38.5	103.8	382.3	39.2	44.2	167.8	1.62
Check basin								
IW: CPE 0.8	126.7	-50.3	100	390.3	32.5	36.6	141.9	1.42
IW: CPE 1.0	130.1	-57.4	100	397.4	32.7	36.8	145.7	1.46
IW:CPE 1.2	149.4	-69.2	100	409.2	36.5	40.9	167.3	1.67
CD (P=0.05)	NS							
Drip Mean	151.1	-48.0	71.6	359.6	42.0	47.9	169.2	2.61
Check basin mean	135.4	-56.2	100.0	399.0	33.9	38.1	151.6	1.79

mm. The gross, returns and gross returns per mm-applied as well as net returns and net returns per mm applied of water followed the same trend.

5.1.2 Effect of irrigation schedule on onion

The mean onion yield (151.1 q/ha) under drip irrigation was higher in comparison to check basin irrigation (135.4 q/ha).The highest yield (169.1 q/ha) was obtained under drip irrigation scheduled at 1.0 IW: CPE ratio followed by drip irrigation scheduled at 1.2 IW: CPE ratio. The lowest yield (126.7 q/ha) was recorded under check basin irrigation scheduled at the rate of 0.8 IW: CPE ratio (Table 5.1). The gross returns were calculated on the basis of whole sale price (Rs 1120 per quintal) of Haldwani market.

5.1.3 Effect of irrigation schedule on Garlic

The mean garlic yield (101.7 q/ha) under drip irrigation was higher in comparison to check basin irrigation (78.7 q/ha) and farmer practice (80.4 q/ha).The highest yield (118.7 q/ha) was obtained under drip irrigation scheduled at 11.0 (CPE-R) followed by drip irrigation scheduled at 10.8 (CPE-R) .The lowest yield (71.6 q/ha) was recorded under drip irrigation scheduled at the rate of 0.8 IW: CPE ratio(Table 5.2).

5.2 Belvatagi

5.2.1 Evaluation of different cropping systems under different water available

Evaluation of different cropping systems under different water available release situations showed that water released during July middle recorded significantly higher maize equivalent yield of 94.81 q/ha and was on par with July end water release situation (79.38 q/ha) (Table 5.3). August middle and August end water release situation recorded significantly lowest maize equivalent yields. Full season maize hybrid followed by chickpea recorded significantly highest MEY of 102.58 q/ha compared to all other cropping systems. The next best system was Sunflower hybrid followed by chickpea with 77.03 q/ha. Bt cotton recorded the lowest MEY (36.37 q/ha). However, this system was on par with early maize hybrid followed by

Table 5.2 Garlic Bulb yield and water use of irrigation levels

Treatments	Bulb yield (q/ha)	PMC (±)	Irrig (mm)	WE (mm)	WEE (kg/ha mm)	WUE (kg/ha mm)	Gross returns (ooo Rs/ha	Gross returns (per mm applied water in 000 Rs/ha)
Drip								
0.4 (CPE-R)	91.0	-65.1	105.6	413.7	22.0	24.4	176.93	1.68
0.6 (CPE-R)	97.0	-67.3	160.2	470.5	20.6	22.6	188.62	1.18
0.8 (CPE-R)	100.2	-73.7	212.4	529.1	18.9	20.5	194.81	0.92
1.0 (CPE-R)	118.7	-69.6	264.6	577.2	20.6	22.1	230.86	0.87
CB IW: CPE 0.8	71.6	-51.0	200	494.0	14.5	15.8	139.34	0.70
CB IW: CPE 1.0	85.8	-68.6	200	511.6	16.8	18.2	166.85	0.83
Farmer practice	80.4	-52.5	200	495.5	16.2	17.7	156.42	0.78
Drip Mean	101.7	-68.9	185.7	497.6	20.5	22.4	197.8	1.16
Check basin mean	78.7	-59.8	200.0	502.8	15.6	17.0	153.1	0.77
CD (P=0.05)	12.48							

Total Rainfall= 243.0 Effective rainfall =201.7

Table 5.3 Effect of different cropping systems under water available situations on Maize Equivalent Yield (q/ha) of 2013-14

	Maize–Chickpea (full season maize hybrid)	Maize (PEEHM5) Chickpea (early maize hybrid)	Maize (PEEHM5) Safflower (early maize hybrid)	Sun-flower Chick-pea	Bt cotton	Maize (PEEHM5) Durum wheat	Mean
July middle	141.60	111.44	79.26	131.48	53.09	51.98	94.81
July end	123.82	85.05	71.89	96.36	51.08	47.60	79.38
August middle	101.29	63.06	52.11	58.10	31.22	48.22	59.00
August end	43.61	21.39	21.67	22.19	10.06	29.17	24.68
Mean	102.58	70.35	56.23	77.03	36.37	44.24	
			SEm	CD			
	Water Release	6.25	21.64				
	Cropping systems	3.86	11.02				
	Interaction	9.42	26.90				

Table 5.4 Effect of different cropping systems under water available situations on Water Use Efficiency (kg/ha mm) of 2013-14.

	Maize–Chickpea (full season maize hybrid)	Maize (PEEHM5) Chickpea (early maize hybrid)	Maize (PEEHM5) Safflower (early maize hybrid)	Sun-flower Chick-pea	Bt cotton	Maize (PEEHM5) Durum wheat	Mean
July middle	17.71	13.94	9.91	16.44	6.64	6.50	11.86
July end	15.40	10.64	8.95	11.99	6.36	5.92	9.88
August middle	13.12	8.17	6.75	7.53	4.04	6.25	7.64
August end	7.97	3.91	3.96	4.05	1.84	5.33	4.51
Mean	13.55	9.16	7.39	10.02	4.72	5.99	
			SEm	CD			
	Water Release	0.78	2.71				
	Cropping systems	0.54	1.54				
	Interaction	1.26	3.59				

wheat (44.24 q/ha). Similar results were obtained with the water use efficiency (Table 5.4).

5.3. Chalakudi

5.3.1 Production system for high water use efficiency in Cauliflower

Evolving a production system for high water use efficiency in Cauliflower showed that online drippers were superior to inline drippers with regard to yield and water use efficiency and irrigation at 80% PE recorded the highest yield (Table 5.5). Application of boron at 5 kg/ ha had significant influence on the yield and WUE of Cauliflower. Among the different interaction effects, method and levels of irrigation had significant influence on the yield and WUE of cauliflower. With respect to yield of cauliflower per plant yield and per hectare yield was highest in treatment receiving irrigation at 80 % PE through online drippers followed by online drippers receiving water at 60 % PE. The maximum WUE was realized for irrigation at 60% PE through online drippers. Application of boron at 5 kg/ ha had significant influence on the yield and WUE of Cauliflower.

Soil nutrient dynamics under varying moisture regimes in banana: Banana under Drip Irrigated Condition showed that biometrical observations on growth and yield parameters showed that application of P at 75% and K at 125% (T4) of RDF was found to be better. Second year crop planted in Nov 2014 is in the field and treatments are being imposed.

5.3.2 Evaluation of different integrated weed management practices under modified water regimes in SRI

The paddy var. MTU1010 of 120-130 days duration was cultivated under different water regimes and weed management methods during the year 2013-14. The results obtained are presented in Table 5.6. Tiller number (45) and yield (45.15 q ha^{-1}) were significantly higher in as compared to rest other irrigation treatments (Table 5.6). Among weed management methods, number of tillers was significantly higher in W_2, whereas number of panicle per plant, length of panicle, number of filled grain per panicle and yield (54.52 q ha^{-1}) were significantly higher in W_4 .The variation in

Table 5.5 Effect of irrigation methods and fertilizer levels on yield of banana

Factor-Airrigation methods	Factor-Bfertilizer levels		Mean
	Basin	Drip at 75%PE	
NPK-100-100-100	6.547	7.330	6.938
NPK-100-100-125	7.773	7.690	7.732
NPK-100-75-100	7.917	6.618	7.268
NPK-100-75-125	8.767	7.527	8.147
NPK-100-50-100	7.630	6.635	7.133
NPK-100-50-125	7.770	7.247	7.508
Mean	7.734	7.174	

Table 5.6 Effect of irrigation and methods of weed control on yield and yield attributes in SRI

Treatments	Tiller No.	No. of panicles/ plant	Length of panicle (cm)	No. of filled grains/ panicle	Test weight (g)	Yield (qha^{-1})
I_1	45	24	17	72	21.87	47.15
I_2	44	24	16	56	21.95	40.58
I_3	35	21	14	58	21.64	34.75
SEM	2.36	NS	NS	NS	NS	5.12
CD	8.17	NS	NS	NS	NS	17.71
W_1	24.25	16.79	10.83	50.08	21.50	26.4
W_2	54.50	20.54	14.03	60.23	21.76	39.98
W_3	38.25	25.25	17.00	68.60	22.20	42.4
W_4	48.75	30.83	20.33	69.21	21.84	54.52
SEm	1.83	0.95	0.53	4.51	NS	3.47
CD	5.29	2.74	1.54	13.09	NS	10.08

test weight was non-significant among the weed management practices. Kolhe (1999) observed that post emergence application of Fenoxaprop-p-ethyl +ethoxysulfuron was as effective as hand weeding twice. The cono weeder was found to increase the grain yield. This might be due to the fact that cono weeding incorporated the weeds in the soil and minimized the weeds besides increasing the soil aeration and root pruning (Uphoff, 1999). The irrigation levels affected the weed population and at saturation the weed count and its dry weight was found to be significantly higher than rest two irrigation levels. Among different weed management methods, application of pre and post emergence weedcides suppressed the germination of the broad leaves and sedges. The best weed management methods were achieved by application of both pre and post emergence weedicide in treatment W_4 (Table 5.7) Among irrigation treatment surface irrigation of 0.80 IW/CPE recorded highest equivalent yield (43.98 q ha^{-1}) followed by 0.90 IW/CPE. Maize intercropped with green gram in 2:2 ratio recorded the highest equivalent yield (48.65 q ha^{-1}) followed by 1:1 row ratio. Land equivalent ratio: Highest LER was recorded with irrigation at 0.8 IW/CPE (1.33). Among the intercropping treatments, 2:2 and 1:1 row ratios recorded the same LER (1.56) which were higher than all other treatment combinations. Advantages from non-legume+legume intercropping systems have been reported in crops such as wheat + legume (Barik, 1996), pea +barley (Chen et.al. 2005), field bean + wheat (Bulson et.al.1997) and maize + faba bean (Li et.al. 1999), and maize +cowpea (Dahmardeb et.al. 2009). The B: C ratio was higher (2.25) under surface irrigation scheduled at 0.8 IW/CPE ratios. Surface irrigation at 1 IW/CPE ratio recorded the least B: C ratio (1.66). Among the intercropping system, maize + green gram at 2:2 row ratio recorded the highest BC ratio (2.28). Intercropping commonly gave greater combined yields and monetary returns than obtained from sole crops (Ahmad and Rao, 1982). Surface irrigation scheduled at 0.70 IW/CPE ratio has consumed 500 mm water for the whole period with a water use efficiency of 7.93 kg ha^{-1} mm^{-1} (Table 22). This was followed by surface irrigation scheduled at 0.80 IW/CPE ratio with a consumption of 556 mm and WUE of 7.91 kg ha^{-1} mm^{-1}.Optimizing irrigation scheduling and nutrient management for onion

Table 5.7 Weed analysis

Grass		Broad leaf			Sedge	
Treatments	number	Dry weight (g)	number	Dry weight (g)	number	Dry weight (g)
I_1	8	3	5.50	2.31	180.81	168
I_2	10	5	5.25	2.81	209.56	204
I_3	18	6	7.25	4.63	258.13	226
SEM	2.91	0.47	0.76	0.25	7.32	3.98
CD	5.04	1.2	2.18	0.72	21.12	12.99
W_1	16.33	7.25	8.33	9.67	323.7	320.7
W_2	15.50	4.67	14	10.8	202.8	224.3
W_3	13.83	4.92	25	09.2	162.5	183.5
W_4	5.00	1.33	6	03.3	108.8	112.8
SEm	6.52	1.35	1.39	0.97	16.04	18.23
CD	NS	NS	4.04	2.82	46.55	52.89

5.3.3 Effects of water regimes and crop geometry on yield and water productivity in maize – green gram intercropping system

The yield attributes such as number of cobs/plant, seeds/cob, 1000 seed weight and yield were higher in treatment with irrigation at 0.80 IW/CPE ratio followed by 0.90 IW/CPE. Among the intercropping system, sole maize recorded more number of cobs/plant, grains/cob and 1000 seed weight followed by green gram intercrop with maize in 2:2 ratio. Tsubo et al. (2005) observed legume+cereal intercropping is generally more productive than monocrop. Total equivalent yield:

Effect of irrigation scheduling irrespective of nutrient management was studied. The bulb yield showed an increased trend from 0.8 to 1.2 IW/CPE (169.9 to 194.1 q ha^{-1}).Irrigation schedule IW/CPE ratio of 1.2 recorded significantly higher bulb yield (194.1 q ha^{-1})over IW/CPE 0.8 ratio but was at par with IW/CPE 1.0. Effect of sulphur on the seed yield of onion was studied irrespective of irrigation scheduling. As evident from Table 23 the yield was influenced by sulphur application and showed an increase trend upto 40 kg S ha^{-1} and of course produced significantly highest bulb yield i.e 192.5 q ha^{-1} which was reduced to 181.1 q ha^{-1} with application of 60 kg S ha^{-1} Hence, it may be concluded that onion crop responded well up to 40 kg S ha^{-1} ina sulphur deficient soil. Water Requirement (WR) and Water Use Efficiency (WUE) for different irrigation treatment was presented in Table 23. Highest water requirement of 70 cm was observed with IW/CPE 1.2 ratio whereas, lowest value of 60 cm was observed with IW/CPE 0.8 ratio. The treatment with IW/CPE ratio 1.0 registered a highest mean water use efficiency of 28.09 kg ha^{-1} cm^{-1} whereas, lowest value of 27.72 kg ha^{-1} cm^{-1} was observed in IW/CPE ratio 1.2. Onion variety N 53 produced significantly highest bulb yield at 40 kg S ha^{-1} with an irrigation schedule at 1.2 IW/CPE. Highest water use efficiency was observed when less water was applied. The application of 40 kg S ha^{-1} (192.5 q ha^{-1}) along with irrigation scheduling at 1.2 IW: CPE (194.1 q ha^{-1}) can produce economically higher bulb yield in onion. The highest water use efficiency was observed with irrigation scheduling at 1.0 IW: CPE ratio.

5.3.4 Growth and yield response of toria to irrigation scheduling and sulphur application

The toria variety Sushree of 65-70 days duration was cultivated under different water regimes and sulphur management practices for first year i.e 2013. The results obtained are presented in Table 5.8.

Table 5.8 Effect of irrigation and sulphur levels on yield and water use efficiency in toria

Treatment	Seed yield (q ha^{-1})	Water requirement (cm)	Water use efficiency (kg ha^{-1} cm^{-1})
Irrigation scheduling			
I_1:IW/CPE = 0.6	4.91	15	32.7
I_2: IW/CPE = 0.8	5.20	20	26.0
I_3: IW/CPE = 1.0	5.43	25	21.7
CD (5%)	NS	-	-
Sulphur levels			
S_1: 30 kg S ha^{-1}	4.89		
S_2: 45 kg S ha^{-1}	5.69		
S_3: 60 kg S ha^{-1}	4.96		
CD (5%)	0.33		

Effect of irrigation scheduling irrespective of nutrient management was studied Though irrigation schedule at IW/CPE 1.0 ratio recorded highest seed yield i.e., 5.43 q ha^{-1} but it was not significantly higher than other two irrigation schedules. Hence, IW/CPE 0.6 ratio with seed yield 4.91 q ha^{-1}may be considered as best irrigation practice. Effect of sulphur on the seed yield of toria was studied irrespective of irrigation scheduling. As evident from Table 24 the yield was influenced by sulphur application and showed an increase trend up to 45 kg S $ha^{-1}$and produced significantly highest yield i.e., 5.69 q ha^{-1}.The yield to 4.96 q ha^{-1} with application of 60kg S ha^{-1}. Hence, it may be concluded that toria crop responded well up to 45 kg S ha^{-1}. Water requirement and water use efficiency for different irrigation treatments is presented in Table 24. Highest water requirement of 25 cm was observed with IW/CPE 1.0 ratio whereas, lowest value of 15 cm was observed in IW/CPE 0.6 ratio. The treatment with IW/CPE 0.6 ratio registered highest mean water use efficiency of 32.7 kg ha^{-1} cm^{-1} whereas, lowest value of 21.7 kg ha^{-1} cm^{1} was observed in IW/CPE 1.0. Toria variety Sushree produced significantly highest seed yield at 45 kg S ha^{-1} with an irrigation schedule at 0.6 IW/CPE.

Higher water use efficiency was observed when less water was applied. Application of 45 kg S ha^{-1} (5.69 q ha^{-1}) along with irrigation scheduling at 0.6 IW: CPE (4.91 q ha^{-1}) can produce economically higher seed yield in Toria. The highest water use efficiency was observed with irrigation scheduling at 0.6 (IW/ CPE).

5.4 Dapoli

5.4.1 Effects of irrigation combined with nutrients and paclobutrazol (cultar) on the growth and fruiting behaviour of mango on hill slopes of Konkan region

The effect of irrigation levels on canopy volume was found significant. Maximum average canopy volume was found in I_2 treatment (106.43m^3) and the lowest average canopy volume was found in treatment I_0 (92.43m^3). The data reveals that mango crop responds to irrigation to increase the crop canopy. The effect of fertilizer levels combined with PBZ application was found significant. The treatment N_1 showed highest and significant volume (152.66m^3) as compared to N_2 & N_3 levels. The lowest canopy volume was found in N_3 treatment (64.10m^3) indicating the role of PBZ on restriction of vegetative growth. The interaction effect of irrigation and fertilizer application was significant on increase of canopy of mango crop. In treatment combination I_0N_3 (No irrigation + 50% RD + PBZ) the lowest canopy volume (51.20m^3) was observed and the maximum canopy volume (158.80m^3) was observed in treatment I_2N_1 (Irrigation 50% of PE+ RD without PBZ application) (Table 5.9).

Table 5.9 Effect of irrigation combined with nutrients and paclobutrazol on average canopy volume (m³) of trees

Treatments	N_1 (100%R.D.)	N_2 (100%R.D. + PBZ)	N_3 (50% R.D. + PBZ)	Mean canopy volume (m³)
I_0 - No irrigation	144.90	81.20	51.20	92.43
I_1 - 75% PE	154.30	85.10	70.30	103.23
I_2 - 50% PE	158.80	89.70	70.80	106.43
Mean	152.66	85.33	64.10	
Statistical parameters	Irrigation	Fertilizer	Irrigation x Fertilizer	
S.E. ±	0.255	0.255	0.442	
C.D. at 5%	0.7648	0.7648	1.325	

The effect of irrigation levels on yield kg/plant was found significant. The average yield was found maximum in I_1 treatment (16.33kg/plant) and the lowest average yield was found in treatment I_2 (13.13 kg/plant), however, the yield was at par with no irrigation treatment. This indicated that irrigation played important role in enhancing the yield. The application of water @50%PE may not be sufficient to produce the significant effect; however, it was useful to increase the volume of tree. The effect of fertilizer levels combined with PBZ application was found non-significant. The interaction effect of water application and fertilizer application was significant. Highest yield of mango crop water recorded in I_1N_2 (Irrigation 75% of PE+ 100%RD +PBZ application), while lowest was recorded in I_2N_3 (50% PE irrigation + 50% RD + PBZ). The highest yield under treatment combination could be attributed to the effect of water and fertilizer application in increasing the yield. The water use efficiency was also determined for the treatments incorporated and is presented in Table 5.10.

Table 5.10 Yield and water use efficiency of mango under various treatments

Treat-ments	Mango yield (t/ha)	Water applied (ha-cm)	WUE (kg/ ha-cm)
I_0 N_1	1.32	—	—
I_0 N_2	1.26	—	—
I_0 N_3	1.45	—	—
I_1 N_1	1.62	60.3	26.87
I_1 N_2	1.70	60.3	28.19
I_1 N_3	1.58	60.3	26.20
I_2 N_1	1.42	40.2	35.32
I_2 N_2	1.31	40.2	32.59
I_2 N_3	1.21	40.2	30.10

Water use efficiency in producing the mango yield was found maximum in treatment I_2 N_1 (50%PE irrigation and 100%RDF+PBZ), while minimum WUE was found in treatment I_1 N_3 (75%PE irrigation and 50%RDF+PBZ). The results on water use efficiency indicate that in case of water scarcity, the mango yield can be increased by about 17% with the application of 60 cm water as compared to no irrigation.

5.4.3. Effect of amount of irrigation during critical stages on cashew nut

The effect of amount of water application during the critical stages of fruit development of cashew nut is presented in Table 5.11.

delivered up 40 days from peanut stage of cashew nut. Yield under treatment irrigation up to 80 from peanut size of cashew nut was decreased, which indicated that cashew may require water up to 60 days from peanut size of cashew nut to increase the yield. The interaction effect of irrigation amount and its application during different growth stages of fruit development on yield was significant. Highest yield could be observed in treatment combination I_2T_2 i.e. irrigation application @ 50 litres/plant up to 40 days after peanut stage of fruit development. The results clearly indicated that application of total water of 6 ha-mm (60000 litres) up to 40 days after the peanut stage of cashew nut could increase the cashew yield of fully grown crop to 1.30 tonnes/ha with the WUE of 216.7 kg/ha-mm.

Table 5.11 Effect of water application during different growth stages on yield of cashew nut

Treatments	T_1 - 20 days	T_2 - 40 days	T_3 - 60 days	T_4 - 80 days	Mean yield, kg/plant
I_0 – No irrigation	2.60	3.40	3.60	3.00	3.20
I_1 -25 lit/week	2.50	3.70	4.30	3.30	3.45
I_2 – 50lit/week	2.90	6.50	4.93	4.70	4.76
Mean	2.67	4.53	4.28	3.66	
Statistical parameters	Irrigation	Days	Irrigation X Days		
S.E. ±	0.234	0.271	0.469		
C.D. at 5%	0.687	0.794	1.375		

5.4.4. Effect of amount of irrigation on average yield of trees:

The effect of amount of irrigation on yield (kg/plant) was found significant. The cashew nut yield was significantly superior under treatment I_2 over other I_1 and I_3. Treatments I_1 and I_3 were at par with each other. The highest yield recorded due to amount of irrigation was 4.76 kg/plant in I_2 treatment. This indicated that cashew responds to irrigation and its yield can be enhanced by about 49% by irrigating the crop weekly @ 50 lit/plant/week. The application of water @ 25 lit/plant/week could not produce any significant effect on yield per plant.

5.4.5. Effect of water application during growth stages on cashew yield:

Cashew yield can be significantly increased due to irrigation in different growth stages of fruit development. Irrigation up to 20 days from peanut stage of cashew nut could not increase yield, whereas, the yield was significantly increased and was highest (4.53 kg/plant) when irrigation was

5.6. Gayeshpur

5.6.1. Effects of irrigation schedules and integrated nitrogen on yield and water use efficiency of lettuce (Lactuca sativa L.)

Yield attributes and yields of lettuce

The yield attributes and head yield of lettuce were significantly influenced by different irrigation schedules and N fertilizers levels (Tables 5.12). Irrigation at IW/CPE 1.0 produced significantly the maximum head yield (10.81 kg/ha) and yield attributes such as head diameter (16.5 cm), number of leaves per plant (16.3) and single head weight (97 g), which was at par with irrigation schedule at IW/CPE 0.8 excepting the number of leaves per plant. Both treatments were superior to the remaining two irrigation schedules. On the other hand, irrigation at IW/CPE 0.6 registered significantly the lowest head yield and yield contributing parameters. The effect of surface irrigation in promoting the yield and yield attributes, however, was intermediate. The combined application of 50% organic N and 50% inorganic N fertilizers recorded maximum head yield (10.71 kg/ha), head diameter (15.9 cm), leaves per plant (16.7) and single head weight (95 g) and was superior to the recommended 100% inorganic N fertilizer. Addition of 100% organic N as vermicompost registered the minimum yield contributing parameters and head yield. The interaction effect between irrigation schedules and fertilizer N levels was significant. Relatively higher head yield (11.3 kg/ha), head diameter (17.2 cm), leaves per plant (17.8) and single head weight (98 g) was obtained with irrigation at IW/CPE 0.8 coupled with 50% inorganic N plus 50% organic N fertilizers, which was on par with irrigation scheduled at IW/CPE 1.0 enriched with 50% inorganic N plus 50% organic N fertilizers.

The total water use and water use efficiency by lettuce plant varied with the variation of irrigation water applied and use of inorganic and organic N fertilizers (Tables 5.3 and 5.14). The highest water use (192.26 mm) was found in surface irrigation and the lowest (105.42 mm) in irrigation at IW/CPE 0.6. Conversely, the highest water use efficiency (88.22 kg/ha-mm) was recorded with irrigation at IW/CPE 0.6, whereas the lowest (51.77 kg/ha-mm) in the conventional surface irrigation. The interaction effects revealed that maximum water use efficiency of 93.57 kg/ha-mm was obtained with irrigation at IW/CPE 0.6 provided with 50% inorganic N plus 50% organic N (vermicompost) fertilizers and minimum (51.75 kg/ha-mm) with conventional surface irrigation supplemented with 100% inorganic N fertilizer.

Table 5.12 Interaction effect of irrigation and fertilizer N levels on yield attributes and head yield of lettuce plant during 2013-2014

Inter-action (I x N)	Head diameter (cm)	No. of leaves/ plant	Single head weight (g)	Fresh head yield (t/ha)
$I_1 N_1$	13.5	16.2	90	9.96
$I_1 N_2$	14.1	16.4	93	10.24
$I_1 N_3$	11.3	14.5	88	9.66
$I_2 N_1$	12.2	14.1	90	9.30
$I_2 N_2$	13.8	15.7	92	9.86
$I_2 N_3$	10.9	14.1	87	8.74
$I_3 N_1$	16.7	16.7	95	10.74
$I_3 N_2$	17.2	17.8	98	11.30
$I_3 N_3$	13.6	16.1	95	10.28
$I_4 N_1$	17.2	16.5	96	10.46
$I_4 N_2$	18.4	16.9	99	11.44
$I_4 N_3$	13.8	15.5	96	10.52
SEm±	0.51	0.39	0.47	0.17
CD(0.05)	1.57	1.23	1.45	0.52

Table 5.11 Effect of irrigation and fertilizer N levels on yield attributes, head yield, water use and water use efficiency of lettuce plant during 2013-2014

Treatment	Head diameter (cm)	No. of leaves/ plant	Single head weight(g)	Fresh head yield (t/ha)	Water use (mm)	WUE (kg/ ha-mm)
Irrigation schedule (I)						
I_1	13.0	15.7	91	9.95	192.26	51.77
I_2	12.3	14.6	90	9.30	105.42	88.22
I_3	15.8	16.9	96	10.77	133.65	80.61
I_4	16.5	16.3	97	10.81	163.27	66.19
SEm±	0.25	0.16	0.35	0.11	-	-
CD (0.05)	0.86	0.55	1.21	0.38	-	-
Fertilizer N level (N)						
N_1	14.9	15.9	93	10.12	148.64	71.13
N_2	15.9	16.7	95	10.71	148.70	75.34
N_3	12.4	15.1	92	9.80	148.62	68.63
SEm±	0.33	0.17	0.29	0.07	-	-
CD (0.05)	1.30	0.67	1.13	0.29	-	-

Table 5.13 Components of water balance, water use and water use efficiency of lettuce plant under varied irrigation and fertilizer N levels during 2013-2014

Inter-action (I x N)	Profile contribution (cm)	Irrigation (mm)	Rainfall (mm)	Total water use* (mm)	Yield (kg/ha)	WUE (kg/ ha-mm)
$I_1 N_1$	9.98	150	12.5	192.48	9960	51.75
$I_1 N_2$	9.76	150	12.5	192.26	10240	53.26
$I_1 N_3$	9.54	150	12.5	192.04	9660	50.30
$I_2 N_1$	12.92	60	12.5	105.42	9300	88.22
$I_2 N_2$	12.88	60	12.5	105.38	9860	93.57
$I_2 N_3$	12.96	60	12.5	105.46	8740	82.88
$I_3 N_1$	11.12	90	12.5	133.62	10740	80.38
$I_3 N_2$	11.18	90	12.5	133.68	11300	84.53
$I_3 N_3$	11.16	90	12.5	133.66	10280	76.91
$I_4 N_1$	10.52	120	12.5	163.02	10460	64.16
$I_4 N_2$	10.96	120	12.5	163.46	11440	69.99
$I_4 N_3$	10.82	120	12.5	163.32	10520	64.41

*including a common irrigation of 20 mm depth for seedling emergence and crop establishment

5.6.2. Effect of moisture regimes on yield, water use efficiency and economics of safflower (Carthamus tinctorius L.) based intercropping systems

The mean seed yields of the main crop and intercrops during the year 2013-14 and their pooled values over the three years (2011-12, 2012-13 and 2013-14) given in Tables 5.14 showed that equivalent seed yield of safflower was found maximum in the cropping system when pea intercropped in between rows of main crop safflower. The highest safflower equivalent yield of 7.56 q/ha was registered under irrigation at CPE 30 in safflower + pea intercropping system (I_1C_3). The second higher production in terms of

Table 5.14 Effect of irrigation and cropping systems on seed yields of safflower, French bean, pea and faba bean in 2013-14

Treatment	Safflower (q/ha)	French bean (q/ha)	Pea (q/ha)	Faba bean (q/ha)	Safflower eq. seed yield (q/ha)
I_1C_1	5.48	-	-	-	5.48
I_1C_2	4.38	2.04	-	-	6.97
I_1C_3	4.27	-	2.25	-	7.47
I_1C_4	4.15	-	-	2.56	6.94
I_2C_1	5.42	-	-	-	5.42
I_2C_2	4.32	1.87	-	-	6.70
I_2C_3	4.23	-	2.13	-	7.26
I_2C_4	4.11	-	-	2.41	6.73
I_3C_1	4.80	-	-	-	4.80
I_3C_2	4.10	1.56	-	-	6.08
I_3C_3	3.85	-	1.82	-	6.44
I_3C_4	3.81	-	-	2.05	6.04

NB: C_1: Sole safflower; C_2: Safflower + french bean; C_3: Safflower + pea; C_4: Safflower + faba bean; market price of safflower Rs. 3300/-, french bean Rs. 4200/- , pea Rs. 4700/- and faba bean Rs. 3600 per quintal.

safflower equivalent yield (7.37 q/ha) was obtained in safflower and pea intercropping system irrigated at CPE 45 (I_2C_3). However, the yield advantages of growing more than one crop simultaneously in the same piece of land instead of sole cropping were due to efficient utilization of inter-row spaces of safflower with short duration high value pulses, which may compensate the yield losses of safflower and bring an additional economic return to the resource poor farmers.

Profile moisture contribution, effective rainfall, irrigation water use and water use efficiency in different cropping systems is furnished in Table 5.15. The total water use was found maximum where more number of irrigation was applied. But water use efficiency appeared to be higher where lesser number of irrigation applied and that too in intercropping system than in sole cropping of safflower. Maximum water use efficiency of 3.03 kg/ha-mm was recorded in lower irrigation regime of CPE 60 under safflower + pea intercropping system (I_3C_3). In addition to main crop safflower, short duration intercrops like pea could be grown successfully in between rows of safflower without any additional expenses on irrigation water. This approach may offer substantial income to the poor farmers exploiting every parcel of land.

Table 5.15 Effect of irrigation and cropping systems on safflower equivalent yield (average of 2011-2012, 2012-2013 and 2013-2014)

Treat-ment	Safflower equivalent seed yield (q/ha)			
	2011-12	2012-13	2013-14	Mean
I_1C_1	5.41	5.57	5.48	5.48
I_1C_2	6.93	7.13	6.97	7.01
I_1C_3	7.57	7.66	7.47	7.56
I_1C_4	7.14	7.12	6.94	7.06
I_2C_1	5.31	5.50	5.42	5.41
I_2C_2	6.82	6.86	6.70	6.79
I_2C_3	7.42	7.43	7.26	7.37
I_2C_4	7.02	6.88	6.73	6.87
I_3C_1	4.62	4.89	4.80	4.77
I_3C_2	5.78	6.23	6.08	6.03
I_3C_3	6.31	6.61	6.44	6.45
I_3C_4	5.95	6.18	6.04	6.05

C_1: Sole safflower; C_2: Safflower + french bean; C_3: Safflower + pea; C_4: Safflower + faba bean

5.7. Hissar

5.7.1. Irrigation scheduling in wheat under FIRBS planting

Wheat crop was planted on furrow irrigated raised bed system (FIRBS) by tractor driven bed planter. In this machine, the beds of desired width, sowing of seed and fertilizer application was carried out at same time. Two rows of wheat were planted on the bed at a spacing of 20 cm. A pre-sown irrigation of 6.0 cm depth was applied and another a common irrigation at CRI stage was applied in all the treatments. Thereafter, irrigations were applied on the basis of treatments schedule. On this basis, 3 post-sown irrigations in treatment CRI+100 mm CPE, 2 in CRI+150 mm and CRI+200 mm CPE were applied. Depth wise soil samples were collected before and after each irrigation. In conventional planting, 13.5 cm of irrigation water was applied while it was 9.7 cm under FIRBS. The rainfall received during the wheat crop season was 6.15 cm the same was considered as effective.

The soil moisture depletion from profile (SMD) in wheat crop was higher (8.53 cm) under FIRBS than under conventional system of planting (8.87 cm) while the contribution from shallow water table (GWC) was higher in conventional planting than the FIRBS (Table 5.16). The total water use as consumptive use was 35.95 cm in FIRBS whereas it was 39.72 cm in conventional planting. The GWC increased with the decrease in the level of moisture regime from irrigation at CRI+100 mm to 200 mm CPE. The consumptive use was highest i.e. 39.70 cm in moisture regimes of CRI+ 100 mm CPE primarily due to larger amount of applied irrigation water.

Planting of wheat in FIRBS resulted in significantly higher grains/spike and grain weight but lower number of effective tillers as compared to the conventional sowing but the difference in the grain yield was not significant (Table 5.17). The effective tillers reduced significantly when irrigation were applied at CRI+200 mm CPE whereas grains/spike were significantly lower in CRI+150 mm CPE as compared to other moisture regimes. The grain weight was observed to be significantly higher in CRI+100 mm CPE as compared to CRI+150 mm CPE. A significant increase in grain yield was recorded with increase in moisture regimes from CRI+200 mm CPE to CRI+100 mm CPE.

Table 5.16 Water use by wheat under different irrigation methods and moisture regimes during 2013-14

Treatment	Water use (cm)				
	SMD	GWC	Rainfall	Irrigation	CU
Sowing method					
Conventional	8.53	11.57	6.15	13.47	39.72
FIRBS	8.87	11.20	6.15	9.73	35.95
Moisture regime					
CRI+100 mm CPE	8.45	10.60	6.15	14.50	39.70
CRI+150 mm CPE	9.10	11.50	6.15	10.00	36.75
CRI+200 mm CPE	8.55	12.05	6.15	10.30	37.05

SMD-soil moisture depletion, GWC- ground water contribution, CU- consumptive use
Note: Water table depth of the field varied between 65 to 108 cm during the crop season

Table 5.17 Yield attributing parameters and yield of wheat under different treatments during 2013-14

Treatment	Effective tiller/m^2	Grains/ spike	1000-grain wt. (g)	Grain yield, kg/ha
Sowing method				
Conventional	352.0	39.4	37.3	4982
FIRBS	342.0	40.1	38.2	5064
CD at 5%	8.7	0.6	0.5	NS
Moisture regimes				
CRI+100 mm CPE	359.0	40.2	38.1	5293
CRI+150 mm CPE	354.0	39.2	37.3	4988
CRI+200 mm CPE	328.0	40.0	37.9	4787
CD at 5%	12.6	0.7	0.7	101

The interaction between irrigation methods and moisture regimes was significant (Table 5.18) revealing that there was significant increase in grain yield of wheat when irrigated at CRI+100 mm CPE under FIRBS of planting.

Table 5.18 Grain yield (kg/ha) of wheat under different methods of irrigation and moisture regimes during 2013-14

Sowing method	Moisture regime, irrigation at CRI+CPE			
	100mm (3)	150mm (2)	200mm (2)	Mean
Conventional	5149	4967	4829	4982
FIRBS	5437	5009	4745	5064
Mean	5293	4988	4787	

CD at 5%: Irrigation methods = NS; Moisture regimes = 101; Interaction = 143, Moisture regimes at the same level of irrigation method = 227, Irrigation method at the same level of moisture regime = 290. Note: WT depth = 68-122 cm; Rainfall = 61.5 mm, Values in parentheses indicate number of irrigations applied

5.7.2 Performance of wheat under FIRBS (2006-07 to 2013-14)

The wheat grain yield under FIRBS was significantly higher as compared to conventional sowing during 2007-08 to 2011-12 but no significant differences were observed during 2006-07, 2012-13 & 2013-14 (Table 5.19). The mean grain yield of eight years experimentation under FIRBS was higher (255 kg/ha, 5%) as compared to the conventional sowing. The irrigation applied at CRI+100 mm CPE produced higher grain yield

Table 5.19 Grain yield (kg/ha) of wheat under FIRBS with various moisture regimes in different years (2006-07 to 2013-14)

Treatment	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Average
Irrigation method									
Conventional	4735	4285	6360	5427	5525	5445	4531	4982	5161
FIRBS	4734	4927	6760	5736	5801	5735	4571	5064	5416
CD at 5%	NS	256	265	147	249	262	NS	NS	208
Moisture regimes									
CRI+100 mm CPE	5115	5681	6845	5790	5842	5783	4732	5293	5635
CRI+150 mm CPE	4703	4412	6570	5565	5665	5676	4602	4988	5273
CRI+200 mm CPE	4385	3725	6265	5390	5483	5310	4319	4787	4958
CD at 5%	349	368	301	85	208	339	257	101	285

than the other moisture regimes in all the years. Highest grain yield was achieved with irrigation at CRI+100 mm CPE and decreased significantly with decrease in moisture regimes.

The contribution of shallow water table towards crop ET was more in conventional sowing than FIRBS. The average irrigation water applied under FIRBS was less by 2.35 cm over the conventional sowing and thus, a saving of 14.6 % irrigation water (Table 5.20 and Fig 5.1). The total was use was also less by 2.85 cm in FIRBS than the conventional sowing.

Table 5.20 Water use components (cm) of wheat under FIRBS with various moisture regimes (mean of 2006-07 to 2013-14)

Treatment	SMD	GWC	Irrigation	RF	Total water use
Irrigation method					
Conventional	9.00	9.11	18.43	4.98	41.51
FIRBS	9.20	8.40	16.08	4.98	38.65
Moisture regimes					
CRI+100 mm CPE	8.30	8.52	21.92	4.98	43.71
CRI+150 mm CPE	9.30	8.68	16.64	4.98	39.60
CRI+200 mm CPE	9.71	9.07	13.21	4.98	36.99

SMD – Soil Moisture depletion, GWC – Ground water contribution, RF- Rainfall

Fig. 5.1 Components of total water use (cm) in wheat under FIRBS with various moisture regimes (mean of 2006-07 to 2013-14)

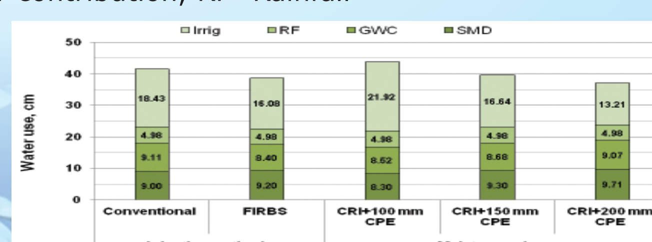


Fig. 5.1

Consequent upon better grain yield and lesser irrigation water use in FIRBS, the average WP of applied irrigation water was 3.60 kg grain/m^3 as compared to 2.96 kg grain/m^3 . Irrigation applied at CRI+ 200 mm CPE resulted in highest WP ie., 4.14 kg grain/m^3 of irrigation water followed by CRI+ 150 mm CPE (3.42 kg grain/m^3) and lowest with CRI+ 100 mm CPE (2.69 kg grain/m^3). The WP of total water applied varied within a narrow range of 1.29 to 1.35 kg grain/m^3. From the research results of eight years of field experimentation on sandy loam soil under semi-arid conditions, it can be assertively concluded that FIRBS is an efficient method of planting wheat for achieving higher crop and water productivity as FIRBS found to save 12.75 % irrigation water coupled with 255 kg/ha higher grain yield and

Table 5.21 Yield parameters and yield of wheat under different treatments during 2013-14

Treatment	Effective tillers/m²	Grains/ spike	1000-grain wt.(g)	Grain yield, kg/ha
Preceding crop				
Mungbean	335	40.0	37.4	4781
Sorghum	325	39.4	36.6	4465
CD at 5%	NS	0.5	0.3	289
Tillage practice				
Conventionnel	340	39.8	37.4	4826
Zero-rabi	334	39.8	37.3	4717
Complete zero	316	39.5	36.3	4327
CD at 5%	11	NS	0.4	113
Moisture regime				
IW/CPE=0.60	318	39.4	36.7	4380
IW/CPE=0.75	331	39.6	37.1	4636
IW/CPE=0.90	341	40.1	37.2	4853
CD at 5%	12	0.8	0.3	120

consequently enhanced the productivity of irrigation water by 22% over surface irrigation method. For harvesting higher grain yield, irrigations be applied at CRI+100 mm CPE, however to achieve higher water productivity, irrigation be applied at CRI+200 mm CPE.

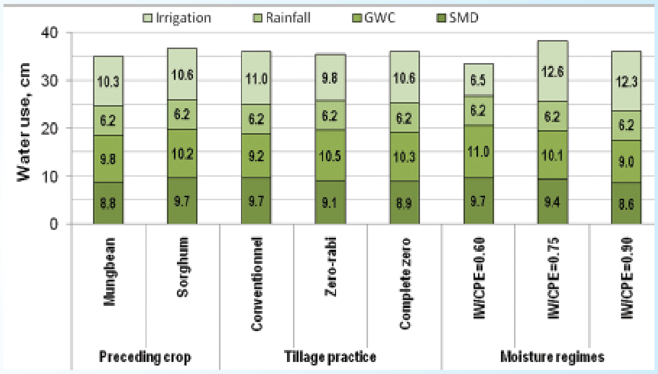
5.7.3 Effect of varying moisture regimes in zero-till wheat succeeding mungbean and sorghum

Wheat succeeding mungbean produced significantly higher number of grains/spike, 1000-grain weight and grain yield (4781 kg/ha) than sorghum (4465 kg/ha). The yield and yield parameters did not differ significantly between conventional tillage and zero-tillage in rabi but were significantly higher than complete zero (Table 5.21). Among the moisture regimes, the yield attributing parameters as well as grain yield of wheat were highest under irrigation at IW/CPE of 0.9 and decreased with decrease in the level of moisture regime.

SMD= Soil moisture depletion, GWC= ground water contribution, CU= Consumptive use

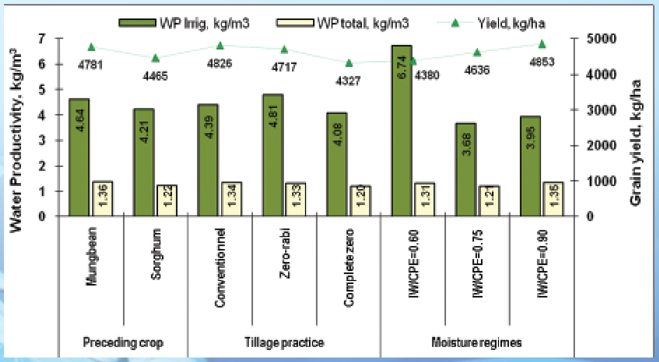
Fig. 5.2. Water use components in wheat crop under different tillage practices and moisture regimes preceding mungbean and sorghum during 2013-14

The interaction between preceding crops and tillage practices was significant revealing that there was significant increase in grain yield of wheat with either conventional tillage or zero-tillage in rabi sown after mungbean.



The WP of irrigation and total water used was higher after mungbean (4.64 & 1.36 kg/m³) than sorghum (4.21 & 1.22 kg/m³). The water productivity of irrigation water under zero tillage in rabi was higher than the conventional and zero tillage in both the seasons. Among the moisture regimes, the WP was highest with irrigation at IW/CPE of 0.6 (Fig. 5.3).

Fig. 5.3 Yield and water productivity of wheat under different methods of irrigation and moisture regimes during 2013-14



The net return in raising wheat crop after mungbean was higher than after sorghum. Among the three tillage practices, highest net return was obtained under zero tillage in rabi followed by conventional and complete zero in both seasons (Table 5.22). Applying irrigation at IW/CPE of 0.90 resulted in highest net return of Rs. 28569/ha followed by IW/CPE of 0.6 (Rs. 25068/ha) and 0.75 (Rs. 24350/ha).

5.7.4 Effect of varying moisture regimes on the yield of soybean and maize grown under different intercropping patterns

In response to irrigation at different IW/CPE ratios, it was found that the entire yield attributes viz., cob/m2, cob weight, grain/cob and grain weight were increased significantly upon increase in each level of moisture regimes from IW/PCE ratio of 0.6

Table 5.22 Economics (Rs/ha) of wheat under tillage practices and moisture regimes preceding crop of mungbean and sorghum

Treatment	Variable cost	Total cost	Gross return over variable cost	Net return
Preceding crop				
Mungbean	30315	63615	61577	28277
Sorghum	31355	64655	54467	21167
Tillage practice				
Conventionnel	31395	64695	61352	28052
Zero-rabi	26568	59868	64094	30794
Complete zero	27063	60363	56101	22801
Moisture regimes, irrigation at				
IW/CPE=0.60	30815	64115	53368	20068
IW/CPE=0.75	31455	64755	57650	24350
IW/CPE=0.90	31415	64715	61869	28569

Table 5.23 Yield attributing parameters, yield and harvest index of maize under different moisture regimes and intercropping planting geometry during 2014

Treatment	Yield attributing parameters				Yield, kg/ha			Harvest
	Cob/m²	Cob wt.,g	Grain/cob	Grain wt.,g	Cob	Grain	Straw	index,%
Moisture regimes, irrigation at								
IW/CPE=1.0	6.01	0.171	405	306	10303	7005	9765	41.8
IW/CPE=0.8	5.78	0.156	380	294	9001	6120	8314	42.4
IW/CPE=0.6	5.52	0.138	348	285	7618	5180	6916	42.8
CD at 5%	0.17	0.006	24	11	196	133	216	-
Planting geometry (maize:soybean)								
01:01	5.81	0.154	379	297	8984	6110	8276	42.5
01:02	5.71	0.155	380	296	8889	6044	8245	42.3
02:01	5.72	0.157	375	293	8991	6114	8395	42.1
02:02	5.84	0.154	376	293	9031	6140	8411	42.2
CD at 5%	NS	NS	NS	NS	NS	NS	NS	

to 1.0. As a consequence, the highest grain yield of 7005 kg/ha was obtained when irrigation was applied at IW/PCE ratio of 1.0 and decreased significantly to 6120 and 5180 kg/ha with irrigation at IW/PCE ratio of 0.8 and 0.6, respectively (Table 5.23). The difference in yield between the different planting geometry of maize:soybean was similar since the soybean crop could not be establish as intercrop during the season.

The amount of water used under different components of total water use with different moisture regimes (Table 5.24) indicated that the amount of irrigation water of 23.2, 18.2 and 12.6 cm was applied in IW/CPE of 1.0, 0.8 and 0.6, respectively. The corresponding total water use was 62.1, 57.9 and 52.9 cm. The productivity of irrigation water was 302 kg grain/ha-cm with irrigation at IW/CPE of 1.0 which increased to 336.3 under IW/CPE of 0.8 and to 411.1 kg grain/ha-cm under IW/CPE of 0.6, however reverse was found in case of productivity of total water use. The productivity of irrigation as well as total water use did not differ substantially under different planting geometry of maize:soybean intercropping.

Economics calculated on the basis of the prevailing input and produce prices for intercropping of maize and soybean under different moisture regimes and planting geometry (Table 5.25) showed that the gross returns ranged between Rs. 98076 to 72525 and a net return of Rs. (-) 25 under irrigation at IW/CPE of 0.6 to Rs. 24526 under irrigation at IW/CPE of 1.0. The net returns was highest in maize:soybean::1:1 and 2:1 and the lowest in 1:2 plant geometry in maize-soybean intercropping system.

Table 5.24 Water use components and water productivity (WP) of maize under different moisture regimes and planting geometry during 2014

Treatment	Components of water use, cm				WP, kg grain/ha-cm	
	Irrigation	Eff. RF	SMD	Total	Irrigation	Total water
Moisture regimes, irrigation at						
IW/CPE=1.0	23.2	28.5	10.4	62.1	302.0	112.8
IW/CPE=0.8	18.2	28.5	11.2	57.9	336.3	105.7
IW/CPE=0.6	12.6	28.5	11.8	52.9	411.1	97.9
Planting geometry (maize:soybean)						
01:01	18.0	28.5	11.0	57.5	339.4	106.3
01:02	18.0	28.5	10.6	57.1	335.8	105.8
02:01	18.0	28.5	11.4	57.9	339.6	105.6
02:02	18.0	28.5	11.2	57.7	341.1	106.4

Table 5.25 Economic of intercropping of maize and soybean under different moisture regimes and planting geometry (Rs/ha) during 2014

Treatment	Gross return	Cost of cultivation	Net return
Moisture regimes, irrigation at			
IW/CPE=1.0	98076	73550	24526
IW/CPE =0.8	85679	73050	12629
IW/CPE =0.6	72525	72550	-25
Planting geometry (maize: soybean)			
1:1	85540	72475	13065
1:2	84613	73990	10623
2:1	85591	72285	13306
2:2	85962	73450	12512

5.7.5 Performance of maize-soybean intercrop in different years

The maize grain yield obtained during individual years as well as pooled of the three crop seasons revealed that significantly highest grain yield during 2014 as well as pooled was achieved with the application of irrigation at IW/CPE = 1.0. It decreased significantly with decrease in each level of moisture regime (Table 5.26). During 2011, also application of irrigation at IW/CPE = 1.0 resulted in significantly higher yield over the other two moisture regimes, however, the difference between irrigation at IW/CPE = 0.8 and 0.6 was only marginal. Intercropping of maize:soybean in 1:1 planting geometry produced substantially higher maize grain yield as compared to 1;2 and 2:1 planting geometry during 2011, 2014 as well as polled (Table 5.27). The pooled grain yield was significantly higher under maize:soybean ::

Table 5.26 Maize grain yield under different moisture regimes and intercropping planting geometry during the three crop seasons

Treatment	Maize grain yield, kg/ha			
	2011	2013	2014	Pooled
Moisture regimes, irrigation at				
IW/CPE=1.0	4533	6836	7005	6125
IW/CPE=0.8	4000	6959	6120	5693
IW/CPE=0.6	3945	6936	5180	5354
CD at 5%	384	NS	133	227
Planting geometry (maize:soybean)				
01:01	4834	7126	6110	6024
01:02	4296	6653	6044	5664
02:01	4049	6745	6114	5636
02:02	3457	7119	6140	5572
CD at 5%	424	348	NS	158

Table 5.27 Soybean grain yield under different moisture regimes and intercropping planting geometry during the three crop seasons

Treatment	Soybean grain yield, kg/ha			
	2011	2013	2014	Pooled
Moisture regimes, irrigation at				
IW/CPE=1.0	172	303	-	158
IW/CPE=0.8	154	302	-	152
IW/CPE=0.6	135	302	-	146
CD at 5%	23	NS	-	8
Planting geometry (maize:soybean)				
01:01	138	317	-	152
01:02	222	341	-	188
02:01	59	262	-	107
02:02	198	287	-	161
CD at 5%	28	17	-	7

1:1 planting geometry over others. The difference among maize:soybean :: 1:2, 2:1 and 2:2 was not marked. The maize grain yield during 2013 under varying moisture regimes and during 2014 with different plant geometry of maize:soybean intercropping was found to be statistically at par.

Grain yield of soybean during 2011 and pooled was significantly higher with application of irrigation at IW/CPE=1.0 over IW/CPE=0.6, but was at par with at IW/CPE=0.8. The difference between at IW/CPE=0.8 and 0.6 was not marked. Planting of soybean as intercrop in maize:soybean :: 1:2 planting geometry produced significantly higher pooled soybean grain yield over other planting geometry.

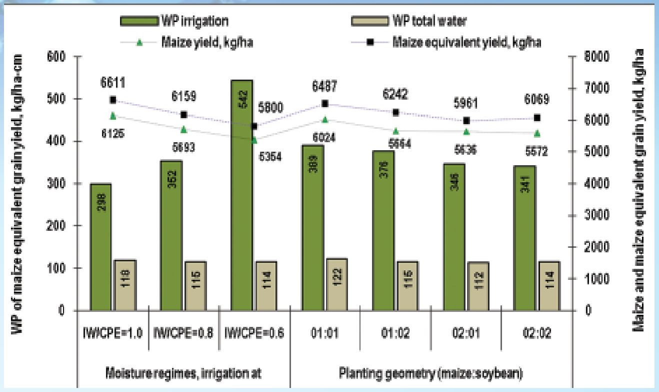


Fig. 5.4 Average grain yield of maize and maize equivalent, and water productivity (WP) maize equivalent yield under different moisture regimes and intercropping planting geometry (average of 2011, 2013 and 2014)

Table 5.28 Maize equivalent grain yield under different moisture regimes and intercropping planting geometry during the three crop seasons

Treatment	Maize equivalent grain yield, kg/ha			
	2011	2013	2014	Pooled
Moisture regimes, irrigation at				
IW/CPE=1.0	5083	7745	7005	6611
IW/CPE=0.8	4492	7864	6120	6159
IW/CPE=0.6	4377	7842	5180	5800
CD at 5%	279	NS	133	188
Planting geometry (maize:soybean)				
01:01	5274	8077	6110	6487
01:02	5005	7676	6044	6242
02:01	4236	7533	6114	5961
02:02	4087	7981	6140	6069
CD at 5%	432	363	NS	166

The maize equivalent yield during 2011, 2014 as well as pooled was found to be significantly higher with the application of irrigation at IW/CPE=1.0 and decreased substantially with decrease in each level of moisture regime (Table 5.28). Planting of soybean as intercrop in maize:soybean :: 1:1 planting geometry produced significantly higher pooled maize equivalent grain yield over other planting geometry. Maize: soybean either 1:1 or 1:2 planting geometry had a significant edge over 2:1 or 2:2 in terms of maize equivalent grain yield. The maize equivalent grain yield did not differ substantially under varying moisture regimes during 2013 and with different plant geometry of maize:soybean intercropping during 2014.

Highest productivity of applied irrigation water (542.3 kg maize grain equivalent/ha-cm) was achieved with the application of irrigation at IW/

Table 5.29 Water productivity (WP) of irrigation and total water use under of under different moisture regimes and intercropping of maize and soybean with varying planting geometry (Mean of the three crop seasons)

Treatment	WP, kg maize equivalent grain/ha-cm	
	Irrigation water	Total water
Moisture regimes, irrigation at		
IW/CPE=1.0	297.9	118.0
IW/CPE=0.8	352.2	114.8
IW/CPE=0.6	542.3	114.2
Planting geometry (maize:soybean)		
01:01	389.5	122.0
01:02	376.4	115.4
02:01	346.3	112.3
02:02	340.9	113.8

CPE=0.6. It decreased with increase in moisture regimes and the lowest (279.9 kg/ha-cm) was with irrigation at IW/CPE=1.0. (Table 5.29 and Fig. 5.4). The productivity of total water use did not vary substantially among the varying moisture regimes. The irrigation as well as total water use productivity of maize equivalent yield was highest in maize:soybean :: 1:1 planting geometry.

The average cost of cultivation, gross and net returns which was calculated on the basis of the prevailing input and produce prices for intercropping of maize and soybean under different moisture regimes and planting geometry (Table 5.30) revealed that the gross and net returns were highest with irrigation at IW/CPE=1.0 and declined with reduced moisture regime. Planting of maize:soybean :: 1:1 planting geometry as intercrop gave the highest net returns of Rs. 21268/ha.

Table 5.30 Economic (Rs/ha) of intercropping of maize and soybean under different moisture regimes and planting geometry (Mean of the three crop seasons)

Treatment	Gross return	Cost of cultivation	Net return
Moisture regimes, irrigation at			
IW/CPE=1.0	92554	70233	22321
IW/CPE =0.8	86220	69900	16320
IW/CPE =0.6	81198	69567	11631
Planting geometry (maize: soybean)			
1:1	90820	69552	21268
1:2	87380	70603	16777
2:1	83453	69328	14125
2:2	84972	70117	14856

5.8 Jammu

5.8.1 Effect of establishment methods and irrigation regimes on water productivity of basmati rice

The results of the first year of the study during Kharif, 2013 revealed that the water expense efficiency (WEE) values with regard to establishment methods were recorded as 1.28, 1.29, and 1.27 kg/ha-mm for corresponding conventional, SRI, and modified-SRI methods. Water expense efficiency of the order of 0.91, 1.44, 1.38, and 1.70 kg/ha-mm were registered with continuous flooding, 3 DADW, tensiometric approach, and SRI norms, respectively. The minimum value of 0.91 kg/ha-mm (with continuous flooding) and the maximum value of 1.70 kg/ha-mm (with SRI irrigation) represents an 87% enhancement in WEE with SRI than that of continuous flooding.

5.9 Jorhat

5.9.1. Irrigation schedules and nutrient management on Indian mustard (yellow sarson)

Irrigation schedules and nutrient management on Indian mustard (yellow sarson) grown after kharif rice showed that different levels of irrigation influenced plant height, number of siliquae/plant, siliqua length, seeds/siliqua and seed yield of yellow sarson significantly. Total branches/plant and test weight were not significantly influenced by different irrigatinal treatments. Two irrigations at flowering and siliqua development stage (I_3) being at par with one irrigation at flowering (I_1) and siliqua development stage (I_2) recorded significantly higher plant height, siliqua length and number of seeds/siliqua than the rainfed crop. Two irrigations, one each at flowering and siliqua development stage recorded significantly higher number of siliqua/plant and seed yield of yellow sarson than one irrigation either at flowering or siliqua formation stage and rainfed crop

Different level of fertilizers significantly influenced the total branches/plant, number of siliquae/plant and seed yield of yellow sarson. Application of 90-60-60 N-P_2O_5-K_2O kg/ha being at par with 75-50-50 N-P_2O_5-K_2O kg/ha recorded significantly higher branches/plant, number of siliquae/plant and seed yield than 60-40-40 N-P_2O_5-K_2O kg/ha. Plant height, siliqua length and number of seeds/siliqua and test weight were not significantly influenced by different fertilizer management practices. Interaction effect of irrigation and fertilizer was found to be significant on number of siliqua/plant and seed yield of yellow sarson. Application of 90-60-60 N-P_2O_5-K_2O kg/ha with two irrigation at flowering and siliqua formation stage being at par with 75-50-50 N-P_2O_5-K_2O kg/ha with two irrigation - one each at flowering and siliqua formation stage recorded significantly higher siliqua/plant and seed yield than rest of the treatments. Under rainfed condition, response

Table 5.31 Total water used and WUE (kg/ha-cm) of yellow sarson

Treatments	Seed yield (kg/ha)	IW (cm)	Total water used (cm)	Field WUE (kg/ha-cm)
I_1 = One irrigation at flowering	985	4.0	12.3	80.1
I_2 = One irrigation at siliqua development stage	1024	4.0	12.7	80.6
I_3 = Two irrigations at flowering and siliqua development stage	1090	8.0	14.5	75.2
I_4 = Rainfed	745	-	9.8	76.0

of higher dose of fertilizer was not realized in terms of seed yield. It was observed that the amount of irrigation as well as total water used by the crop increased with the increasing levels of irrigation regimes. Thus, the highest amount of irrigation (8.0 cm) and total water use (14.5 cm) were recorded under irrigations at flowering and siliqua development stage (Table 5. 31).

5.9.2 Effect of potassium and different moisture regime on growth and quality of gladiolus

Application of 100% RD of K and 150% RD being at par with each other recorded significantly higher plant height, florets/spike, spike length, rachis length, spike weight and spike yield of gladiolus. Spike/bulb and spike/m^2 were not significantly influenced by different levels of potassium. Different level of irrigation significantly influenced the growth, yield attributes and flower yield of gladiolus (Table 4.32). Irrigation at plant emergence + spike initiation, 4 leaves + spike initiation, plant emergence + 4 leaves + spike initiation and plant emergence + 4 leaves + spike initiation + flower initiation being at par with each other recorded significantly higher spike/bulb and spike/m^2 than rainfed crop. Gladiolus irrigated at plant emergence + 4 leaves + spike initiation + flower initiation and plant emergence + 4 leaves + spike initiation being at par with each other recorded significantly higher plant height, florets/spike, spike length, rachis length, spike weight and spike yield than rainfed, irrigation at plant emergence + spike initiation and irrigation at 4 leaves + spike initiation.

The highest field WUE was observed under rainfed control (1722.6 kg/ha-cm) followed by irrigation at 4 leaves and spike initiation (1718.9 kg/ha-cm). It was followed by irrigation at plant emergence and spike initiation (1554.0 kg/ha-cm). The lowest field WUE (1259.7 kg/ha-cm) was observed under irrigations at plant emergence, 4 leaves, spike initiation and flower initiation. Pooled analysis of flower yield revealed that 100% and 150% RD of K being at par with each other recorded the highest flower yield of gladiolus. Among the irrigation levels, irrigation at plant emergence + 4 leave stage + spike initiation and irrigation at plant emergence + 4 leave stage + spike initiation + flower initiation being at par with each other recorded significantly higher flower yield than rest of the treatments.

Table 5.32 Total water used and WUE (kg/ha-cm) of gladiolus

Treatments	Flower yield (t/ha)	IW (cm)	Total water used (cm)	Field WUE (kg/ha-cm)
I_1 = Controlo (no irrigation)	15.9	-	9.23	1722.6
I_2 = Irrigation at PE and SI	22.3	8.0	14.35	1554.0
I_3 = Irrigation at 4 leaves and SI	25.8	8.0	15.01	1718.9
I_4 = Irrigation at PE, 4 leaves and SI	26.9	12.0	17.91	1502.0
I_5 = Irrigation at PE, 4 leaves, SI and FI	26.1	16.0	20.72	1259.7

PE = plane emergence; SI = Spike initiation; FI = Flower initiation

The flower of gladiolus fetches price on the basis of its quality which is determined by size, number of florets, spike length, colour etc. In our experiment, colour of the florets was uniform. Number of florets indirectly influenced the weight of the flower. It was observed that heavier flowers had more florets/spike and more spike length. Thus considering ₹ 10/- as the maximum price fetched by the heaviest flower, the price considered for K_1, K_2, K_3, I_1, I_2, I_3, I_4 and I_5 are 8.21, 8.94, 9.11, 7.16, 8.15, 8.70, 9.75 and 10.00. As such price/kg flower comes up as 80.65. Cost of corm is considered as 6.00 for all treatments. It was observed that, among the K levels, 100% recommended dose of K recorded the highest net return (2187476/-) and B: C ratio (2.09). Among the irrigation levels, Irrigation at plant emergence, 4 leaf stage and spike initiation stage recorded the net return (2413147/-) and B: C ratio (2.31).

5.9.3 Response of irrigated autumn rice (ahu) to Zinc application in acid soil

DTPA extractable Zn recorded at different days after sowing revealed that their contents tend to decrease upto 60 days under rainfed and 40 days under improved irrigation management system and thereafter there was trend to increase further upto 100 days of sowing. Thus, under improved irrigation management, Zn availability was found to increase 20 days prior to the rainfed situation. Results further showed that increased level of Zn led to higher content of DTPA extractable Zn and maximum value was recorded at Zn level @ 20 kg/ha which did not show any significant difference with no Zn application

Pooled analysis of the effect of improved irrigation practice in direct seeded autumn rice did not show any significant increase in total Zn uptake, however comparatively higher value was recorded at 100 of sowing of rice. It was observed further that Zn uptake was found to be more with increasing levels of Zn application and considerable uptake of Zn was recorded under application of Zn @ 20 kg/ha which was further recorded to be at par with other application rate of Zn (Table 4.33).

Pooled data on yield and yield attributing characters as affected by the irrigation regimes and levels of Zn application are depicted in Table 4.63b. Results revealed that improved irrigation management increased the plant height significantly while, there was no influence on number of effective tillers, 1000 grains weight and grain yield over the rainfed treatment. Application of increased levels of Zn found to increase the plant height, no. of effective tiller/hill, length of panicle and 1000 seed weight and the results were found to be prominent upto 20 kg of Zn application per hectare. Regarding grain yield, highest value was recorded in the treatment receiving 20 kg Zn/ha without showing any treatment difference with respect to no Zn application.

Correlations between available Zn content in soil and its uptake by rice crop with yield is presented in Table 4.64. Highest correlation coefficient between available Zn and yield was observed in 80 days of crop growth while, total Zn uptake correlated well at 60 days of crop growing stage

Table 5.33 Effect of irrigation regimes and Zn application on growth and yield attributes of rice (pooled over 2012 and 2013)

Irrigation	Plant height (cm)	No. of effective tiller/hill	Length of panicle(cm)	1000 grain weight(g)	Grain yield (q/ha)
I_1	77.75	11.12	20.11	19.16	19.66
I_2	80.76	11.83	21.72	21.72	22.64
C.D. 5%	1.79	1.13	NS	NS	3.46
Levels of Zn					
Zn_1	77.42	10.22	19.44	19.11	17.49
Zn_2	76.71	11.14	19.79	19.65	18.35
Zn_3	79.81	11.44	20.70	20.64	21.04
Zn_4	80.93	11.35	21.42	20.75	22.03
Zn_5	82.27	12.42	22.16	21.50	24.12
Zn_6	80.84	12.11	21.47	21.17	23.79
C.D. 5%	NS	1.13	1.57	1.53	NS

Table 5.34 Kinetic constants as influenced by irrigation and Zn levels

Treatments	KC-I(ìg/g/day)	R^2	KC-II (g/ìg/day)	R^2
Irrigation				
I_1	0.115	0.919	0.172	0.802
I_2	0.130	0.954	0.188	0.823
Zn levels (Kg/ha)				
0	0.140	0.922	0.298	0.761
5	0.139	0.935	0.253	0.779
10	0.142	0.946	0.247	0.794
15	0.129	0.942	0.192	0.797
20	0.107	0.948	0.120	0.832
25	0.101	0.960	0.110	0.863

highlighting the importance of soil management of Zn at 80 days of crop growth. In regards to kinetic constant, results revealed that both first and second order kinetic constant showed highest value under improved irrigation management and more that 80 percent data on available Zn varied well in accordance with the days of crop growth. Comparative study on kinetic constant showed that first order kinetic constant to study available Zn release could be depicted well over that of second order kinetic constant (Table 5.34)

Pooled analysis over two years experiments conducted during 2012 & 2013 revealed that improved irrigation practice i.e. 5 cm irrigation at 3 days after disappearance of ponded water (DADPW) did not have any significant effect on periodical total Zn uptake by rice crop. Although Zn uptake was found to be more with increasing levels of Zn application but it was found prominent up to the rate of 25 kg $ZnSO_4.7H_2O$ during 2012 while, it was up to 20 kg $ZnSO_4.7H_2O$ during the year 2013. Pooled analysis to study the effect of irrigation practice and levels of Zn application also showed no treatment differences among the treatments depicting an insignificant role of Zn under improved irrigation management in autumn rice more particularly in medium low land situation. It was further reaffirmed through on-station observation trial conducted during 2014 and no definite trend was observed.

5.9.4. Response of summer moong to levels of irrigation and boron in an acidic soil of Assam

Pooled analysis of biometric observations revealed that plant height, no. of branches per plant and thousand grain weights were not affected significantly by the irrigation regimes. Same observation was also recorded in respect of numbers of pod/plant and grain yield. Application of increasing levels of boron although increased the numbers of pod/plant and grain yield but highest value was recorded in the treatment receiving application of boron @ 15 kg/ha irrigated with IW/CPE ratio of 1.0 that too without showing any significant difference with the remaining treatments both under irrigation schedule and levels of boron application

Different irrigation schedules influenced the effective tillers/m^2, panicle length, grains/panicle, grain yield and straw yield of aerobic rice significantly during 2013-14 (Table 5.35). Saturated condition being at par with 75 available moisture recorded significantly higher effective tillers/m^2, panicle length, grain yield and straw yield than 50% available water and rainfed crop.

5.10 Bhavanisagar

5.10.1 Conjunctive use of groundwater and canal water in the command area-LowerBhavani Project.

Study was undertaken for Conjunctive use of groundwater and canal water in the command area-Lower Bhavani Project.Water table fluctuation indicated that there was steady decline in ground water from Jan – July 2014 since there was no rainfall during Jan- April and only slight rains between May – July. Wells with shallow depth dried and in the other wells water table has gone below 50 feet.The fluctuation in water table both in I turn and II turn wells is similar , the variation

Table 5.35 Effect of irrigation schedule and variety on yield attributes and grain and straw yield of aerobic rice

Treatment	Effective tillers/m^2	Panicle length (cm)	Grains/ panicle	Test weight (g)	Grain Yield (q/ha)	Straw Yield (q/ha)
Irrigation Schedule (I)						
I_0 = Rainfed	106.3	19.5	82.3	20.0	15.4	26.3
I_1 = Saturation	180.1	21.2	107.3	20.1	35.3	71.1
I_2 = 75% Available moisture	193.3	21.1	87.3	20.1	30.6	73.5
I_3 = 50% Available moisture	130.1	20.8	87.6	20.1	20.7	40.6
SEm ±	4.8	0.5	3.8	0.5	1.4	2.8
CD (P = 0.05)	14.3	1.6	11.3	NS	4.8	8.3
Variety (V)						
V_1 = Luit	134.3	17.6	77.1	21.9	20.5	45.8
V_2 = Englongkiri	167.3	23.5	129.2	16.3	33.0	61.6
V_3 = Banglami	159.3	21.5	90.6	21.3	28.9	58.9
V_4 = Dubaichenga	149.2	20.1	67.5	20.9	19.6	45.4
SEm ±	4.9	0.5	3.6	0.5	1.4	2.8
CD (P = 0.05)	13.9	1.5	10.2	1.5	4.0	8.0

is small, since the command of I turn and II turn sluices are nearby.Nearly more than 75 per cent of farmers having open wells are also having bore wells (one or two) so that they can give irrigation to annual crops during summer. Among them nearly 60 per cent of farmers pump out water from bore wells in to open wells / surface level tanks and give irrigation to fields by pumping water from open wells/diverting water from surface level tanks. The reason being the low yield from bore wells which cannot be directly let in to the fields.When water was released from Aug-2014, the farmers at head reaches mostly irrigate with canal water and one or two farmers irrigate with well water and it was reverse in tail reaches (more irrigation from well & less irrigation from canal) because the tail end farmers are not getting canal water sufficiently. The following are the details of number of irrigations through well and canal water in the selected well commands. In the I turn wells, water was not released for irrigation from canal during the year 2014. Hence all the farmers used groundwater only for irrigation. During summer period, when water table depth gone in open wells dried, farmers who are having bore wells, pumped water from bore wells and store the water in open well/surface level tank and use this for irrigation. Water was released for irrigation from canal for II turn from August 2014 to December 2014. During this period, i.e. up to August 2014 well water was used for irrigation and after canal water is released, they used ground water in conjunction with canal water. Farmers who are at the head of the sluice use more of canal water whereas at the tail reach of sluice, farmers use comparatively more of groundwater since the availability at tail reach is less compared to head reach farmers who installed drip system used only groundwater.

5.11. Ludhiana

5.11.1 Evaluation of furrow irrigation system with poor quality water in wheat- cotton cropping sequence.

The effect of irrigation water on water use parameters was given in table 5.36. The furrow irrigation considerably saved irrigation water. The irrigation to each furrow (EF) and alternate furrow (AF) saved 26.7 and 46.7 per cent of irrigation water applied as compared to flat (check basin, CB) method of irrigation on an average basis. The difference in plant height was significant under different irrigation methods.The grain yield and

Table 5.36 : Irrigation water applied, profile water use, water expense, yield water expense efficiency and yield attributing parameters of wheat with poor quality water in different methods of irrigation

Irrigation methods	Irrigation water applied (cm)	Profile water use (cm)	Water expense (cm)	Grain yield ($kgha^{-1}$)	Water expense efficiency ($Kgha^{-1}$ cm^{-1})	Plant height (cm)	Tillers/ m-row length (no)
Canal Water							
Check basin (CB)	30.0	15.5	53.42	4172	78.1	90.4	118.2
Each furrow (EF)	22.0	14.0	43.84	3779	86.2	92.8	111.2
Alternate furrow (AF)	16.0	10.0	33.91	3117	91.9	86.9	102.3
Mean	22.7	13.2	43.7	3689	85.4	90.0	110.6
Tube well water							
Check basin (CB)	30.0	14.1	52.00	4025	77.4	89.4	115.5
Each furrow (EF)	22.0	12.8	42.72	3672	86.0	92.4	109.7
Alternate furrow (AF)	16.0	11.0	34.88	3157	90.5	87.9	103.4
Mean	22.7	12.6	43.2	3618	84.6	89.9	109.5
Pre-sowing irrigation with canal water and all other irrigation with tube well water							
Check basin (CB)	30.0	11.5	49.39	3898	78.9	90.2	112.6
Each furrow (EF)	22.0	8.0	37.92	3559	93.9	92.0	106.5
Alternate furrow (AF)	16.0	10.7	34.54	3286	95.1	87.3	104.6
Mean	22.7	10.1	40.6	3581	89.3	89.8	107.9
Overall average							
Check basin (CB)	30.0	13.7	51.6	4032	78.1	90.0	115.4
Each furrow (EF)	22.0	11.6	41.5	3670	88.7	92.4	109.1
Alternate furrow (AF)	16.0	10.6	34.4	3187	92.5	87.4	103.4
CD (5%)							
Irrigation water				NS		NS	NS
Irrigation method				235		3.6	5.78
Interaction				NS		NS	NS

tillers/m-row length were found to be significant under different methods of irrigation.The grain yield was significantly higher in the flat (CB) and each furrow (EF) irrigation methods as compared to alternate furrow (AF) method of irrigation.The water expense efficiency was in the order of alternate furrow (AF) > each furrow > check basin irrigation method irrespective of water quality.

The effect of varying qualities of irrigation water and different irrigation methods on water use parameters and seed cotton yield are given in table 5.37.The amount of irrigation water applied and total water use was in the order of check basin irrigation method > each furrow irrigation > alternate furrow irrigation.The overall seed cotton yield was highest in each furrow irrigation method. The water expense efficiency was also highest in each furrow irrigation method.The tube well water irrigation decreased the seed cotton yield in flat (check basin) method of irrigation.On an average basis, tube well water irrigation alone yielded 1454

Table 5.37: Irrigation water applied, profile water use, water expense, yield and yield attributing parameters of cotton with poor quality water in different methods of irrigation

Irrigation methods	Irrigation water applied (cm)	Profile water use (cm)	Water expense (cm)	Yield (kg/ha)	Water expense efficiency (kg/ha -cm)	Plant height (cm)	Bolls/ plant (No.)	Sympod Plant (no)
Canal water								
Check basin (CB)	52.5	1.6	81.9	1918	20.3	98.5	45.5	32.2
Each furrow (EF)	38.5	6.3	77.5	1996	23.7	100.8	45.3	33.1
Alternate furrow (AF)	28	6.1	73.0	1678	17.3	94.9	42.4	31.1
Mean	39.7	4.7		1864	20.4	98.1	44.4	32.1
Tube well water								
Check basin (CB)	52.5	-0.6	80.8	1245	12.0	84.1	28.5	22.3
Each furrow (EF)	38.5	4.0	77.3	1603	14.2	91.5	40.5	26.3
Alternate furrow (AF)	28	3.0	72.8	1513	13.6	85.7	37.1	25.5
Mean	39.7	2.1	77.0	1454	13.3	87.1	35.4	24.7
Rauni with canal water and subsequent irrigation with tube well water								
Check basin (CB)	52.5	0.7	82.5	1368	14.5	97.2	38.1	24.9
Each furrow (EF)	38.5	3.4	76.2	1842	17.7	99.3	41.6	30.3
Alternate furrow (AF)	28	4.4	71.8	1675	17.6	93.9	39.1	27.3
Mean	39.7	2.8	76.8	1628	16.6	96.8	39.6	27.5
Overall average								
Check basin (CB)	52.5	0.6	81.7	1510	15.6	93.3	37.4	26.5
Each furrow (EF)	38.5	4.6	77.0	1814	18.5	97.2	42.5	29.9
Alternate furrow (AF)	28.0	4.5	72.5	1622	16.2	91.5	39.5	28.0
CD(5%)								
IrrigationWater				201.9		4.4	5.4	2.2
IrrigationMethod				155.7		4.1	3.1	1.9
Interaction				NS		NS	5.5	NS

kg/ha seed cotton yield as compared to 1628 kg/ha in which pre-sowing (rauni) with canal water followed by all other irrigations with tube well water and (1864 kg/ha) with canal water irrigation alone. The difference in seed cotton yield and other yield attributing characters viz. no. of sympods / plant, no. of bolls/plant and plant height were statistically significant under both different water qualities and different irrigation methods. However, interaction among different water qualities and different irrigation methods were found to be non significant.

5.11.2. Effect of quality of water on growth, yield and quality of potato under varying mulch conditions

The effect of quality of irrigation water under varying mulch conditions on tuber yield and water use parameters was given in Table 5.38 . Under no mulch condition, tubewell water irrigation alone gave significantly lower tuber yield than canal water alone and alternate irrigation of canal and tubewell water irrigation. In general, mulching with straw and plastic mulch produced significantly

Table 5.38 : Irrigation water applied, profile water use, water expense, yield, water expense efficiency of potato with different water qualities under varying mulch conditions

Irrigation methods	Irrigation water applied (cm)	Profile water use(cm)	Water expense (cm)	Marketable tuber yield (q/ ha^{-1})	Water expense efficiency, (kg ha^{-1} cm^{-1})
T_1 = No mulch under canal water (CW)	35	10.96	51.08	131.1	256.7
T_2 = No mulch under tubewell water (TW)	35	8.96	49.08	71.4	145.4
T_3 = No mulch under CW /TW (alternate irrigation)	35	10.55	50.67	104.1	205.5
T_4 = Straw mulch under canal water (CW)	35	9.67	49.79	142.5	286.2
T_5 = Straw mulch under tubewell water (TW)	35	10.03	50.15	83.8	167.1
T_6 = Straw mulch under CW /TW (alternate irrigation)	35	9.91	50.03	120.1	240.1
T_7 = Plastic mulch under canal water (CW)	35	10.46	50.58	158.5	313.3
T_8 = Plastic mulch under tubewell water (TW)	35	9.49	49.61	85.3	171.9
T_9 = Plastic under CW /TW (alternate irrigation)	35	9.86	49.98	124.5	249.1
CD (5%)				25.9	

Rainfall = 5.12 cm

higher marketable tuber yield than non mulching conditions. The tuber yield with polythene mulch was at par with straw mulch in all the water qualities. Similarly the water expense efficiency was higher under straw and plastic mulch than without mulch.

5.11.3 Effect of quality of water on growth, yield and quality of okra under varying mulch conditions

The effect of quality of irrigation water under varying mulch conditions on okra yield and water use parameters was given in Table 5.39. The application of mulch irrespective of the quality of irrigation water improved the okra yield.Application of tubewell water alone produced lower fruit yield than canal water alone or its alternate use with canal water irrespective of mulch application.The highest fruit yield was obtained with canal water alone under plastic mulch followed by straw mulch.The fruit yield increment was significant under plastic mulch and straw mulch irrespective of the quality of water.Similarly the water expense efficiency was

Table 5.39 : Irrigation water applied, profile water use, water expense, yield, water expense efficiency of okra with poor quality water under varying mulch conditions

Irrigation methods	Irrigation water applied (cm)	Water Profile water use (cm)	Water expense (cm)	Green okra yield (kg/ha)	water expense efficiency (kg/ha-cm)
T_1 = No mulch under canal water (CW)	60	3.63	70.9	8013	113.0
T_2 = No mulch under tubewell water (TW)	60	2.62	69.9	3258	46.6
T_3 = No mulch under CW /TW (alternate irrigation)	60	3.25	70.5	6259	88.8
T_4 = Straw mulch under canal water (CW) @ 6 ton/ha	60	1.92	69.2	9175	132.6
T_5 = Straw mulch under tubewell water (TW) @ 6 ton/ha	60	4.39	71.7	3863	53.9
T_6 = Straw mulch under CW /TW (alternate irrigation) @ 6 ton/ha	60	2.14	69.4	7003	100.9
T_7 = Plastic mulch under canal water (CW) Plastic mulch 50 micron	60	3.97	71.3	9861	138.3
T_8 = Plastic mulch under tubewell water (TW) Plastic mulch 50 micron	60	2.34	69.6	4256	61.1
T_9 = Plastic mulch under CW /TW (alternate irrigation) Plastic mulch 50 micron	60	3.77	71.1	7544	106.1
CD (5%)				890	

Irrigation depth: 6.0 cm

higher under plastic mulch and straw mulch application than without mulch.The irrigation water applied was 60 cm, profile water use ranged from 1.92 to 4.39 cm under different treatments.The water expense efficiency was maximum (138.3 kg /ha-cm) under T_7 and minimum (46.6 Kg /ha-cm) under T_2 treatments.

5.11.4. Screening of wheat cultivars under varying saline sodic irrigation water conditions

The effect of quality of irrigation water on yield and other parameters of different wheat cultivars are studied.The mean profile water use was 9.65 and 7.79 cm under canal and tubewell water, respectively.The quality of water had non-significant effect on grain yield of different wheat cultivars, however, various wheat cultivars showed significant difference with respect to grain yield and height among themselves.The overall water expense efficiency of cv. PBW 343 and PBW-550 was higher than remaining cultivars. The quality of water had non significant effect on grain yield of different wheat cultivars.. The wheat cultivars PBW 550 and PBW 343 gave significantly higher grain yield than other varieties under canal water as well as tube well water. However, the wheat cultivars viz. PBW- 343, and PBW-550 performed better than KRL 19 under tube well water alone. The water use efficiency was also maximum under canal water than tube well water alone application at both the locations.

5.11.5. Study the growth and water use of tree species under different saline sodic water environments.

The plantation of three tree species viz. Poplar, Eucalyptus and Burma Dek was done during 2010-11. The data of growth parameters (height and girth) was taken in the month of November 2014 and is given in table 5.40 . Different proportions of canal water and tubewell water had non-significant effect on girth and height in case of Eucalyptus. In case of Dek, maximum height was found in canal water, which was significantly higher than irrigation with TW and 2 TW:1CW. The lowest height of dek was recorded under tubewell water alone. Among different treatments, theheight of poplar trees with canal water irrigation was significantly higher than other treatments except in 2CW:1TW. The girth of poplar trees was at par among CW, CW:TW and 2CW:1TW treatments which were significantly higher than the TW and 2 TW:1CW treatments. The data in table V.8.2 indicates that water expense under different tree species was lowest in canal water followed by 2CW:1TW treatment.

5.12. Morena

5.12.1 Effect of fertilizer on seed yield and economics of Blackgram (Urid) under Blackgram –Fennel cropping sequence.

Application of 125% RDF produced more grain yield, straw yield and B: C ratio. Application of 150% RDF is more expensive & reduced returns & B: C ratio. (Market rates: Grain Rs.4000/-per qt. & Straw @ Rs.200/= per qt.)

Table 5.40. Height and Girth of Dek, Eucalyptus and Poplar under different qualities of water during November, 2014

Treatment	Dek		Eucalyptus		Poplar	
	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)	Height (cm)	Girth (cm)
CW	9.2	44.2	15.3	50.0	11.4	40.9
TW	8.0	38.5	14.6	47.6	9.1	34.7
CW:TW	8.8	41.6	14.8	48.2	10.0	38.1
2CW:1TW	9.0	43.7	15.2	49.8	11.1	39.0
2TW:1CW	8.2	38.8	14.7	48.0	9.5	36.1
CD(5%)	0.7	3.7	NS	NS	1.2	3.4

Table 5.41. Irrigation Water Applied (IWA), Profile Water Use (PWU) and Water Expense (WE) in different tree species

Treatment	IWA (cm)	PWU (cm)	Rainfall (cm)	WE (cm)
Dek				
CW	33.6	10.32	36.92	80.84
TW	33.6	16.72	36.92	87.24
CW:TW	33.6	15.61	36.92	86.13
2CW:1TW	33.6	13.01	36.92	83.53
2TW:1CW	33.6	14.16	36.92	84.68
Eucalyptus				
CW	39.2	13.13	36.92	89.25
TW	39.2	18.4	36.92	94.52
CW:TW	39.2	17.56	36.92	93.68
2CW:1TW	39.2	13.95	36.92	90.07
2TW:1CW	39.2	17.58	36.92	93.7
Poplar				
CW	39.2	10.88	36.92	87.00
TW	39.2	16.63	36.92	92.75
CW:TW	39.2	16.49	36.92	92.61
2CW:1TW	39.2	13.71	36.92	89.83
2TW:1CW	39.2	14.07	36.92	90.19

Table 5.42. Effects of treatments on seed yield and economics of blackgram

Treatments (Fertility levels)	Grain Yield (kg/ha)	Straw yield (kg/ha)	Total Income (Rs/ha)	Cost of cultivation (Rs/ha)	Net Income (Rs/ha)	B:C Ratio
75% RDF	890	2002	39602	11102	28502	3.56
100% RDF	1024	2560	46080	12870	33210	3.58
125% RDF	1156	2832	51904	14380	37524	3.61
150% RDF	1126	2815	50670	15950	34720	3.17
Sem±	0.032	0.148	-	-	-	-
CD(P=0.05)	0.069	0.302	-	-	-	-

Table 5.43: Effects of treatments on growth, yield, WUE and economics of Fennel

Treatments	Plant height (cm)	No. of umbels/ plant	No. of seeds/ umbel	Test weight (g)	Yield (kg/ha)	WUE (kg/ha/ cm)	Net income (Rs)	B:C ratio
Irrig. Schedules								
I_1 - 0.6 IW/CPE	131.6	25	626	11.7	2136.38	30.5	54830	2.78
I_2 - 0.8 IW/CPE	139.7	28	661	11.9	2239.47	40.0	61954	3.24
I_3 - 1.0 IW/CPE	119.4	24	611	11.7	2058.44	42.0	56213	3.15
Sem±	2.12	0.96	2.89	0.06	8.97	0.02	-	-
CD(P=0.05)	4.65	1.95	5.89	0.12	18.30	0.04	-	-
Fertility levels								
F_1 - 75% RDF	115.9	19	584	10.9	1835.85	32.2	47184	2.81
F_2 - 100% RDF	125.2	24	507	11.5	2079.33	36.4	55673	3.04
F_3 - 125% RDF	139.7	29	670	12.3	2352.55	41.2	65352	3.28
F_4 - 150% RDF	140.1	29	669	12.3	2311.33	40.4	62453	3.09
Sem±	3.05	1.02	3.11	0.08	10.22	0.03	-	-
CD(P=0.05)	6.57	2.19	6.70	0.17	22.06	0.06	-	-

5.12.2. Effect of irrigation scheduling& fertilizer levels on growth, yield, WUE and economics of Fennel under Blackgram-Fennel cropping sequence

Irrigation scheduling at 0.8 IW/CPE along wth 125% dose of nutrients yielded the maximum yield, growth, WUE, net income & B:C ratio.

5.13. Navasari

5.13.1 Effect of irrigation and fertigation levels on growth and yield of annatto (Bixaorllana)

Seed yield and shell

The results pertaining to seed yield and shell: seed ratio are reported in tables 5.4.11 and 5.4.12, respectively. The individual effect of fertigation and interaction effect between irrigation and fertigation were found to be significant on seed yield during pooled analysis only. Wherein treatment F_2 recorded significantly higher seed yield as compared to F_3 level, but it remained at par with treatment F_1. While treatment I_2F_2 gave significantly higher seed yield than rest of treatment combinations, but it remained at par with treatment combinations I_2F_1, I_2F_3, I_3F_2, I_3F_3 and I_1F_2. In case of seed : shell ratio of annatto, the I x F effect was significant during pooled analysis only and treatment combination I_2F_2

registered significantly higher shell : seed as compared to rest of the treatment combinations, but it remained at par with treatment combinations I_1F_1, I_3F_1, I_1F_3, I_3F_2 and I_3F_3. With respect to control v/s rest analysis, no significant difference was found between treatments mean and control during individual years as well as in pooled analysis for both the cases.

Water use efficiency (WUE)

Irrespective of treatments, the WUE ranging from 0.9 kg/ha-mm with control to 3.79 kg/ha-mm with I_1F_2treatments . Based on mean data of total water applied, 75 per cent water saving was recorded with lower drip irrigation ratio (I_1) over control. Since interaction effect of irrigation and fertigation levels on seed yield was found significant hence economics was calculated for different treatment combinations (Table 5.44). Considering seed yield of annatto, maximum net profit realized under control treatment (Rs. 21629/ha) followed by treatment combination of I_1F_2 (Rs. 17686/ha).

Table 5.44. WUE as influenced by different treatments (pooled)

Treat-ments	Seed yield (kg/ha)	Water applied (mm)	WUE (kg/ha mm	Water saving (%)
I_1F_1	794	296	2.68	75
I_1F_2	1120	296	3.79	
I_1F_3	796	296	2.69	
I_2F_1	964	573	1.68	51
I_2F_2	1128	573	1.97	
I_2F_3	1098	573	1.92	
I_3F_1	806	650	1.24	44
I_3F_2	842	650	1.29	
I_3F_3	1032	650	1.59	
Control	1049	1160	0.90	-

Table 5.45. Effect of irrigation and fertigation levels on seed yield of annatto (kg/ha)

Treatments	2010-11	2011-12	2012-13	2013-14	Pooled
I_1 (0.2 PEF)	529	1172	852	865	854
I_2 (0.4 PEF)	547	1446	1144	984	1030
I_3(0.6 PEF)	567	1321	1137	877	975
SEm±	47.3	132.0	168.2	76.7	58.0
CD at 5%	NS	NS	NS	NS	NS
F_1(N& K 40%)	495	1155	958	1007	904
F_2(N& K 80%)	679	1519	1141	915	1063
F_3 ((N& K 40%)	469	1266	1033	804	893
SEm±	47.3	132.0	168.2	76.7	58.0
CD at 5%	NS	NS	NS	NS	166
Treat. Mean	548	1313	1044	909	953
Control(0.8 IW/CPE)	702	1604	1165	724	1049
I x F					
SEm±	82.0	228.7	291.3	132.8	100.5
CD at 5%	NS	NS	NS	NS	288
Cont. v/s rest					
SEm±	84.8	184.0	213.1	101.2	74.9
CD at 5%	NS	NS	NS	NS	NS
CV%	13.9	15.5	21.6	21.8	18.2
Interaction.	-	-	-	-	Y

Table 5.46. Economics of different treatments

Treat-ment	System cost (Rs/ha)	Culti-vation cost (Rs/ha)	Total cost (Rs/ha)	Seed yield (kg/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)
I_1F_1	15291	22617	37908	794	39700	1792
I_1F_2	15291	23023	38314	1120	56000	17686
I_1F_3	15291	23430	38721	796	39800	1079
I_2F_1	15291	22828	38119	964	48200	10081
I_2F_2	15291	23234	38525	1128	56400	17875
I_2F_3	15291	23641	38932	1098	54900	15968
I_3F_1	15291	22886	38177	806	40300	2123
I_3F_2	15291	23293	38584	842	42100	3516
I_3F_3	15291	23699	38990	1032	51600	12610
Control	3667	27154	30821	1049	52450	21629

* Selling price of Annatto seed @ Rs. 50/kg

5.13.2 Study on pit method of planting in sugarcane under drip irrigation

The results of first ratoon crop of sugarcane experiment presented in table 5.47. The results revealed that all the growth parameters as well as yield attributes, the main effect of pit diameters was found to be significant only on average cane weight, wherein treatment D_1 (1.79 kg) recorded significantly higher can weight as compared to treatment D_3, but it was at par with treatment D_2.With respect to pit spacing, the effect was significant only on girth of internodes and length of internodes. In both the cases treatment S_2 and S_3 remained at par with each other and both were significantly superior over treatment S_1. In case of cane yield, treatment D_2 (135.7 t/ha) registered significantly higher yield as compared to treatment D_1, but remained at par with treatment D_3. Among the three spacing tested, treatment S_2 and S_1

Table 5.47. Growth parameters and yield of sugarcane as influenced by different treatments

Treatments	Inter nodes girth	Av. length of inter-nodes (cm)	No. of inter-nodes/cane	Full cane height (m)	Millable cane length (m)	Av. cane weight (kg)	Cane yield (t/ha)
Pit diameter(cm)							
D_1 -45	8.75	10.7	28.2	4.25	3.12	1.79	119.9
D_2 -60	8.69	10.7	28.3	4.31	3.14	1.67	135.7
D_3 -75	8.87	10.4	28.2	4.33	3.13	1.59	132.8
SEm±	0.10	0.11	0.47	0.06	0.05	0.03	3.74
CD at %	NS	NS	NS	NS	NS	0.12	14.8
Pit Spacing(m)							
S_1 (1.5 x 1.5)	8.14	9.9	29.5	4.17	3.09	1.66	135.8
S_2 (1.75 x 1.75)	8.96	10.9	28.0	4.39	2.98	1.54	137.7
S_3 (2.1 x 2.1)	9.20	10.9	27.2	4.33	3.31	1.85	115.0
SEm±	0.23	0.18	0.69	0.13	0.08	0.08	3.34
CD at %	0.73	0.61	NS	NS	NS	NS	11.55
D x S							
SEm±	0.18	0.18	0.81	0.11	0.08	0.05	6.47
CD at %	NS	0.54	2.39	NS	NS	0.15	NS
Control v/s rest(mean)							
Treat. Mean	8.77	10.6	28.2	4.30	3.13	1.68	129.5
Control	8.26	10.8	27.1	4.25	3.00	1.58	117.10
SEm±	0.02	0.02	0.51	0.01	0.01	0.00	20.11
CD at 5%	0.07	NS	NS	NS	NS	NS	NS
CV %	4.12	3.47	5.76	3.28	5.14	6.21	9.99

Table 5.48. Qualitative parameter of sugarcane (%) as influenced by different treatments

Treatments	Pol	Purity	CCS	Fibre	Pol per cent	Recovery(%)
Pit diameter(D)						
D_1	17.49	93.20	12.40	14.74	13.16	10.24
D_2	17.76	90.17	12.41	14.39	13.43	10.44
D_3	17.60	90.88	12.34	14.39	13.31	10.33
Pit spacing (S)						
S_1	17.91	91.71	12.61	14.83	13.47	10.55
S_2	17.20	91.03	12.07	14.46	13.00	10.04
S_3	17.74	91.51	12.47	14.23	13.44	10.42
Control	17.43	92.22	12.30	14.73	13.12	10.20

remained at par with each other and both were significantly superior over treatment S_3.As regards to D x S interaction (Table 5.4.21), the effect was significant on length of internodes, girth of internodes and average cane weight. The value of internodes girth was significantly higher in D_3S_1 treatment combination as compared to rest of the treatment, but it was at par with treatment combinations of D_2S_1, D_3S_2 and D_1S_3. The value of length of internodes was significantly higher in all the combinations of S_2 and S_3 with D. In case of average cane weight, treatment D_1S_3 and D_2S_3 were remained at par with each other and both were superior over rest of the treatment combinations. With respect to control v/s rest analysis, the effect was found significant with only in case of girth of internodes and higher girth of internodes was registered with treatment mean than control. The quality parameters viz., pol, purity, CCS, fibre, pol % in cane and estimated recovery were also determined. Not much variation was observed in all quality parameters due to different treatments. However, as compared to control, treatments S_1 and D_2 showed an edge with respect to pol per cent (Table 5.48).

5.13.3 Effect of water application in different layers of soil on growth and yield of drip irrigated young mango plantation Results and interpretations

During the year, the growth parameters and fruit yield of mango were recorded (Table 5.49). The differences among the treatments were not significant in growth parameters as well as fruit

Table 5.49: Growth parameters of young mango as influenced by different treatments

Treatments	Stem girth (cm)	No. of fruits per plant	Fruit yield (kg/ tree)	Water applied (mm)	WUE (kg/ ha-mm)
T_1-Surface drip	51.5	168.3	31.4	709	17.7
T_2-30 cm below ground level through drip	50.7	168.3	29.4	709	16.5
T_3-40 cm below ground level through drip	50.2	124.7	24.6	709	13.9
T_4-50 cm below ground level through drip	54.8	192.7	36.3	709	20.5
T_5-60 cm below ground level through drip	53.3	168.8	35.7	709	20.1
SEm±	2.06	2.63	3.14		
CD @ 5%	NS	NS	NS		
CV %	11.7	33.65	28.0		

Table 5.50. Yield attributes and fruit yield of banana as influenced by different treatments

Treatments	Av. bunch wt./plant (kg)	Length of bunch (cm)	No. of hands/ bunch	No of fingers/ bunch	Fruit yield (t/ha)
Source (S)					
S_1 :Routine Fertilizers: Urea + Phosphoric acid + MoP	28.42	94.67	9.83	145	96.40
S_2 :Water soluble fertilizers : (Urea,12:61:0, 13:00:45)	29.19	100.72	10.06	148	99.96
SEm±	0.37	0.88	0.13	1.3	1.265
CD at 5%	NS	2.58	NS	NS	NS
Fertigation levels (L) (% RDF)					
L_1 (40 % RDF)	25.97	86.44	9.06	138	85.23
L_2 (60 % RDF)	28.76	102.1	9.96	148	98.60
L_3 (80 % RDF)	31.89	104.6	10.81	153	110.72
SEm±	0.45	1.1	0.153	1.6	1.55
CD at 5%	1.31	3.2	0.450	5.0	4.54
Fertigation frequency (F)					
F_1 :(Once in a week)	27.96	96.53	9.81	143	94.18
F_2 :(Twice in a week)	29.66	98.86	10.08	149	102.20
SEm±	0.37	0.88	0.13	1.3	1.265
CD at 5%	1.07	2.60	NS	4.0	3.71
Sig. Interactions	-	-	-	-	-
Treatment Mean	28.81	92.61	9.94	146	100.0
Surface-control	23.81	73.67	8.83	136	82.70
SEm±	4.842	5.795	1.123	16.900	11.371
CD at 5%	NS	NS	NS	NS	18.11
PFDC-package	27.34	85.25	10.08	145	94.90
SEm±	4.786	6.196	1.114	17.010	11.671
CD at 5%	NS	NS	NS	NS	14.66
CV %	5.2	2.85	5.30	5.7	6.00

yield. Though, not significant, yet applying water at 50 and 60 cm depth through drip recorded relative higher fruit yield than 30 and 40 cm depth treatments. This was reflected in WUE as T_4 and T_5 recorded higher WUE as compared to remaining three treatments.

5.13.4 Comparative performance of water soluble and routinely used fertilizer in banana (cv. Grand Naine) under drip irrigation

In case of fruit yield, only the effects of levels of fertigation (L), frequency of fertigation (F) and control v/s rest analysis were significant (Table 5.4.4). The fruit yield followed the significant descending trend on L levels i.e. $L_3>L_2>L_1$ between the two frequency of fertigation, F_2 recorded significantly higher fruit yield of 102.2 t/ha as compared to F_1 (94.18 t/ha). In case of control v/s rest analysis, treatment mean (100.0 t/ha) was better than drip method (94.9 t/ha) and drip better than surface method (82.7 t/ha).

5.7. Parbani

5.7.1 Influence of mulching and irrigation level on growth and yield of summer groundnut under drip irrigation.

Application of irrigation water through drip at 1.0 PE recorded significantly higher pod yield (4211.11 kg ha^{-1}) of summer groundnut as compared to rest of the irrigation treatments. However, lowest pod yield (3341.85 kg ha^{-1}) of summer groundnut was observed in irrigation level I_4 (1.2 PE).As regard to mulching treatment, significantly maximum pod yield (4370 kg ha^{-1}) of summer groundnut was harvested in Transparent Polythene Mulch (M_1) as compared to rest of the mulches. The maximum water use efficiency i.e. 7.51 kg ha^{-1}-mm was recorded in irrigation level 0.6 PE (I_1) followed by 0.8 PE (I_2) i.e. 5.96 kg ha^{-1}-mm. Water use efficiency of 5.41 kg ha^{-1}-mm was recorded in irrigation level 1.0 PE. Lowest water use efficiency 3.58 kg ha^{-1}-mm was observed in irrigation treatment I_4 (1.2 PE). As regards to economics significantly highest gross monetary return was observed in irrigation at 1.0 PE treatment (I_3) as compared to rest of the irrigation levels.In case of mulches treatments the maximum gross monetary return was recorded (185729 Rs.ha^{-1}) in transparent polythene mulch (M_2) which was found significantly superior over rest of the treatment. Significantly maximum net monetary return (95461 Rs.ha^{-1}) was observed in irrigation level 1.0 PE (I_3) as compared to rest of the treatments.Similarly, significantly maximum net monetary return (86310 Rs.ha^{-1}) was recorded in transparent polythene mulch (M_2) over rest of the mulches.

Table 5.51: Growth and yield of summer groundnut as influenced by irrigation levels and various mulches during 2014-15.

Treatment	Plant ht. (cm)	Dry Pod yield (kg ha^{-1})
Irrigation levels		
I_1 - Irrigation at 0.6 PE	25.89	3507.59
I_2 - Irrigation at 0.8 PE	26.52	3712.59
I_3 - Irrigation at 1.0 PE	31.20	4211.11
I_4 - Irrigation at 1.2 PE	24.12	3341.85
SE $\pm$	0.46	102
CD at 5%	1.59	354
Mulches		
M_1 - Black polythene mulch	27.77	3931.85
M_2 - Transparent polythene mulch	31.01	4370.00
M_3 - Soybean straw mulch	25.84	3492.22
M_4 - Control	23.11	2979.07
SE $\pm$	0.51	105
CD at 5%	1.76	364
I x M		
SE $\pm$	0.91	191
CD at 5%	NS	NS
GM 26.93	3693.00	

Table 5.52. Water use efficiency of summer groundnut as influenced by different irrigation levels during 2014-15.

Irrigation levels	Water Applied (mm)	Dry Pod Yield (kg ha^{-1})	Water Use Efficiency (kg ha^{-1} mm)
I_1 : 0.6 PE	466.92	3507.59	7.51
I_2 : 0.8 PE	622.56	3712.59	5.96
I_3 : 1.0 PE	778.20	4211.11	5.41
I_4 : 1.2PE	933.84	3341.85	3.58

Table 5.53 : Economics of summer groundnut as influenced by different treatments

Treatment	GMR (Rs.ha^{-1})	Total cost (Rs. ha^{-1})	NMR (Rs. ha^{-1})	B:C ratio
Irrigation levels				
I_1-Irrigation at 0.6 PE	148360	83256	65104	1.79
I_2-Irrigation at 0.8 PE	157616	83360	74256	1.92
I_3-Irrigation at 1.0 PE	179054	83594	95461	2.15
I_4-Irrigation at 1.2 PE	141796	83186	58611	1.75
SE $\pm$	4477	-	1781	-
CD at 5%	15492	-	6162	-
Mulches				
M_1- Black polythene mulch	167045	95353	71692	1.75
M_2- Transparent polythene mulch	185729	99419	86310	1.87
M_3- Soybean straw mulch	148315	78878	69436	1.88
M_4 - Control	125739	59745	65993	2.10
SE $\pm$	4572	-	3185	-
CD at 5%	15822	-	11021	-
I x M				
SE $\pm$	8099	-	4053	-
CD at 5%	NS	-	12042	-
GM	156707	83349	73358	1.90

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AICRP-IWM Latitude and Longtidue of the Centre

Sl. No.	Name of University/ ICAR Institute	AICRP Centre Location	Lagitude	Longitude
1	a) ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha	Bhubaneswar	20º 18′ 52" N	85º 48′ 40" E
	b) ICAR-IIWM Research Farm, Mendhasal, Khurda, Odisha	Mendhasal, Khordha	20º 17′ 30" N	85º 41′ 34" E
2	G.B.Pant University of Agriculture & Technology Pantnagar- 263 145 Uttarakhand	GBPUA&T, Pantnagar, 263145, Uttarakhand	29º 01′ 26" N	79º 29′ 04" E
3	Mahatma Phule Krishi Vidyapeeth M.P.K.V., Rahuri, Dist: Ahmednagar - 413 722 Maharashtra	M.P.K.V., Rahuri,Dist : Ahmednagar, 413 722, Maharashtra	19º 45′ to 19º 57′ N	74º 18′ to 74º 19′ E
4	Rajendra Agricultural University, R.A.U., Pusa, Dist: Samastipur - 848125, Bihar	R.A.U., Pusa, Dist:Samastipur, 848 125, Bihar	25º 59' N	85º 48' E
5	Punjab Agricultural University PAU, Ludhiana-141 004, Punjab	a) Regional Research Station, Punjab Agricultural University, Dabhawali Road, Bhatinda, 151 001, Punjab	30º 58′ N	74º 18′E
		b) College of Agril. Engineering, P.A.U., Ludhiana, 141 004, Punjab	30º 54′ N	75 º 48′ E
6	Jawaharlal Nehru Krishi Vishwa Vidyalaya J.N.K.V., Jabalpur- 482 004, Madhya Pradesh	a) JNKV Zonal Agril. Research Station, Powarkheda, Dist: Hoshangabad, 476001, Madhya Pradesh	22º 41′ 38" N	77º 45′ 12" E
		b) College of Agril. Engineering, J.N.K.V., Jabalpur, 482 004, Madhya Pradesh	23º 12′ 57" N	79º 57′ 38" E
7	Tamil Nadu Agricultural University T.N.A.U., Coimbatore 641 003, Tamil Nadu	a) T.N.A.U., Agricultural Research Station, Bhavanisagar, 638 451, Tamil Nadu	11º 47′ N	76º 56′ 16′′ E
		b) Dept. of Agronomy, Agril. College & Research Institute (TNAU), Madurai, 625 104, Tamil Nadu	09º 58′ 13" N	78º 12′ 16" E
		c) Water Technology Centre, T.N.A.U., Coimbatore : 641 003, Tamil Nadu	11º 01′ 01" N	76º 56′ 03" E

Sl. No.	Name of University/ ICAR Institute	AICRP Centre Location	Lagitude	Longitude
8	Maharana Pratap University of Agriculture & Technology M.P.U.A. & T.Udaipur- 313 001, Rajasthan	College of Technology & Agricultural Engineering Campus, M.P.U.A. & T., Udaipur, 313 001, Rajasthan	24º 35' 46" N	73º 44' 04" E
9	Agriculture University, Kota	Regional Research Station, Ummedganj Farm, Nayapura, Kota, 324 001, Rajasthan	26⁰ 0' N	76Ú 6' E
10	Indira Gandhi Krishi Vishwavidyalaya I.G.K.V., Raipur, 492 012, Chhattisgarh	a) Faculty of Agricultural Engineering, I.G.K.V., Raipur, 492 012, Chhattisgarh	21º 14' 06" N	81º 42' 57" E
		b) I.G.K.V., Regional Agricultural Research Station, Sarkanda Farm, Bilaspur, 495 001, Chhattisgarh	22º 06' 18" N	82º 08' 27 E
11	Junagadh Agriculture University, J.A.U., Junagadh- 362 001, Gujarat	Junagadh Agriculture University, J.A.U.,Junagadh- 362 001, Gujarat	21º 31.73' N	70º 27.47' E
12	Navsari Agriculture UniversityNAU, Navsari, 396 450, Gujarat	Navsari Agriculture UniversityNAU, Navsari, 396 450, Gujarat	20º 57'N	72º54' E
13	University of Agricultural Sciences, Dharwad, 580 005, Karnataka	Coord. Project for Res. on Water Management, Belvatgi, P.O. Navalgund, Dist.: Dharwad, 582 208, Karnataka	15º 36.6' N	75º 13.8' E
14	Kerala Agricultural University, P.O. 680 656, Thrissur, Kerala	Kerala Agricultural University, P.O. 680 656, Thrissur, Kerala	10º 20' N	76º 26' E
15	Orissa University of Agriculture & Technology OUAT, Bhubaneswar, 751 003, Odisha	OUAT Regional Agril. Research Station, Chiplima, Dist.: Sambalpur, 768 025, Odisha	20º 43' to 20º 11' N	82º 39' to 82º 15' E
16	Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist.: Ratnagiri, Dapoli, 415 712, Maharashtra	Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist.: Ratnagiri, Dapoli, 415 712, Maharashtra	17º 45'	73º 26'
17	Narendra Dev University of Agriculture & Technology NDUAT, Faizabad, 224 229, U.P	Narendra Dev University of Agriculture & Technology NDUAT, Faizabad, 224 229, U.P	26⁰ 47' N	82⁰ 12' E
18	Bidhan Chandra Krishi Viswavidyalaya BCKV,Mohanpur, Nadia, W.B.	Bidhan Chandra Krishi Viswa Vidyalaya BCKV, Mohanpur, Nadia, W.B.	23º 0' N	89º 0' E

Sl. No.	Name of University/ ICAR Institute	AICRP Centre Location	Lagitude	Longitude
19	CCS Haryana Agriculture University, Hisar, 125 004, Haryana	CCS Haryana Agriculture University, Hisar, 125 004, Haryana	29º 10' N	75º 46' E
20	S.K. University of Agricultural Science & Technology, Jammu, 180 00	S.K. University of Agricultural Science & Technology, Jammu, 180 002	32º 40′ N	74º 53′ E
21	Assam Agriculture University, Jorhat, 785 013, Assam	Assam Agriculture University, Jorhat, 785 013, Assam	26º 44′ N	94º 10′ E
22	Rajmata Vijayaraje Scindiya Krishi Vishwa Vidyalaya, Zonal Agricultural Research Station, Morena, 476 001, Madhya Pradesh	Rajmata Vijayaraje Scindiya Krishi Vishwa Vidyalaya, Zonal Agricultural Research Station, Morena, 476 001, Madhya Pradesh	25° 15' to 26° 45' N	70° 30' to 76⁰ 22′ E
23	Ch. Sarwan Kumar Krishi Vishwavidyalaya, Palampur, 176 062, H.P.	Ch. Sarwan Kumar Krishi Vishwavidyalaya, Palampur, 176 062, H.P.	32° 6′ N	76° 3′ E
24	Marathwada Agriculture University,Parbhani – 431 402Maharastra	Marathwada Agriculture University,Parbhani – 431 402Maharastra	17º 35′ N	70º 40′ E
25	Rajasthan Agriculture UniversityRegional Research StationSriganganagar – 335 001Rajasthan	Rajasthan Agriculture UniversityRegional Research StationSriganganagar – 335 001Rajasthan	29º 50′ N	75º 53′ E
26	ICAR Research Complex for NEH Region, Umroi Road, Barapani,Shillong – 793 103 (Meghalaya)	ICAR Research Complex for NEH Region, Umroi Road, Barapani,Shillong – 793 103 (Meghalaya)	25° 38′ N	91° 53′ E
27	Vivekanand Parvatiya Krishi Anusandhan Sansthan Almora – 263 601, Uttarakhand	Vivekanand Parvatiya Krishi Anusandhan Sansthan Almora – 263 601, Uttarakhand	29º 37′ N	79º 40′ E

SCIENTIFIC STAFF POSITION OF AICRP ON IRRIGATION WATER MANAGEMENT AS ON 31-12-2014

	Almora	**Bilaspur + Raipur**	**Bathinda+Ludhiana**
Chief Scientist	Dr.S.C.Pandey	Dr.A.K.Sahu	Dr. Rajan Aggarwal
Agronomist	Dr.Sher Singh	Dr.A.K.Swarnkar	Vacant
Soil Physicst	Dr.S.C.Pandey	Sh.P.K.Keshri	Dr. Ajaib Siddhu
Agril Engineer	Vacant	Dr.Devesh Pandey	Dr.Sudhir Thaman
Jr.Agronomist	Dr. D.Mohanta	Dr.Geet Sharma	Dr.Mrs A. Kaur
		Dr. M. P. Tripathy	Dr. K.S.Sekhon
		Er. P. Katre	Dr. Sunil Garg
		Er. D. Khalko	Dr. (Mrs.) S Kaur
			Dr. Sanjay Satpute
	Chalakudy	**Belvatgi**	**Chiplima**
Chief Scientist	Dr.Mini Abraham	Dr.Gopal.V.Dasar	Dr. A.K.Mohanty
Agronomist	Dr.Anitha. S.	Dr. G.B.Shashidhar	Dr.(Mrs).S.Mohapatra
Soil Physicst	Vacant	Dr.S.S.Gundlur	Dr.P.K.Samant
Agril Engineer	Er.E.B.Gilsa bai	SriJ.K.Neelakanth	Dr.N.Panigrahi
Jr.Agronomist	Dr.Deepa Thomas	Dr. S.P.Halagalimath	Dr.B.R.Nayak
	TNAU (Bhavanisagar+Madurai+Coimbatore)	**Dapoli**	**Faizabad**
Chief Scientist	Dr.V.K.Duraiswamy	Dr.R.T.Thokal	Dr.G.R.Singh
Agronomist	Dr.S.K.Natarajan	Dr.(Smt) R.S.Patil	Vacant
Soil Physicst	Dr.S.Thenmozhi	Dr.K.P.Vaidya	Dr.T.P.S.Katiyar
Agril Engineer	Dr. P.K. Selvaraj	Dr.B.L.Ayare	Dr.R.C.Tiwari
Jr.Agronomist	Dr.K. Ramah	Dr.T.N.Thorat(on Study leave)	Dr.B.N.Singh
Chief Scientist	Dr.S.Krishnasamy		
Agronomist	Vacant		
Soil Physicst	Dr.R. Indirani		
Agril Engineer	Dr.N.Anandaraj		
Jr.Agronomist	Dr.A.Gurusamy		
	Dr. A.Raviraj		
	Dr. A.Valliammai		
	Dr.P.Jothimani		
	Jorhat	**Gayeshpur**	**Kota**
Chief Scientist	Dr.R.K.Thakuria	Dr.S.K.Patra	Dr.Pratap Singh
Agronomist	Dr.K.Pathak	Dr.D.Datta	Dr.H.P.Meena
Soil Physicst	Dr.B.K.Medhi	Dr.K.Bhatacharya	Dr.N.N.Sharma
Agril Engineer	Dr.P.Baruah	Er.S.Saha	Er.I.N.Mathur
Jr.Agronomist	Dr.A.Sharma	Dr.S.B.Goswami	Dr.R.S.Narolia

	Hissar	**Jammu**	**Jabalpur (Powerkheda+Jablpur)**
Chief Scientist	Dr.A. S. Dhindwal	Dr.A.K.Raina	Dr. N. K. Seth
Agronomist	Dr.A.S.Dhindwal	Vacant	Dr.P.B.Sharma
Soil Physicst	Dr.V.K.Phogat	Dr.Abhijit Samanta	Vacant
Agril Engineer	Er.Mukesh Kumar	Er.N.K.Gupta	Vacant
Jr.Agronomist	Vacant	Dr. Vijay Bharti	Dr. Vinod Kumar
			Dr. R. K. Nema
			Dr. N. K. Awasthi
			Er. Y. K. Tiwari
	Morena	**Pusa**	**Navsari**
Chief Scientist	Dr.Y.P.Singh	Dr.Vinod Kumar (I/c)	Dr.V.P.Usadadiya
Agronomist	Vacant	Dr.Vinod Kumar	Dr.V.P.Usadadiya
Soil Physicst	Vacant	Dr.Mukesh Kumar	Dr.J.M.Patel
Agril Engineer	Dr.K.Kishore	Dr.S.P.Gupta	Er.N.G.Savani
Jr.Agronomist	Dr.S.K.Tiwari	Dr.Rajan Kumar	Dr.R.B.Patel
	Palampur	**Parbhani**	**Pantnagar**
Chief Scientist	Dr.V.K.Suri	Dr. A. S. Kadale(I/C)	Dr.Subhash Chandra
Agronomist	Dr.Kapil Saroch	Dr.K.T.Jadhav	Vacant
Soil Physicst	Dr.Naveen Datt	Dr.U.N.Karad	Dr.H.S.Kushwaha
Agril Engineer	Vacant	Ds. A.S. Kadale	Dr.Vinod Kumar
Jr.Agronomist	Dr.S.K.Sandal	Dr. G. D. Gadade	Dr.Gurvinder Singh
Prof. & IC			Dr.H.C.Sharma
Prof.			Dr.Yogendra Kumar
SRO			Dr.Harish Chandra
	Sriganganagar	**Rahuri**	**Shillong**
Chief Scientist	Vacant	Dr.M.B.Dhonde	Dr.D.J.Rajkhowa
Agronomist	Dr.R.P.S.Chauhan	Dr.J.B.Shinde	Vacant
Soil Physicst	Dr.B.S.Yadav	Dr.B.D.Bhakare	Dr.U.S.Saikia
Agril Engineer	Vacant	Dr.S.B.Gadge	Vacant
Jr.Agronomist	Vacant	Dr.S.S.Tuwar	Vacant
Assoc. Prof.		Dr.S.D.Dahiwalkar	
Asst. Prof.		Er.S.A.Kadam	
Jr. Reseach Asst.			
	Junagadh		**Udaipur**
Research Er.	Dr.H.D.Rank		Dr. P. K. Singh
Assoc. Prof.	Er.P.B.Sharma		Dr. K. K. Yadav

Revised Budget Estimate (RE) of AICRP Irrigation Water Management for Year 2014-15

Rs. in Lakhs

The head-wise allocation of budget (ICAR share) for each centre under AICRP on Irrigation Water Management based on Revised Estimate for the year 2014-15

Sl. No.	Name of the Center	Estt. Charge	RC/ Research Expenses	IT/ Commu-nication	TA	NRC	Total for Non-TSP Comp.	Total for TSP Comp. (Opera-tional cost)	Total (TSP & Non-TSP comp.)
		NON-TSP COMPONENT							
1	VPKAS Almora*	0	4	1	1	0	6	0	6
2	PAU, Ludhiana (Bath+Ludh)	155	9	0	1	0	175	0	165
3	UAS, Belvatgi	50	5	0	1	0	56	0	56
4	TNAU, Coimbatore (Madurai+BSR+Coimb)	180	15	0	2	0	197	0	197
5	IGKV, Raipur (Bilaspur+Raipur)	115	7	0	1	0	123	15	138
6	KAU, Chalakudy	55	6	0	1	0	62	0	62
7	OUAT, Chipilima	35	8	0.75	1	0	44.75	25	69.75
8	BSKKV, Dapoli	50	6	0	1	0	57	25	82
9	NDUAT, Faizabad	55	6	0	1	0	52	0	62
10	BCKV, Gayeshpur	75	6	0	1	0	82	0	82
11	CCSHAU, Hissar	55	2	0	1	0	58	0	58
12	SKUAST, Jammu	75	7	0.75	1	0	83.75	0	83.75
13	MPUAT, Udaipur	63	4	0.75	1	0	68.75	0	68.75
14	MPUAST,Kota	75	5	0.75	1	0	81.75	10	91.75
15	JAU, Junagadh	45	3	0	1	0	49	0	49
16	RVSKV, Morena	45	4	0	1	0	50	0	50
17	NAU, Navsari	50	7	0	1	0	58	0	58
18	CSKHPKV, Palampur	91	6	1	1	0	99	10	109
19	GBPUAT Pantnagar (WM+GWU)	46	7	0	1	0	54	0	54
20	MAU, Parbhani	48	5	0	1	0	54	0	54
21	JNKV, Jabalpur (Powkheda+Jabalpur)	115	6	0	1	0	122	0	122
22	RAU, Pusa (WM+GWU)	62	7	0	1	0	70	0	70
23	MPKV, Rahuri (WM + GWU)	95	8	1	1	0	105	15	120
24	RAU, Sriganganagar	65	5	0	1	0	71	0	71
	Sub Total	1700	148	6	25	0	1879	100	1979
25	AAU, Jorhat(NEH)	49	7	0	1	0	57	0	57
26	ICAR-RCNEH Shillong(NEH)*	0	12	0	1	0	13	0	13
	Sub Total NEH	49	19	0	2	0	70	0	70
	Grand Total	1749	167	6	27	0	1949	100	2049