A Decade of
Research Achievements
(2010-11 to 2019-2020)

उत्तमा वृत्तिस्तु कृषिकर्मेव

DIRECTORATE OF RESEARCH

Swami Keshwanand Rajasthan Agricultural University

Bikaner - 334 006 Rajasthan

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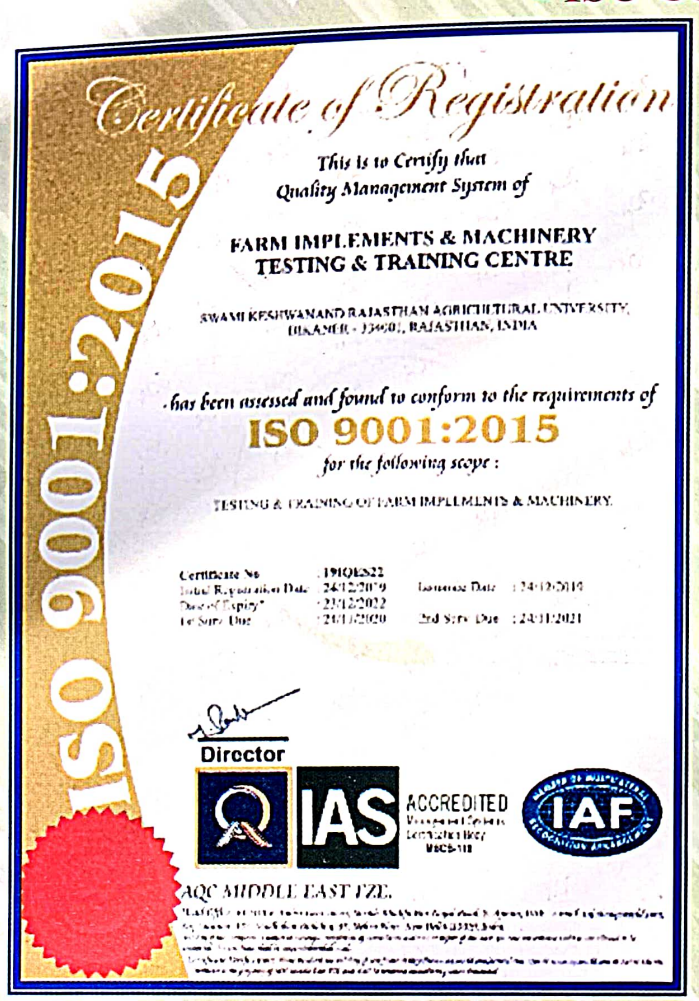

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A Decade of Research Achievements

(2010-11 to 2019-2020)

उत्तमा वृत्तिस्तु कृषिकर्मेव

DIRECTORATE OF RESEARCH

Swami Keshwanand Rajasthan Agricultural University

Bikaner - 334 006 Rajasthan

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कलराज मिश्र
राज्यपाल, राजस्थान

सत्यमेव जयते

Kalraj Mishra
Governor, Rajasthan

Message

I am happy to learn that Swami Keshwanand Rajasthan Agricultural University was established on August 01, 1987 with its headquarters at Bikaner. Teaching, research and transfer of technologies among farmers in the field of agriculture and its allied subjects are the major activities of the University. Achievements of the Universtiy in these areas of activities during the past 10 year have made considerable impact on the devlopment and sustainability of agriculture in the state. A large number of technologies viz,improved varieties of crops, precision farming, off season cultivation of vegetables, nutrient management, organic production, climate resilient/stress management, post harvest management and value addition, insect, pest and diseases management in crops, weed management technologies etc., have been generated for the benefit of farmers. The pace of agricultural research continues unabated with innovations and newer strategies to combat the emerging problems of agriculture today. In last one decade, University has developed 36 new improved varieties of different crops and 107 improved technologies for the betterment of farming communities in the state of Rajasthan in particular and national level in general.

I am glad to know that last ten year Research Achievement (2010-11 to 2019-20) of Swami Keshwanand Rajasthan Agricultural Univesity, Bikaner has been compiled in the form of bulletin. This compilation would certainly prove useful for the agricultural scientists, students and planners at large to chalk out future strategies and programmes for accelerated agricultural development in the state. I compliment and congratulate prof. R. P. Sing, Vice Chancellor and his team for taking this initiative.

Kalraj Mishra

(Kalraj Mishra)

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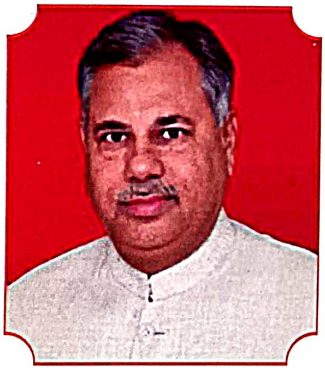


Prof. R. P. Singh
Vice-Chancellor

FOREWORD

Indian economy is mainly dependent on agriculture even today as about 65% of the population is living in rural areas and over 80% of them are dependent on agriculture and allied activities for their livelihood. Realising the urgency of enhancing food production in rainfed areas, scientists recommends some important measurements for rain-fed areas which are highly effective for soil and water conservation through watershed development, increased use of organic nutrients, introduction of drought tolerant and short duration crops varieties, efficient use of available water resources through micro-irrigation and mulching, timely tillage operations to conserve moisture and control weeds, development of wastelands through tree-based farming and introduction of appropriate farm tools to improve the efficiency of labour.

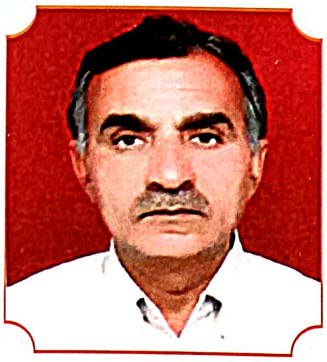
The service area of Swami Keshwanand Rajasthan Agricultural University, Bikaner after its bifurcations, is mainly of arid environment imposing a great challenge to agricultural production and development. Conservation of natural resources (land and water) is the most urgent and ultimate need to address agricultural research in desert environmental condition of the North- Western part of the state. Therefore, integrated approach on cropping systems, rainwater conservation, drought management, nutrient management, biotic and abiotic stress management and pressurized irrigation system and also use of plastics for high water use efficiency, management of saline water for irrigation purpose etc, need utmost attention for researchers. Integrated Farming System (IFS) with emphasis on Precision Agriculture(PA), Integrated Nutrient Management (INM), Integrated Pest Management (IPM), Integrated Disease Management (IDM) and Integrated Weed Management (IWM) including bio-agents, specialty agriculture with emphasis on low -tunnel or protected agriculture (Flowers & Vegetables) are some priority research areas to reduce costs of production and enhancing benefits per rupee invested by the farmers.

Presently, SKRAU Bikaner is gearing up its research system to address these priorities. Several high yielding varieties and improved technologies for the region have been developed for ensuring high productivity of crops. Eco-friendly plant protection schedules have been worked out. As a result, agricultural research is benefiting the farmers at large in the state in general and arid areas in particular. The North-Western region of the state have a large livestock population, hence, there is an urgent need to develop IFS models including fodder production for agro-climatic zones(1b & 1c).

I appreciate Dr. P. S. Shekhawat, Director Research, Dr. S. M. Kumawat, Prof. (Agronomy) and Deputy Director, Directorate of Research, Dr. A. R. Naqvi Prof. (Entomology) and Dr. R. S. Rathore Assoc. Prof. (Horti.) AICRP on Arid fruits, ARS, SKRAU, Bikaner for their sincere efforts for compiling and editing the ten years research document **"A Decade of Research Achievements (2010-11 to 2019-20)"**. Hope this publication would prove useful to research scientists, agricultural extension officials, research scholars, policy makers, progressive farmers who are concerned with agriculture in general.

RPS

(R. P. Singh)



Dr. P. S. Shekhawat
Director Research

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PREFACE

Rajasthan is a resource poor state in the field of agriculture occupying a land area of 34.2 mha and covering 10.4% of India's geographical area but has only 1 per cent available water resource of the country. Moreover the extreme climatic conditions, urges the scientists for integration and conservation of resources. Swami Keshwanand Rajasthan Agricultural University, Bikaner is all geared up to address these priorities. The economy of the rural Rajasthan primarily depends on agriculture and secondarily on livestock or mixed farming. The university has the mandate to carry out agricultural research and development activities in six districts of the state covering two agro-climatic zones (Ib and Ic), out of ten zones and is acting as a good catalyst for the all round development of agriculture through its research works. Despite odds, poor soil health conditions and minimum water resources the scientists' of this University are working hard to boost up the productivity of crops in the North-Western arid region of the state. Several high yielding varieties and improved technologies for the region have been developed for ensuring high productivity of crops. Eco-friendly plant protection schedules have been worked out to benefit the farmers at larger scale in the state. Focusing research on stress agriculture is an utmost priority in order to develop technologies for climate change adaptation and mitigation strategies, and thus making agriculture climate resilient and sustainable.

The present publication entitled "A Decade of Research Achievements (2010-11 to 2019-20)"contains research findings generated from experiments carried out by the scientists' at Agricultural Research Stations at Sriganganagar and Bikaner located in agro-climatic zone Ib and Ic, respectively. The publication also includes research development *i.e*, salient findings and achievements in agriculture under its jurisdiction. A total 36 new varieties / hybrids developed, about 80 improved varieties of different crops and 107 improved production and protection technologies developed and included in the package of practices of respective agro-climatic zones of Rajasthan. Whole hearted efforts and dedication of scientists, technical and supporting staff made it possible to emphasize on new research issues including adaptation / mitigation strategies for high temperature, and other abiotic / biotic stresses. Development of technologies for organic cultivation of crops, fruits/vegetables, protected cultivation of vegetable and off season vegetables/ cucurbits cultivation in shade net / poly houses for higher productivity, enhancing water productivity, micro nutrient management (zinc, iron, Mn). Further, four seed hubs one at KVK (Abusar) Jhunjhunu, two at ARS Sriganganagar and one at University headquarter under NSP, Bikaner were established during the reporting period.

The contributions of Zonal Director(s) Research with their teams, Additional Director Research (Seed), O/Ic, ARSS, and all the staff of the university indulged in the publication are thankfully acknowledged. Dr. S.M. Kumawat, Prof. (Agronomy) & Deputy Director at Directorate of Research, Dr. A.R. Naqvi, Prof.(Entomology) and Dr. R.S. Rathore, Assoc. Prof. (Horticulture) made their sincere and dedicated efforts in compiling and editing this publication. I hope the information contained in this publication would prove useful for one and all users including researchers, students, extension workers, policy makers and farmers.

Dr. P. S. Shekhawat

Editors'

S. M. Kumawat

A.R. Naqvi

R.S. Rathore

Editor Desk

Though,agriculture in Rajasthan is the largest land-based industry, which supports livelihood of nearly 60% of population in the state. Thus, crops and livestock play a pivotal role in rural economy and agricultural research have always acted as a catalyst of agricultural development. Despite all the large looming challenges *viz.*, deterioration of soil health, declining water resources and climate change have thrown out the biggest ever challenge for ensuring food security. There is an urgent need to emphasize on water saving farming, improving soil health, agro biodiversity and farming system research to meet the requirement of food, fiber, feed and fuel need of the state population. Linking research to fields and farmers is therefore necessary for refinement of technologies in different agro-ecological situations in the state. Focusing research on stress agriculture is an equally urgent priority in order to develop technologies for climate change adaptation and mitigation, and thus making agriculture climate resilient and sustainable.

Of the total gross cultivated area about 41.2 per cent is irrigated and rest is rainfed thereby desert environment has imposed a great challenge to agricultural production particularly in Rajasthan. Therefore integration and conservation of resources, are in urgent need to address in agricultural research. Efficient nutrient management based on cropping systems, rainwater conservation, drought management, biotic and abiotic stresses etc, need utmost attention of researchers and policy makers in the state. Further, judicious use of water in agriculture through 'More Crop Per Drop' would be the utmost importance and need highest attention to increase water use efficiency both in irrigated and rainfed agriculture in the state. Rajasthan possesses a large livestock population, thus, there is an urgent need to develop integrated farming system models including fodder production for different agro-climatic zones, commensurate with socio-economic conditions of the common, resource-poor farmers. Linking farmers to markets for promoting opportunities for agri-business are also needed for enhancing income security of the farmers. Prior its bifurcation, Swami Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner has the mandate for catering the need of agricultural research for agricultural development in 21 districts covering 7 agro-climatic zones out of 10 zones in the state. After division of the University in 2013, SKRAU, Bikaner has the mandate for catering the need of agricultural research for agricultural development in six districts covering two agro-climatic zones out of 10 zones in the state.

In SKRAU, thrust has been placed on water saving farming. For this, the University has developed various technologies on mulching and precision farming through sprinkler and drip irrigation. Developing varieties which have low water requirement but higher yield potential had given on top priority. Management of poor quality water in agriculture is another step to be considered to boost the agricultural productivity of the region. In canal irrigated areas, choice of the crop should be based on the availability of canal water in the season. Over the last ten years (2010-11 to 2019-20), scientists working at different research stations and sub-stations have developed 36 high yielding varieties/ hybrids of crops ,107 agro-technologies and plant protection measuresor findings and benefiting to farmers' in the state of Rajasthan and at national level also. Besides, special emphasis has been given to manage the heat stress and micro nutrient deficiency in different crops of the arid region. Drip irrigation along with fertigation was tested in various horticultural and other crops at both research stations. In recent years, insect-pests and diseases have become recurrent impediment in crop production, therefore pests and disease management modules including bio-agents, organic and new chemicals were tested in field crops, vegetables and fruits as well. Simultaneously some novel findings emerges and included in packages of practice for benefit to common farmer also. Moreover, herbicide recommendation in leguminous crops and their residual effect on succeeding crop have been worked out, thus contributing towards eco-friendly agriculture and environmental sanitation.

This Publication "A decade of Research Achievements (2010-11 to 2019-20)"sincere effort has been made for compiling all information's viz., new improved High Yielding Varieties (HYV)/ Hybrids of crops / fruit and improved production& protection technologies, water saving technologies of crops, vegetables & fruits and novel findings etc, of importance in the present day agriculture, and/or future research and development also. The resultant outcome of day and night hardworking of scientists at Research Station/sub-station situated under different agro-climatic zones under SKRAU jurisdiction in the state, the Zonal Director (s) Research, Scientists, technical staff and supporting services staff etc, all deserve deep sense of appreciations and at this endvour they are thankfully acknowledged. Hope, this publication would be proved beneficial / fruitful to researchers, extension workers, students, farmers, policy makers and also one and all reader/ users who's concern with agriculture in general.

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EXECUTIVE SUMMARY

Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner prior its bifurcation has the mandate for catering the need of agricultural research for agricultural development in 21 districts covering 7 agro-climatic zones out of 10 zones in the state. After bifurecation of the University in 2013, SKRAU has the mandate of agricultural research for agricultural development in six districts (namely Sriganganagr, Hanumangarh, Juhunjhunu, Bikaner, Jaisalmer and Three tehsils of Churu district) covering two agro-climatic zones (zone Ib and Ic) out of 10 zones spreading in North –Western part of the state. Presently, Fourteen All India Coordinated Research Projects on different crops/problems have been operating at Agricultural Research Stations, Sriganganagar and Bikaner. Recently, cotton varieties (RS 2817, RS 2818 and RS 2827), desi chickpea varieties namely GNG 2207 (Awadh), GNG 2171 (Meera) and GNG-2261 (Keshav) have released and notified due to sincere and hard work of scientist's under All India Coordinated Research Project on concern crops operating at Agricultural Research Station, Sriganganagar. Also, first Acid Lime Variety namely Ganganagar AL-1 Released in 2018 from ARS, Sriganganagar. Pearl millet hybrids namely BHB 1602 (MH 2192) at national level (Rajasthan, Haryana and Gujrat) and BHB 1202 for Rajasthan state have released and notified during, 2020, 2017, respectively by the sincere and hard work of scientist's under All India Coordinated Research Project on pearl millt at Agricultural Research Station, Bikaner. Likewise under AICRP on forage crops and utilization at ARS, Bikaner new variety Raj bajra -1 (RBB-1) of fodder pearl millet and Bikaneri dhaman (RCCB-2) of dhaman grass released and notified at state level and variety Krishna of lucern and Jaisalmeri sewan (RLSB-11-50) of sewan grass have released and notified at national level . A total 36 new improved varieties / hybrids of crops developed and nearly 80 new crop varieties were also included in the package of practices of different agro-climatic zones under jurisdiction area of the University during 2010-11 to 2019-20.

Sriganganagar centre got ICAR- Chaudhary Devi Lal outstanding AICRP Best Centre Award given by Hon'ble Union Minister of Agriculture and Farmers welfare (on 16.07.2017 in the 89th foundation day of ICAR) . The Farm Implements and Machinery Testing & Training Centre and National Seed Project at SKRAU Bikaner headquarters and Agricultural Research Station, Sriganganar recently got ISO Certificates in 2020.Emphasis on research issues including adaptation / mitigation strategies for high temperature, abiotic / biotic stresses, development of technologies for organic cultivation of fruits/vegetables, protective vegetable cultivation and off season vegetables/ cucurbits cultivation in shade net / poly houses for higher productivity, enhancing water productivity, micro nutrient management (zinc, iron, Mn), was placed by the scientists at both research stations. Special emphasis has been given to manage the heat stress and micro nutrient deficiency in different crops of the arid region. Drip irrigation along with fertigation was tested in various horticultural and other crops at both research stations. In recent years, insect-pests and diseases have become recurrent impediment in crop production, therefore pests and disease management modules including bio-agents, organics and new chemicals were tested in field crops, vegetables and fruits as well. Simultaneously some novel findings emerges and included in packages of practice for benefit to common farmer. Moreover, herbicide recommendation in leguminous crops and their residual effect on succeeding crop have been worked out, thus contributing towards eco-friendly agriculture and environmental sanitation. A total of 107 improved production and protection technologies of crops, vegetables and fruits have developed by scientists.

Besides production and protection technologies, salient research findings which have immense importance not only in the present day agriculture but also helpful for mitigation of future challenges have also been developed with dedicated and sincere efforts of research scientist. Some of the important challenges in agriculture are shortage of irrigation water availability either by reduced water discharge from canal system, continuous declining the underground water table, increasing salinity/alkality of cultivated area, increasing aridity, uneven or erratic and untimely rain fall, shortening of crop seasons, biotic stress, cold and heat stress due to climate change etc, would be major challenges in future agriculture in the state and national level. Conservation Agriculture/ moisture conservation techniques, development of Agro-forestry system, farming system models for different agro-climatic condition, diversification of crops, Forage production, organic production technology, precision agriculture and climate resilient/ Stress management agriculture technologies have been developed and included in package of practices for benefit of farmers. Production of quality seeds of high yielding varieties unquestionably constitutes the mortar for productive agriculture. A total of 35000 kg breeders seeds of different crop varieties were produced from 2010-11 to 2019-20. Further, four seed hubs one at KVK (Abusar) Jhunjhunu, Two at ARS Sriganganagar and one under National Seed Project, Bikaner were established. Human resource development is utmost need to face the emerging new challenges viz., changing life style of humans, dynamics of pests and diseases, weeds, multiple nutrient deficiency, crop diversification, cut down costs of production and enhancing farmers income, zero budget natural farming, etc. under the climate changing scenario in arid region of Rajasthan and in country as whole.

1. Introduction

Rajasthan is the largest state in India with a land area of 34.2 m ha. The majority of the people live in rural community and the economy is basically agrarian in nature. Thus, agriculture has come out to be backbone for sustainable improvement of rural economy in the state. For development of agriculture and livelihood security of the common farmers, availability of high yielding varieties of crops and cost-effective production technologies are the basic requirements. Deterioration of soil health and chronic water scarcity pose a serious challenge toward realizing higher productivity, which needs to be addressed with multi-pronged approach. Environment sanitation and crop quality have gained importance in recent years and there is need for development of eco-friendly crop management technologies. Towards meeting these objectives, Five Agricultural Universities are operational in the state. Swami Keshwanand Rajasthan Agricultural University, Bikaner prior to bifurcation has the major service area with 21 districts under its jurisdiction out of a total of 33 districts of the state. There were seven agricultural research stations and eight sub-stations across seven agro-climatic zones, out of total 10 zones in the whole state. Each main station has its mandate for which it has adequate arable irrigated/ unirrigated land, research laboratories, farm facilities, irrigation and other required facilities. Total 36 All India Co-ordinated Research Projects on different aspects were in operation at various research stations to develop improved varieties as well as effective agro-techniques for enhancing crop productivity and maximizing economic return. Besides, a large number major adhoc/ regular projects were also functioning in different zones for solving specific / local, or need based problems of the farmers.

Swami Keshwanand Rajasthan Agricultural University, Bikaner after the division in 2013, its service area is mainly concern to North-West part of the state. This region has hot and desert environmental conditions and imposed great challenges to agricultural production. SKRAU, Bikaner has the mandate for catering the need of agricultural research for agricultural development in 6 districts spreading over 3 agro-climatic zones out of total 10 agro-climatic zones in the state thus spreads in geographical area 107.64 lakh hectares only. The annual rainfall ranges between 150-500 mm with poorest in Jaisalmer district. The maximum temperature during summer ranges between 40-48°C and the minimum temperature 3°C or below in winter months. The Directorate of Research with its headquarters at Bikaner is operating Fifteen All India Coordinated Research Projects on different crops/problems at Agricultural Research Stations, Sriganganagar and Bikaner. A total 19 projects funded under Rashtriya Krishi Vikas Yojana (RKVY) by the State Department of Agriculture, Govt. of Rajasthan, Jaipur are also operating at Research Stations, College of Agriculture/ College of Home Science and KVK's. The Directorate of Research has the following mandate for contribution toward sustainable development of agriculture in the state in general and for arid region in particular.

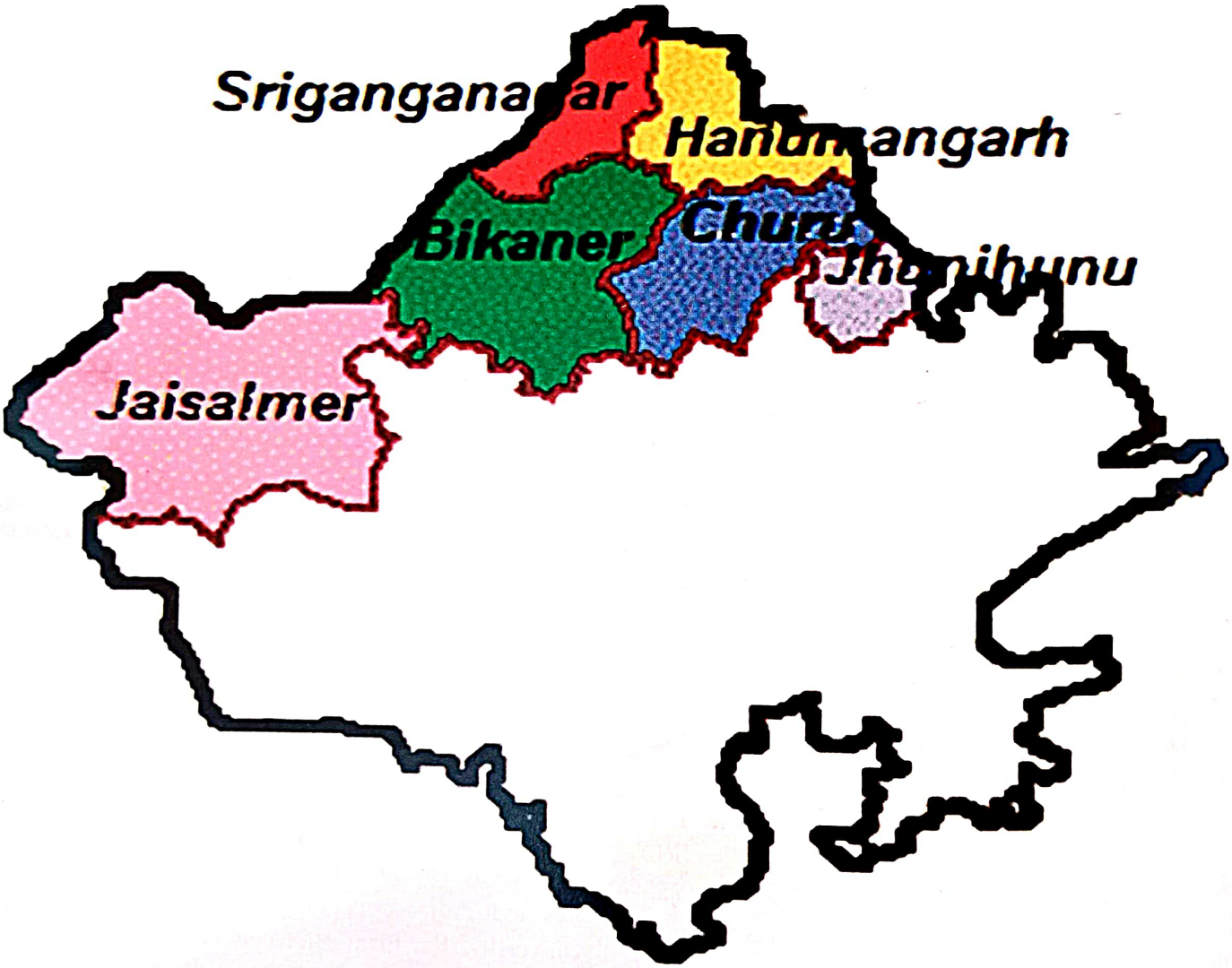
- To plan, coordinate and monitor need-based agricultural research
- To develop new and improved crop varieties as well as appropriate production technologies for optimum use of natural resources in a sustainable manner
- To coordinate and monitor the breeder seed production
- To develop linkages with national and international organizations for fundamental and applied research
- To strengthen the research capabilities of Zonal Research Stations, and
- To extend consultancy and expertise in agriculture sector

The University has established three Centres, i.e., Plant Biotechnology Centre, Centre for Forage Management, and Agro-Biodiversity Centre. Also, the University has centralized facility for Information System (CIMCA) for application in governance and research management. Besides 14 All India Coordinated Research Projects operating at different centres of the University, the Plant Biotechnology Centre and the Centre for Forage Management are engaged in research for providing solutions to the problems confronting agricultural and rural development in Western Rajasthan. The University also undertakes seed production programme under the National Seed Project.

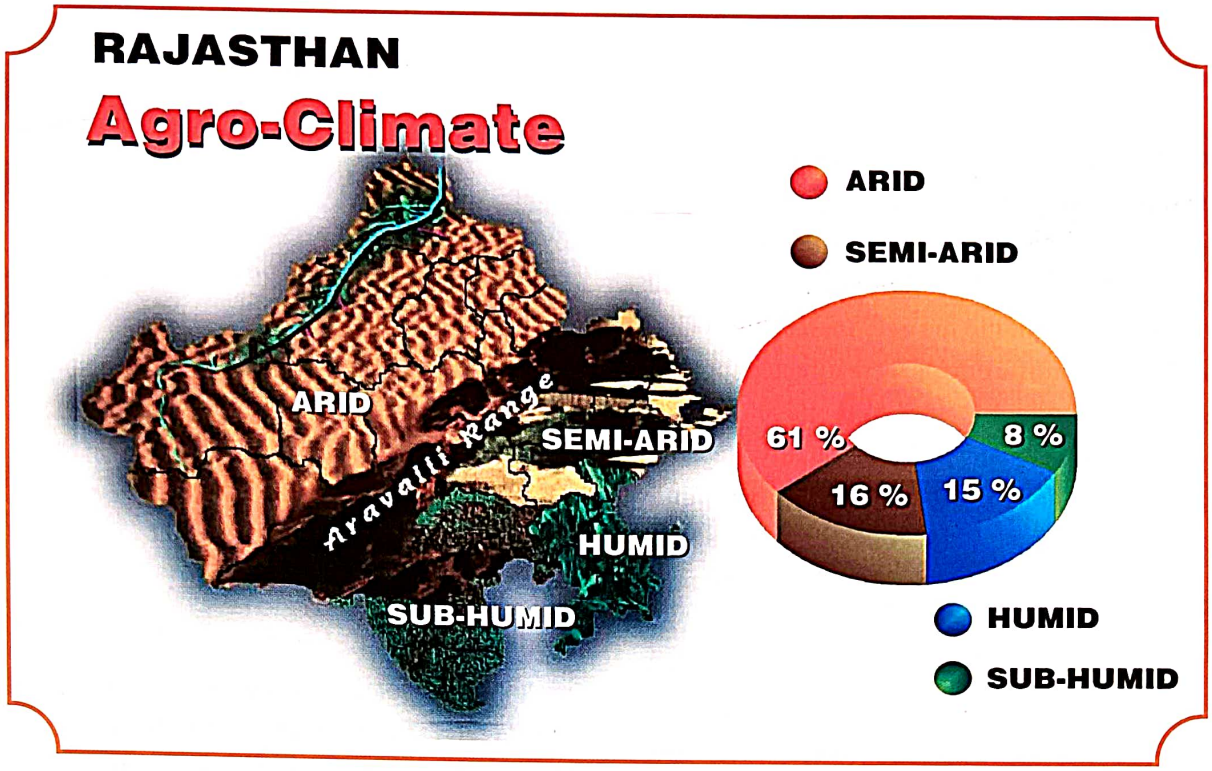
Directorate of Research (HQ-Bikaner)

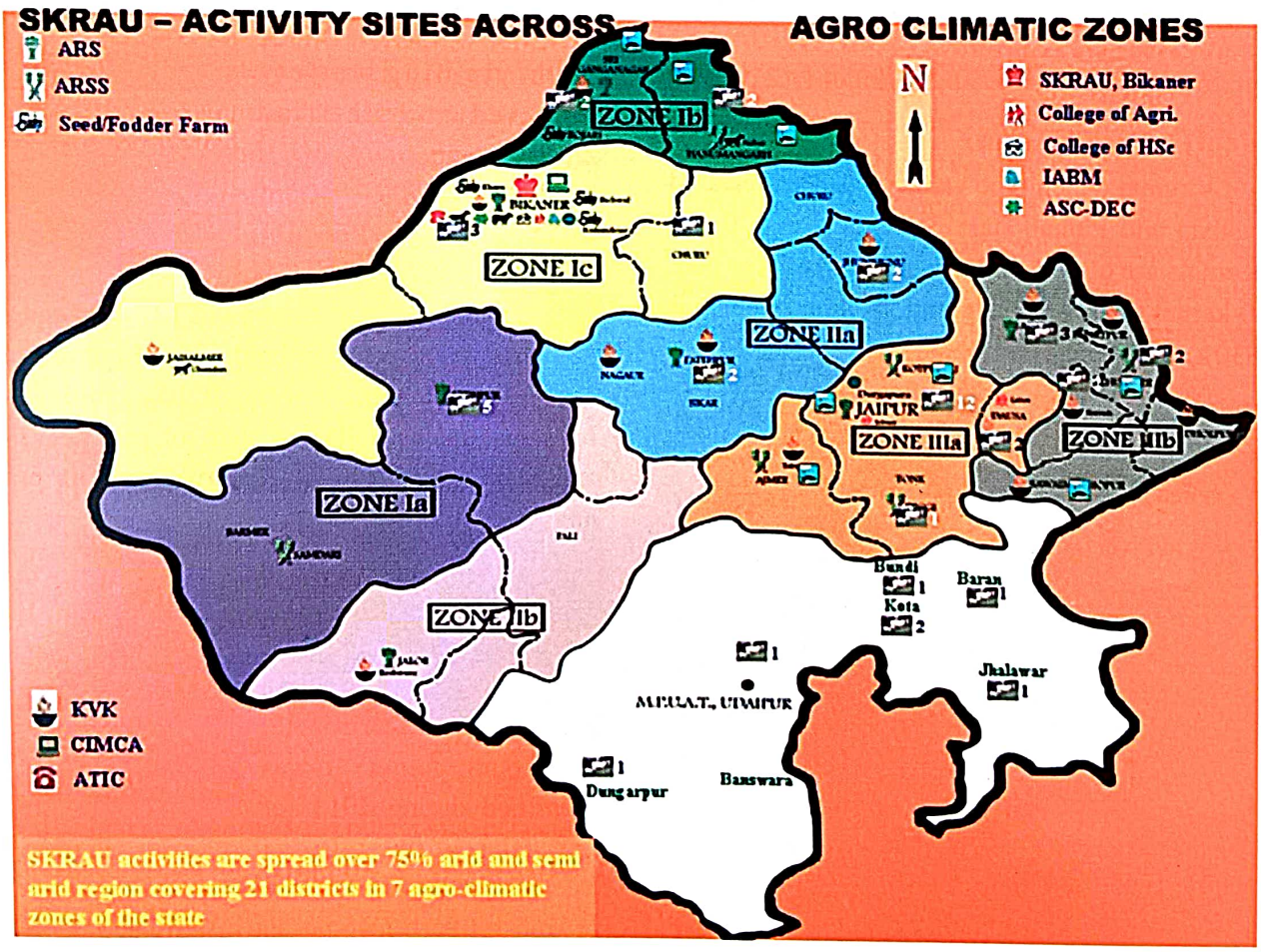
(SKRAU Research System)

ARS Bikaner	ARS SriGanganagar	ARSS Hanumangarh	National Seed Project Bikaner
Establishment year-1995 Area- 146 ha	Establishment Regional station-1962 and as ARS year -1977 Area- 78.6ha	Establishment year -1976 Area- 56 ha	Establishment Year-1987 **Seed Farms** • MAF-Rozari (508 ha) • UCF-Khara (250 ha) • Seed farm,BKN(75 ha)



Map-1: SKRAU Jurisdiction Research Area (2019-20)





Map-2: SKRAU Jurisdiction Research Area (2010-11)

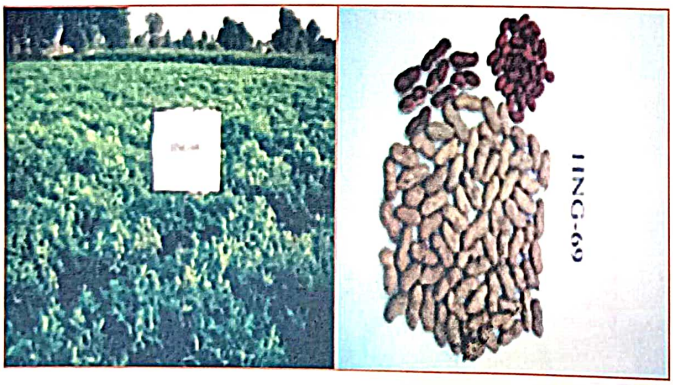
2. Crop improvement: Varieties and national seed project

In changing scenario of agriculture the demand of improved varieties seed is paramount importance for enhancing crop production. Incidence of insect pests and diseases as well as abiotic stresses like frost, heat, drought etc. are major constraints of crop production and their remedial measures are adding the ever increasing cost of cultivation. Thus, scientific efforts were directed towards developing varieties with tolerance to biotic and abiotic stresses. Besides, improvement of crop quality was also an important consideration in crop breeding programme. During last ten years period (2010-11 to 2019-20) a total 36 new improved varieties/ hybrids of field crops namely groundnut (5), mustard (4), wheat (2), chickpea (12), pearl milet (2), cotton (3), fennel, coriander, mothbean and acid lime one in each crop and fodder crops *viz*, bajra, lucerne, sewan and dhaman grass in each one variety have been developed and notified at national level and in Rajasthan as well. Salient characteristics of these varieties are given here as under:

Improved Varieties

Groundnut (*Arachis hypogea*)

HNG 69: Virginia bunch type variety has been released for Rajasthan and Punjab state. It matures in 120-125 days. Kernels are of tan colour with two seeds per pod. The 100-kernel weight is 50 g and shelling is 68%. It gives 2830 kg/ha average pod yield.



ICHG 0440 (Mallika): Virginia bunch, semi-spreading type variety has large pods size. This variety is suitable for timely sown irrigated conditions and matures in 136 days. It has field resistance against collar rot and peanut bud necrosis. Its seeds having export quality with 19.1 mm seed length and 10.5 mm breadth. Kernel colour is tan with 73 g mean 100-kernel weight. The variety has high protein content (20.2%) and good keeping quality (O/L ratio 1.73). Average pod yield is 2579 kg/ha with shelling about 66-70%.

HNG 123: This variety is released and notified for zone 1 comprising of Rajasthan, Punjab and Uttar Pradesh. (Notification:456 (E)/16.03.2012). Virginia bunch type semi-spreading high yielding variety developed through cross between Chandra X RSB-87 by pedigree method at ARSS, Hanumangarh. Kernel is salmon colored. The variety has recorded a mean pod yield of 2648 kg/ha.

RG 510: Virginia runner high yielding variety released and notified Notification no 456(E)/ 16.03.2012 for the states of Rajasthan and Punjab. Average pod yield 2558 kg/ha having maturity duration of 127 days and shelling 68 per cent. It is medium bold with 54 gm mass of 100-seeds and oil content 49%. It has multiple disease resistance against collar rot, stem rot, early leaf spot, rust and peanut stem necrosis. it is tolerant to thrips, jassids and grass hopper.

RG 578 : A semi spreading variety developed by crossing ICG 5013 x RG 141 followed by Pedigree method of selection at ARS, Durgapura, Jaipur. It was Identified during 2013 for the states of West Bengal, Odisha, Jharkhand and Manipur. It has disease resistance against late leaf spot, dry root rot, early leaf spot and rust. It also has tolerance to *Spodoptera litura*, thrips, jassids and leaf miner. RG 578 has high shelling turn over (72%).

Indian Mustard

RGN-229: This variety is a derivative of cross between HEB-3 x LAXMI. It has been identified at national level during 2011 for Mustard growing Zone-II of India comprising of Rajasthan, Punjab, Haryana, Delhi, Jammu and UP under rainfed conditions. It average oil content is 40.66 per cent and 1000 seed weight is 5.04 g. This variety has shown better tolerance to high temperature as well as to salinity. The incidence of *Sclerotinia* stem rot, White rust Altrnaria leaf and pod blight, Powdery and Downy mildew under artificial as well as natual conditions. It matures in about 146 days with average seed yield of 2360 kg/ha.

RGN 236: This variety is a derivative of cross between SBG-00-01 x LAXMI. It has been identified at National level during 2011 for mustard growing Zone-II of India comprising of Rajasthan, Punjab, Haryana, Delhi, Jammu and UP under Late sown conditions. Average oil content is 39.09 per cent and 1000 seed weight is 3.95 gm. Variety has shown better tolerance against *Alternaria* leaf & pod blight and powdery and downy mildew under natural conditions. RGN-236 has no incidence of *Sclerotinia* stem rot under natural conditions.It matures about 127 days with average seed yield of 1640 kg/ha.

RGN-298: Variety RGN-298 was developed from the cross RGN-96 x Pusa bold by Agricultural Research Station, Sriganganagar and identified for release in rain fed areas of Zone-II of India. The average plant height is 207 cm, mature in 143 days, 1000 seed weight is 5.4 gm and oil content 40.0 per cent.

RRN-573 : It was released and notifies in 2013 at national level for cultivation of mustard growing areas. The variety has developed at ARS, Navgaon, Alwar for the cultivation under timely sown irrigated conditions. Its average oil content is 41.85% and 1000 seed weight 4.4 g. The variety attains an average height of 172 cm and matures in 137 days with average seed yield of 2072 kg/ha.

Chickpea (Cicerarietinum)

CSJK-6 (ANJALI) : Variety of Kabuli chickpea developed by crossing RSGK-628 x BG-1053 followed Pedigree method of selection at ARS, Durgapura, Jaipur, notified for North Western Plain Zone (NWPZ) in 2013. The variety is moderately resistant to dry root rot, tolerant to wilt, collar rot and BGM diseases as well as pod borer and root knot nematode. It has good root nodulation also. The variety has medium maturity (188 days) and bold (100 seed wt. 32.8 g) seed size with good quality traits like protein (19.6%), sugar (6.4%) and water absorption ability (0.78%). Its growth habit is semi-erect with profuse branching.

CSJ-515 (AMAN) : It was developed by crossing FG-712 x CSJ-146 followed Pedigree method of selection at ARS, Durgapura, Jaipur. It was identified in 2013 for rain fed cultivation in North Western Plain Zone (NWPZ). The variety has medium maturity (135 days) and bold (100 seed wt. 17.1g) seed size with good quality traits like protein (19.8%), sugar (6.5%) and water absorption ability (0.76%). Its growth habit is semi-erect with profuse branching.

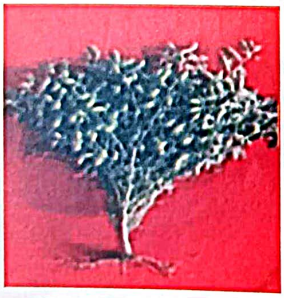
CSJK-21 (ANAND) : It is variety of kabuli chickpea developed by crossing KAK-2 x IPCK 96-3 followed pedigree method of selection at ARS, Durgapura, Jaipur, notified in 2013 for cultivation in Madhya Pradesh. The variety matures in 135-140 days and has extra bold seed (100 seed wt. 60.80 g). Its growth habit is semi-erect with profuse branching.

GNG 1969(Triveni) : This variety of kabuli chickpea was derived from a cross between IPCK 96-3 x GNG 1382 at ARS, Sriganganagar and notified for North West Plain Zone of India which includes North, West and Central parts of Rajasthan, Punjab, Haryana, Western Utter Pradesh, Uttrakhand and Delhi vide notification No. S.O.952 (E) dated 10.04.2013. This variety has medium seed size (26.2 gm/100 seeds) and semi erect plant type. It is suitable for timely sown irrigated conditions. Testa colour is beige while flowers are creamy white. This variety has shown good level of resistance against wilt and root rot. It matures in about 146 days with average grain yield of 2200 kg/ha.

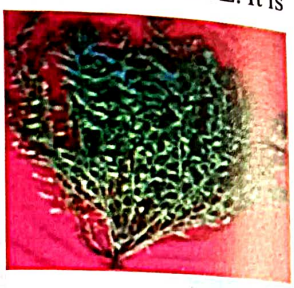
Desi chickpea

GNG 1958 (Marudhar) : GNG 1958 derived from a cross between GNG 1365 x SAKI 9516 developed at ARS, Sriganganagar and notified for North West Plain Zone of India includes North, West and Central parts of Rajasthan, Punjab, Haryana, Western Utter Pradesh, Uttrakhand and Delhi vide notification No. S.O.952 (E) dated 10.04.2013. This variety has shown good level of resistance against wilt, root rot, stunt and collar rot. It matures in about 145 days with average grain yield of 2521 kg/ha.

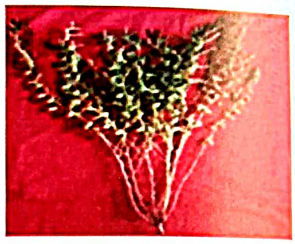
GNG 2144(Teej) : The desi chickpea variety was derivative of a cross between CSJD 901 x CSG 8962 notified in 2016 for cultivation under Late Sown conditions (first week of December) of North West Plain Zone of India comprising of Punjab, Haryana, Rajasthan (excluding southern part), western U.P., Delhi & Uttrakhand. It is a double flowered medium seeded having average 100 seed weight of 15.9 gm. It matures in approximately 133 days. This variety possesses better tolerance against fusarium wilt and root rot disease. Under proper management average yield about 2200 kg/ha.



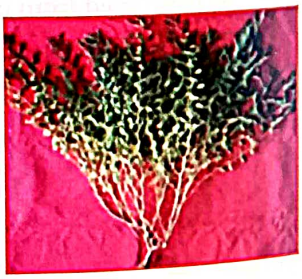
GNG 2171 (Meera): This desi variety was derivative of a cross between CSJD GNG 663 x BG 1044 and developed at ARS, Sriganganagar and released in 2017 at national level for timely sown irrigated conditions of NWPZ. It is a medium seeded having average 100 seed weight of 16.5 gm, matures in about 163 days. This variety possesses better tolerance against important diseases like fusarium wilt, *Ascochyta* blight and root rot. Average yield was 2500 kg/ha, and good level of protein (22.5 per cent).



GNG 2207 (Awadh): This variety was derived from the cross between C 235 x SAKI 9516 developed by ARS, Sriganganagar got notified vide notification No. S.O 6318(E) dated 26.12.2018 for timely sown irrigated conditions in North East Plain Zone of India comprising the state of Assam, West Bengal, Jharkhand, Bihar, Estern Utter Pradesh and Manipur. This variety has shown a good level of tolerance against wilt (*Fusarium oxysporum f. sp. ciceri*) disease and better tolerance against Root Rot, *Ascochyta* Blight and BGM also. It possesses a very good level of protein (23.11 per cent). This variety has attractive seed size of 17.4 g/100 seeds with profuse branching and semi erect plant type. The average grain yield observed was 1648 kg/ha in North Eastern Plain Zone (NEPZ).



GNG 2299 (Purva) : Released in 2018 and suitable for late sown conditions for North Eastern Plain Zone (NEPZ) of India. It has attractive seed size (15.9 gm/ 100 seeds) and has a good level of tolerance against Wilt and *Heliothis* also. good level of protein 20.5 per cent and average yield 1502 kg/ha.



RSG 974: Variety has drought tolerance trait was suitable for rainfed and late sown conditions developed at ARS, Durgapura. The crop matures in 130 to 135 days, average yield of 1200-1500 kg/ha in rainfed condition, 15-20 q/ha

under irrigated late sown conditions. The variety is resistant to wilt, root rot diseases. Grains are medium bold with reddish brown in colour with 100 grain weight of 20-22 g.

Wheat (*Triticum aestivum*)

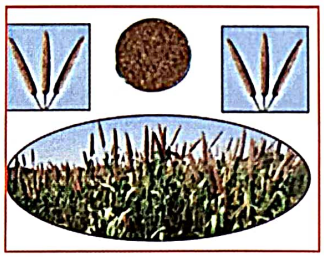
Raj 4079:Double dwarf variety developed through hybridization followed by pedigree method from a cross between UP 2363 / WH 595 at ARS, Durgapura, (Rajasthan). It was notified for cultivation under irrigated, timely sown condition of Rajasthan, gives yield of 4700 – 5000 kg/ha under normal sown, irrigated conditions. It is genetically blessed to thrive and sustain the productivity under high temperature i.e. under heat stress environment of Rajasthan. The variety possesses high degree of resistance against black, brown and yellow rust under natural and artificial conditions. It possess good grain weight (42-46 g/ 100 grains) and also showed early maturity (115 -120 days). It has good grain quality traits, especially for bread and chapatti.

CCNRV 1: It has been developed through hybridization followed by pedigree method from a cross between J 24/AUS 15854 at ARS, Durgapura was the first Cereal Cyst Nematode (*Heterodera avenae*) resistant wheat variety notified in the country. This variety was notified for cultivation in cereal cyst nematode (CCN) infested areas under irrigated, timely sown conditions of Rajasthan. It gives 4000 – 4500 kg/ha yield under irrigated normal sown conditions particularly in cereal cyst nematode infested areas. Besides, this variety possesses resistance to black, brown and yellow rust under natural conditions. It possesses good grain weight (40-42 g/ 100 seeds) and matures in about 120 -125 days. It has good grain quality traits, especially for chapatti.

Pearl millet (*Pennisetum glaucum*)

RHB 173: This dual purpose hybrid is well suited in rainfed and low fertility conditions and it takes 78-80 days to mature. It has long ear head (28-32 cm), more effective tillers (2.53) and more grain weight per ear (35 g). Its plant height is 190-200 cm having lodging tolerance and responsiveness to fertilizers. The hybrid is resistant to downy mildew and other important diseases as well as very less affected by insect pests. Average grain yield under normal conditions is 3070 kg/ha with higher fodder yield (7770 kg/ha).

BHB1202: BHB 1202 is a early flowering dual purpose hybrid of pearl millet, was a cross between a male sterile line ICMA 843-22 (female parent) and a restorer BIB-22 (male parent) released in 2017. On an average, grain yield was 1776 kg/ha, dry fodder yield was 2800 kg /ha, days to 50 per cent flowering slightly earlier (45 days) and maturity duration of 76 days. It's highly resistance to downy mildew and blast. It has high tillering (1.9) and produces compact panicle of 19.10 cm length, filled with medium sized grains (seed weight of 9.84 g/1000 grains) of globular shape and yellow brown colour.



BHB-1602 (duration around 70 days, drought tolerant). More than 20 technologies generated for resource conservation and sustainability. Compaction behind the furrow with 4-5 kg rubber wheel in pearl millet for getting 100% germination. Two Varieties released / notified : BHB1202

Pearl millet hybrid identified for release at National level for Zone A1: MH 2192 (BHB-1602) identified during 54th AGM, New Delhi

Fennel (*Foeniculum vulgare*)

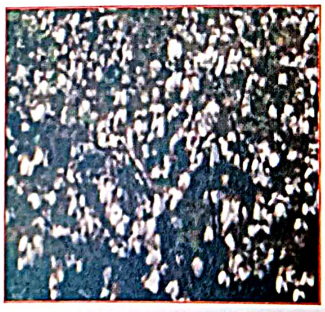
RF 205 (UF 205): This variety was developed through recurrent selection based on individual plant progeny (half-sib) from F2 generation of a cross between JF-25 x RF-125. Erect and medium tall type plant having bolder seed and more branches and umbels per plant. The mean Volatile oil content is 2.48% and mean volatile oil yield is 39.11 l/ha. It has higher yield potential with an average yield of about 1600 kg/ha.

Coriander (*Coriandrum sativum*)

RCr 728 : This variety of coriander was developed through recurrent selection based on individual plant progeny (half sib) performance in UD-728 which was local collection from Garoth, Mandsoor (MP). Its plant type is bushy and erects having early growth vigour is high, more umbellets and seeds per umbel, wilt, Stem gall and powdery mildew incidence is lesser than other varieties. It having higher volatile oil (0.38% with average oil yield of 4.64 liter/ha). Higher yield potential with an average yield of 1370 kg/ha.

Desi cotton (*Gossipium arboreum*)

RG 542: It is recently notified [SO. E 2817(E) dated 19.09.2013] variety of desi cotton (*Gossipium arboreum*) released for the state of Rajasthan developed at SRS, Sriganganagar. It has been derived from the cross between RG 255 X PA 255. The plants are 140-145 cm long. It has sympodial habit, flower with cream petals having red spot on dorsal side of petal and oblong bolls. Average boll weight is 3.0 gm. It has ginning percentage of 35.9 with mean fiber length of 23.2 mm. It matures in 160-170 days with average seed cotton yield of 3000 kg/ha.



RS 2817 (Identified in 2020 for North Zone of India (Rajasthan, Punjab and Haryana): RS 2817 is American cotton developed by AICRP on Cotton of ARS, Sriganganagar for High Density planting system. It has been derived from the cross between H 2132 X F 2052. The variety has showed consistent yield superiority in coordinated varietal trials at different locations in North Zone of India during Kharif 2016-17 to 2018-19. It has given 16.9 and 25.2 percent seed cotton yield superiority under High Density Planting over Zonal Check CSH 3075 and Local Check, respectively. Under closer spacing (67.5 x 20 cm) the cotton variety RS 2817 has good average Seed Cotton Yield potential of 3090 kg/ha ranging from 2047 to 3984 kg/ha. The average lint yield potential of RS 2818 is 1074 kg/ha ranging from 700 to 1365 kg/ha.This variety has showed relatively better disease tolerance (tolerance) against cotton leaf curl virus (CLCuD). RS 2817 has good fiber quality with average Micronaire value (µgm/inch) of 4.46, Fibre length (UHML) of 27.36 mm and Fibre strength (Tenacity) of 29.38 g/tex. It possesses a good level of oil (17.85 percent) also. This variety has good boll weight of 3.2 gm/boll with ginning out turn of 34.6 percent. (Identified in 2020 for North Zone of India (Rajasthan, Punjab and Haryana)

RS 2827 (Identified in 2020 for North Zone of India (Rajasthan, Punjab and Haryana): RS 2827 is American cotton developed by AICRP on Cotton of ARS, Sriganganagar for High Density planting system. It has been derived from the cross between LH 2108 X F 1638. The variety has showed consistent yield superiority in coordinated varietal trials at different locations in North Zone of India during Kharif 2016-17 to 2018-19. It has given 15.5

and 23.7 percent seed cotton yield superiority under High Density Planting over Zonal Check CSH 3075 and Local Check, respectively. Under closer spacing (67.5 x 20 cm) the cotton variety RS 2818 has good average Seed Cotton Yield potential of 3054 kg/ha ranging from 2207 to 3792 kg/ha. The average lint yield potential of RS 2827 is 1016 kg/ha ranging from 717 to 1233 kg/ha. This variety has showed relatively better disease tolerance (tolerance) against CLCuD. RS 2827 has good fiber quality with average Micronaire value (µgm/inch) of 4.38, Fibre length (UHML) of 27.22 mm and fibre strength (Tenacity) of 28.86 g/tex. It possesses a good level of oil (17.2 percent) also. This variety has good boll weight of 3.3 gm/boll with ginning out turn of 33.3 percent.

RS 2814 (Notified in August 2020 for North Zone of India (Rajasthan, Punjab and Haryana): RS 2814 is American cotton developed by AICRP on Cotton of ARS, Sriganganagar for High Density Planting System. It has been derived from the cross between F 2051 X CSH 3120. The variety RS 2814 has shown consistent seed cotton yield superiority in coordinated varietal trials at different locations in North Zone of India during kharif 2015-16 to 2017-18. It has given 22.8 percent seed cotton yield superiority under High Density Planting and 43.2 percent seed cotton yield superiority under recommended spacing over check variety. Under closer spacing the proposed American cotton variety RS 2814 has good average Seed Cotton Yield potential of 2683 kg/ha ranging from 1846 to 3281 kg/ha. This variety has shown relatively better disease reactions (tolerance) against cotton leaf curl virus (CLCuD), bacterial leaf blight (BLB) and fungal foliar leaf spot (FFLS). RS 2814 has good fiber quality with average Micronaire value (µgm/inch) of 4.2, Fibre length (UHML) of 26.5 mm and Fibre strength (Tenacity) of 25.5 g/tex. It possesses a good level of oil (20.9 percent) also. This variety has good boll weight of 3.3 gm/boll with ginning out turn of 34.3 per cent.

Mothbean (*Vigna aconithfolia*)

RMO 2251: A mothbean variety notified in 2017 on all India basis. Developed through mutation of widely adapted popular moth bean variety, RMO-225. Early maturing (63-67 days), erect type of plant, maturity of the variety is synchronized in arid conditions and shattering free. Distinct resistance against Jassids as well as higher resistance against white flies. High score value for quality attributes like protein content, cooking time & IVPD etc. High nutritive value of fodder because it remains green at maturity. Average yield is 486 kg/ha with a potential of 6-8 q/ha.

Acid Lime Variety –

Ganganagar AL-1: Released in 2018

Yield(Fruit/tree)	:1400-1500 Nos.
Yield	: 42-45 kg/tree
Fruit weight	: 28-35 g
Ascorbic Acid	: 30.5 g /100 g pulp
Rind thickness	: 0.18 cm

Forages and Fodder crops

Lucerne (*Medicago sativa*)

Krishna: This variety is a composite in nature. This gives about 45000 kg/ha green fodder in annual condition and 1800 q/ha in perennial condition for three years. Its dry matter yield is approx. 100 q/ha in annual condition and 35000 kg/ha in perennial condition. It is of erect type with good green foliage, light blue flowers and plant height of approx. 70 cm. Its fodder contains 20.6% crude protein, 1.0 leaf: stem ratio, 72.6% IVDMD, 35% ADF and 45.9% NDF.

Fodder pearl millet

Raj Bajra-1 (RBB-1)

- Released at state level.
- Approx. 50000 kg/ha green fodder yield.
- Crude protein : 9.33 per cent
- Green fodder yield productivity per day: 7.17 q/ha.
- Seed yield: Approx. 1500 kg/ha.

Dhaman grass

Bikaneri Dhaman (RCCB-2)

Released at state level.

Approx. 13000 kg/ha green fodder yield from one cutting.

Crude protein : 9.00 per cent

Good resistance to all insect pests and diseases.

Perennial in nature and can be established by seed or rooted slips.

Sewan grass

Jaisalmeri Sewan (RLSB-11-50)

Released at central level in 2016 for North-West zone of India.

Approx. 17000 kg/ha green fodder yield.

Crude protein : 6.59 per cent

Good resistance to all insect pests and diseases.

Perennial in nature and can be established by seed or rooted slips.

Varieties included in packages of practices of different areas:

2010-11

- Results indicated that RCH 314BGI, MRC 6025 BGI, MRC 6304 BGI and JKCH 1947Bt were suitable for all the four agro-ecological situations. However, NCEH 6Bt was recommended only for two agro-ecological situations viz. Ghaggar flood plains and salt affected high water table area. Looking to the infestation of *Spodoptera* in some areas, these five Bt hybrids along with MRC 7017 BGII were also included in package for Sriganganagar region.

- Wheat varieties PBW 550 , PBW 502 , Raj 4037 , HD 2967 and DBW17 varieties were included in package of practices of Sriganganagar region.
- Barley varieties RD 2052, RD 2592 and RD 2660 recorded at per seed yield with check variety RD 2035 and included in package of Sriganganagar.

2011-12

- Pearl millet variety MBC 2 was found suitable for cultivation in zone-Ia.
- Wheat-Raj 4083, Cumin-RZ 223, and Grain amaranths- RMA 7, and Fennel-RF 101 varieties were found suitable for cultivation in the zone -1a.
- Wheat varieties Raj-4083 & Raj-4120 and Mustard: RGN-48 were included in package of practices of Zone IIb.
- Moong variety SML-668 was not only superior yield wise, but also exhibited resistance to YMV disease and thus found suitable for Zone IIIb.
- Green podedurd variety Shekhar-1 was found suitable for Zone IIIb.

2012-13

- Barley variety RD 2552 was found suitable for both saline-alkali and normal soil conditions of zone Ia.
- Bt. cotton hybrids Bioseed 6588 (BG II), Bioseed Bunty (BG II) and RCH 650 (BG II) recommended for cultivation in zone 1b.
- Mungbean varieties IPM-02-03 and Satya were found YMV tolerant and suitable for cultivation in zone 1b.
- Guar variety HG 2-20 was found suitable for cultivation in zone 1b.
- Wheat variety KRL-210 for irrigated problematic soil and Raj-6560 of Durum wheat for normal soil were recommended for cultivation in zone IIb.
- Barley varieties RD-2552 and RD-2660 for irrigated normal soil and RD-2508 for *Sewaj* cultivation (conserved moisture under temporary inundated situation) in IIb.
- Chickpea varieties GNG-469 and GNG-1499 (Kabuli) for irrigated normal soil and RSG-902 for *Sewaj* cultivation (conserved moisture under temporary inundated situation) in zone IIb.
- Grain amaranth variety RMA-7 was found suitable for cultivation in normal soil of zone IIb.
- Yellow mustard variety Navgold was found suitable for cultivation in zone IIb.
- Pearl millet hybrids RHB-173, GHB-732 and GHB-744 were recommended in zone IIb.

2013-14

- Barley malt varieties RD 2503, DWRUB 52 and DWRUB 64 were found suitable for zone Ib.
- Desi chickpea variety GNG 1958 was recommended for cultivation in zone 1b.
- Kabuli chickpea variety GNG 1969 (Triveni) was found suitable in zone 1b.
- Desi cotton variety RG 542 is recommended for cultivation in zone 1b.

2014-15

- Sugarcane variety Co 05009 for early planting has been included in package for zone 1b .
- Recommendation of Beal varieties NB-5 and NB-9 for zone 1b of Rajasthan
- Sorghum variety MFSM-4 for fodder purpose found suitable for zone Ic of Rajasthan.

2015-16

- Wheat varieties WH-1105, DPW 621-50 and HD-3086 for timely sown & DBW-90 for late sown conditions included in package of Zone 1b.
- Barley varieties RD- 2592, RD-2624 & RD- 2552 were found suitable for salt affected area 1b.
- Mustard variety RGN 298 has been recommended for cultivation in rainfed areas of zone 1b.
- Three varieties of chickpea viz., RSG 1969, RSG 1499 and RSG 1488 were included in package of practices in zone 1c
- Two varieties of Oat viz., JHO-822 and HJ- 8 were included in package in zone 1c.
- Two varieties of groundnut viz. HNG 123 and RG 425 (RAJ Durga) were suitable in zone 1c

2016-17

- Groundnut viz. HNG 123 and RG 425 (RAJ Durga) were included inpackage of zone 1c

2017-19

- Gram: GNG 2144 (Teej) and GNG 2171 (Meera) were added in package of zone 1b, and

- Variety GNG 1958 and GNG 2144 were found suitable for cultivation in zone 1c
- Fodder oat variety Bundel Jai-822 was added in package of zone 1b
- Mungbean variety MH 421 was recommended for cultivation in zone 1b
- Pearlmillet Hybrid BHB-1202 was added in package of zone 1c
- Mustard: variety RH 119, RH 749 and NRCHB-101 were found suitable for zone 1c

2019-20

- Wheat variety Raj 4120 and Raj 3765 were found suitable under sudden increase in temperature.
- For the late sown condition (15 to 30 Nov.) NPJ-93 & NRCDR-2 mustard varieties were found suitable under high temperature condition in zone 1c.
- Mustard variety RH 119, RH 749 and NRCHB-101 were found suitable in zone 1c
- Pearl millet hybrid GHB-905 is recommend to include in package of Zone Ic

National Seed Project

- **Seed Production and seed hub programe**

Quality seeds of high yielding varieties unquestionably constitute the mortar for productive agriculture. For adequate availability of certified seeds of high yielding varieties, production of breeder seed in sufficient quantity is a pre-requisite. The university is fulfilling this need through National Seed Project, which is coordinating the breeder seed production programme being undertaken at different centres. A total 35000.37 kg breeders seed of different crops and varieties was produced from 2010-11 to 2019-20. Since seed replacement rate of improved varieties is still low, urgency was felt to intensify breeder seed production programme in order to not only meet the indents put up by the Department of Agriculture and Co-operation, GOI but also to produce seed in excess to guard against any shortfall in the seed production chain. Therefore, seed hub programme has initiated through which certified produced and supplied directly to farmers. In Rajasthan a total Four seed hub established, two at ARS, Sriganganar, one at KVK, Jhunjhunu and one at National Seed Project SKRAU, Bikaner headquarters'.

Table- Seed Production(in quintals) from 2010-11 to 2019-2020

Crop	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-19	2019-20
Wheat	1904	2150	1384	2263	1788	2078	869.6	1064.05	-
Barley	2486	1307	370	994	338	70		454.46	-
Mustard	7	01	6.6	5.0	6.11	13.7	2.3	103.61	4.95
Chickpea	78	742	1085	770	809.41	615	459.2	2250.31	1172.10
Mothbean	19	83	63.6	50	35.2	20.3	57.75	64	28.50
Moongbean	18	223	67.6	29	25.05	58	24.63	113.2	54.00
Cowpea	101	38	11.8	24	0.58	8.20	7.0	6.72	-
Groundnut	440	345	135.5	297	98.5	130	219.5	392	73.0
Sesame	16	16	3.2	3.5	6.06	-	-	-	
Cotton	367	-	-	17	10.5	5.4	11.2	9.0	9.00
Clusterbean	9	556	369.5	220	148.5	117	48	119.39	43.50
Pearl millet	-	-	2.0	2.0	2.5	-	-	-	25.9*
Seed spices	9	129	-	11	-	-	-	-	
Total	**7445**	**5590**	**3498.8**	**4402.5**	**3268.41**	**3115.6**	**1699.18**	**4576.74**	**1410.14**

*Hybrid seed

3. Crop production technologies

Crop management practice in Rajasthan has the need to emphasize on organic farming and integrated nutrient management for having quality produce in a sustainable manner. Enhancement of soil health is the need of the time for sustainable production due to widespread reports of deterioration of soil health throughout the state. Being a desert state efficient use of scarce irrigation water through adoption of pressurized irrigation system is of paramount importance for augmentation of water productivity in agricultural sector. Beside, moisture conservation in rainfed agriculture hold promise, and hence practice like sowing and crop geometry, tillage, production system etc, need emphasis for crop management and production under climate change scenario . Results of research studies carried out in different agro-climatic situations of jurisdiction areas of swami Keshwanand Rajasrthan Agricultural University, Bikaner during 2010-11 to 2019-20 are summarized as under :

Crop geometry and fertilizer requirement for Bt cotton hybrid:

Bt cotton hybrids are quite popular in cotton growing areas of Sriganganagar. Thus, there is an urgent need to find out optimum spacing and fertilizer dose. Result revealed that crop geometry of 108 cm x 60 cm recorded 30.35 q/ha seed cotton yield which was at par with 30.57 and 31.04 q/ha with 108 cm x 45 cm and 67.5 cm x 60 cm spacing, respectively. Further, Bt cotton hybrid RCH-134 gave 31.43 q/ha of seed cotton yield with 100% recommended dose (N-150, P2O5- 40 & K2O-20 kg/ha) of fertilizer which is superior to 75% RD and at par with 125% RD. Thus, crop geometry of 108 cm x 60cm and 150 kg N, 40 kg P2O5 and 20 kg K2O/ha have been recommended for growing Bt hybrids.

Tillage and FYM management in cotton

A field experiment was conducted at ARS, Sri-ganganager to find out the effect of tillage practices and FYM application in Bt cotton to enhance yield and soil improvement in cotton growing areas. The results indicated that deep ploughing in summer was beneficial for Bt cotton. The data further indicate that application 10t FYM/ha was helpful in enhancing Bt cotton yield in a sustainable manner.

Crop geometry of Bt cotton

A field trial was conducted for consecutively for three years at Agriculture Research Station, Sriganganagar on crop geometry of Bt cotton. The results revealed that crop geometry of 67.5 cm x 90 cm gave significantly higher Bt cotton yield in all the years and recommended and included in package of practices of the Zone Ib.

Clusterbean

Three consecutive years study to find out the effect of different crop geometry and seed rate in cluster bean using cluster bean variety HG 2-20. Results based on basis of pooled analysis highest seed yield were recorded with 45 cm row to row spacing and 12 kg seed rate per hectare.

Production System in Pearl millet

Three consecutive years study to find out the suitable hybrid and their crop geometry for hyper arid partially irrigated zone 1c, results revealed that GHB-538 variety gave significantly higher grain yield, net return and B:C ratio as compared to GHB-558. This variety proved more drought resistant as compared to GHB-558. It was further concluded that growing of Bajra at row spacing of 60 cm gave higher grain yield, B:C ratio and net return under drought situation.

Compaction behind the furrow with 4.5 kg rubber wheel in pearl millet for getting 100% germination

❖ Sowing in Pearl millet under climate change scenario

Owing to vagaries of monsoon and to find some solution of sowing pearl millet, if rainfall delay too much, a field trial was laid out at ARS, Bikaner for three consecutive Kahrif seasons (2015-2017). Results reveal that late sowing of pearl millet (25July +5 days) gave better yields as compared to very late (August 10+ 5 days) sowing of the crop. Sowing of pearl millet on 25July +5 days recorded mean grain yield of 1979 kg/ha and stover yield of 3880 kg/ha as against mean grain and stover yields of 1492 and 3367 kg/ha, respectively under very late sowing. Furthermore, application of RDF+5t FYM/ha at sowing + 0.5% NPK foliar spray gave significantly higher grain and stover yields (2034 and 4149 kg/ ha) over recommended dose of fertilizer (1452 and 3069 kg/ha) under late sowing condition.

❖ Sowing method and nutrient management of Quinoa (*Chenopodium quinoa*, or goosefoot)

Recently, study was carried out at ARS, Bikaner and result revealed that sowing of quinoa crop at 50 cm row spacing gave 58.88 per cent higher seed yield as compared to 30 cm row spacing whereas, it was at par with 40 cm row spacing.

Application of 120 kg N /ha gave maximum seed yield of quinoa which was 25.08 per cent higher over 600 kg N /ha and it was at par with 90 kg N/ ha dose

Conservation Agriculture/ moisture conservation techniques

Pearl millet

A field experiment was conducted on pearl millet developing in situ moisture conservation techniques for sustainable pearl millet production under sub optimal conditions at ARS, Bikaner during 2012-13. Result revealed that the application of vegetative mulch at 30 DAS gave significantly higher grain yield, which was 62.26 per cent higher over the control plot.

Chickpea based cropping systems

An experiment was conducted at Agriculture Research Station Sriganganagar to evaluate the effect of tillage and mulch on productivity of chickpea. The conventional tillage (21.6 q/ha) and reduced tillage (21.5 q/ha) found at par in seed yield. However, these were found statistically better over zero tillage (18.8 q/ha). In the mulching treatments, mulching with crop residues found superior (22.5 q/ha) than without mulch (18.7 q/ha).

Cluster bean

Moisture conservation in dry areas has maximum role in crop production. An experiment was conducted at Agricultural Research Station, Bikaner. The results of the experiment indicated that in rainfed areas, sowing of clusterbean at 60 cm row spacing followed by earthing by hand plough or running wheel hoe at 25 and 35 DAS is beneficial for moisture conservation and sustaining yields.

Cotton Crop Production

An experiment was conducted at Agricultural Research Station, Sriganganagar during 2016-17 and results indicated that raised bed with plastic mulch gave significantly higher seed cotton yield as compared with rest of the treatments with or without plastic mulch. Irrigation with drip at 0.8 ETc was found optimum irrigation schedule. In case of canal closer or some other reasons if sowing is not possible in time then the crop may be raised in plastic bags and transplanted in field up to 30th May with drip irrigation without any yield loss.

An experiment was conducted at Agricultural Research Station, Sriganganagar to find out the effect of growth regulators and results indicated that Ethrel @ 8.5 µmols at square initiation followed by MH @ 500 ppm at 95 DAS significantly enhanced the productivity of cotton. In another experiment in the cotton crop, foliar spray of Maleic Hydrazide (MH) (6 hydroxy-3-(2H) Pyrizihone) @ 500 ppm at 75 & 125 DAS or Cycocel (CCC) @ 100 ppm at 75 DAS and 125 DAS were found effective in increasing the seed cotton yield.

Agro-forestry package

- Khari (*Acacia senegal*), neem (*Azadirachta indica*), khejri (*Prosopis cineraria*), ardu (*Ailanthus excelsa*) and anjan (*Hardwickia binata*) were recommended as multi-purpose trees for farm boundary plantation.
- Khejri and desi kikar were found suitable trees for agro-forestry system and bajra and guar were suitable intercrops.

- Ber and aonla were found suitable fruit trees for agri-horticulture with appropriate plant geometry of 6m x 6m. *Gola, Sev* and *Umran* varieties of ber were found better at farmer's fields.
- Israili babool *(Acacia tortilis)* was not found suitable for agro-forestry; however, it was identified as fast growing tree which matured in 15 years. It was recommended for energy plantation on uncultivable and wastelands with the plant geometry of 5m x 5m.
- Ring ditching around the tree base (30 cm deep in 2 m radius) and straw mulch was recommended for moisture conservation in trees.
- *Hardwickia binata* (Anjan) a straight bole tree with palatable fodder leaves was recommended for silvi-pasture and farm boundary plantation in irrigated as well as rain fed situation.
- *Ailanthus excelsa* (Ardu) was recommended for farm boundary plantation to meet their demand for fodder and timber in the situation where temperature does not fall below -1.0°C.
- *Tecomella undulate* (Rohida) and *Prosopis cineraria* (Khejrai) were found tolerant to cold and hot winds.
- Application of FYM @ 10t/ha was found beneficial in *P. cineraria* based agro-forestry system and intercropping of cluster bean provided higher returns than mung bean, cowpea and moth bean.
- Pearl millet and cluster bean were identified most appropriate fodder crops for *Prosopis cineraria* based agro-forestry system for Shekhawati region (zone IIa).

Irrigation Management

Availability of quality water is limiting in most areas in general and more particularly in arid regions of the state of Rajasthan. Agriculture is one of the largest sector and consumes nearly 80 per cent of total available good water. Therefore ground water available is going deeper continuously and exhausted at faster rate, thus more area of dry region has been undergoing to dark zones. Under the circumstance, management of available water through improved methods/ practices or use of improved technology for enhancing water productivity i.e , **More crop per drop of water** need ultimate attention recently and strategies and emphasis were made to work on this aspect of improving water productivity in agricultural crops in general.

▪ Deficit Irrigation Schedule to Improve Wheat Water Productivity

A field trial conducted at Agricultural research station, Bikaner and result indicated that irrigation to wheat crop at ETc 0.8 along with application of 120 kg N /ha was found suitable to get better yield and water productivity.

▪ Wheat varieties WH 1142 & Raj-3077 were found suitable for restricted irrigation conditions (two irrigation at CRI 21 days & Flowering stage 80-85 days)

Six timely sown released varieties of North-West Plain Zone of India were tested for three years with local popular variety Raj 3077 in two and four irrigation levels. The local variety Raj 3077 gave highest mean grain yield in both irrigation levels but it was at par with WH 1142 (56.77 q/ha) at two irrigation level and HD 3086 (63.81 q/ha) and WH 1142 (62.62 q/ha) at four irrigation levels in Sriganganagar region.

Table- : Screening of timely sown wheat varieties at different irrigation schedules

Varieties	Grain Yield q/ha (Two Irrigation)				Grain Yield q/ha (Four Irrigation)			
	2015-16	2016-17	2017-18	Pooled	2015-16	2016-17	2017-18	Pooled
WH 1105	47.24	46.88	56.88	50.33	58.33	60.80	64.36	61.16
HD 2967	48.48	49.11	55.71	51.10	64.35	54.78	59.75	59.63
HD 3086	49.86	56.33	60.05	55.41	65.27	60.87	65.29	63.81
RAJ 3077	50.34	61.89	65.77	59.33	63.84	66.77	68.75	66.45
WH 1142	50.01	58.00	62.30	56.77	60.99	60.22	66.66	62.62
PBW 644	49.72	50.89	58.41	53.01	60.64	54.22	61.29	58.72
Mean	49.27	54.20	59.85	54.44	62.23	59.60	64.35	62.06
CD at 5 %	2.64	5.99	4.20	3.91	2.64	5.99	4.2	3.91

❖ Water management in Cluster bean

A field experiment was conducted at RARI, Durgapura and results indicated that in case of long dry spell, if there is a facility of single irrigation in cluster bean then apply at 50% flowering stage (40-45 DAS). If facility is available for two irrigations then irrigate at vegetative stage (25-30 DAS) and second at 50% flowering stage (40-45 DAS) in zone IIIa.

Clusterbean is a crop which is very sensitive to irrigation scheduling. An experiment was conducted at Agricultural Research Station, Sriganganagar and results indicated that first irrigation at vegetative stage (25-30 DAS) and second at grain development stage (60-65 DAS) was appropriate in cluster bean for optimum production.

❖ Drip irrigation at 0.8 ETc was found optimum irrigation schedule and 45 or 60 cm single row spacing found optimum row spacing for pigeonpea

A field study on "Optimization of crop geometry under drip irrigation in pigeon pea (*Cajanus cajan*)" was conducted during Kharif 2017 to 2019 with 4 levels of irrigation schedule (0.4, 0.6, 0.8 & 1.0 ETc through drip on alternate day) and 5 treatments of crop geometry (45 cm, 60 cm and 90 cm Single Row (Lateral between two lines), 50x100 cm & 60x120 cm Paired Row (Lateral within pair) and Control (Flood irrigation). The effect of irrigation schedules and crop geometry on the yield of pigeon pea was found significant. Drip irrigation was found better than surface irrigation in case of yield of pigeon pea. The maximum seed yield of pigeon pea was recorded at 0.8 ETc. It was significantly higher than the yield obtained at 0.4 and 0.6 and at par with 1.0 ETc. The total water use under drip irrigation at 0.8 ETc was 592.94 mm as against 627.83 mm in surface irrigation. The Water Expense Efficiency (WEE) of the respective treatment was 4.02 & 3.22 kg/ha mm. Further, the yield of pigeon pea increased with increasing the plant stands of the crop. The maximum yield of pigeon pea was recorded with 45 cm single row spacing treatment, which was significantly higher than 90 cm single row, 50 x 100 cm and 60 x 120 cm paired planting and at par with 60 cm single row crop. The interaction effect of irrigation and crop geometry was non significant

Drip irrigation and fertigation schedule for desi cotton

Desi cotton is widely grown in Sriganganagar zone and adoption of drip irrigation system along with fertigation can save precious irrigation water and fertilizer input. Experiment conducted at ARS, Sriganganagar revealed that drip irrigation at alternate days at 0.8 and 1.0 ETc gave at par plant population of 16699 and 17007, respectively. Thus irrigation at 0.8 ETc gave seed cotton yield of 20.18 q/ha which was at par with 1.0 ETc (20.98 q/ha) and superior to flood irrigated crop (16.83 q/ha). Thus, irrigation at 0.8 ETc (687mm) saved 15.57 and 27.95% irrigation water over drip irrigation at 1.0 ETc and flood irrigation, respectively. Further, fertigation with 75% nitrogen in six splits at 15 days interval recorded 20.21 q/ha seed cotton yield, which was at par with 100% (20.57 q/ha) and 125% (20.96 q/ha) recommended nitrogen applied through fertigation.

Bt cotton crop geometry in drip irrigation system

An experiment was conducted at Agricultural Research Station, Sriganganagar during *Kharif* 2009 to 2011 with five crop geometries (60 X 120 paired, 90, 108, 120 and 135 cm single row) for Bt cotton crop under drip irrigation system. Under drip irrigation system row spacing (60 X 120 cm paired, 90, 108 and 120 cm) in cotton gave statistically at par yield. When the row spacing of cotton was further increased to 135 cm, the yield of cotton was significantly reduced as compared to other closer row spacing tested in the study. The water expense efficiency of cotton was almost similar in almost all the treatment except 135 X 60 cm spacing treatment where, it was the lowest.

Irrigation and fertigation schedule for Bt cotton

A field experiment was conducted at ARS, Sriganganagar for the refinement of fertigation schedule for Bt cotton under drip irrigation system. The results indicated that

80% RDF & 2% KNO_3 applied at 90 and 105 days after sowing recorded significantly higher yield of Bt cotton as compared to other treatments. Also, an another experiment was conducted at same location to find out the Irrigation scheduling of Bt Cotton. The results revealed that Bt cotton should be irrigated at IW/CPE of 0.9.

❖ Studies on irrigation scheduling for fodder oat through sprinkler

A field experiment was conducted on fodder oat at farm of ARS, Sriganganagar for three consecutive years from 2011-12 to 2013-14. The treatments consisted of five levels of irrigation (IW/CPE 0.5, 0.7, 0.9, 1.1 with sprinkler and control flood irrigation). The three years results revealed that 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 2012-13, 2013-14 and in pooled data. Thus, sprinkler irrigation at IW/CPE 1.1 was found optimum irrigation schedule for oat. Three irrigations gave 18.2 per cent higher green fodder yield and saved 30.4 per cent irrigation water over conventional flood irrigation.

❖ Optimum irrigation schedule for fodder sorghum under sprinkler irrigation system

An experiment was conducted at Agriculture Research Station Sriganganagar during Kharif 2012 to 2014 to find out the optimum irrigation schedule, water use, WUE and economics of sprinkler irrigation for fodder sorghum. Treatment consisted five levels of irrigation (IW/CPE 0.5, 0.7, 0.9, 1.0 and Control (Surface irrigation)) . 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). Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum.

Irrigation shedulling in Nappier Bajra Hybrid (NBH)

Results of an experiment carried out at ARS, Bikaner indicated that irrigation (DWi = 60 mm) of NBH should be given at at 1.0 IW/CPE ratio and would be scheduled as follows:

Month	Details of Irrigation Schedule
March	4th week March to 1st week April – NB hybrid sowing by root slips & establishment (60 x 60 cm geometry) require 4 irrigations first at sowing and subsequent 2-3 days interval.
April	3 irrigations at 10 days interval from 2nd week April to 1st week of May.
May to 15 July	Further, 10 irrigations about weekly (6+/- 1 days) interval from 2nd week of May to Mid July. Some time dust storm may occurred, and if pre monsoon rain comes during this period 1-2 irrigation may be reduced accordingly.
16 July to 15 Sept.	Monsoon rains occur and hence irrigations would be given during gaps only. Total 3 irrigation at 10 T_5 days interval meet out water requirement
16 Sept. to October	1st October of every year may be considered as IRRIGATION DAY for NBH in arid region and keeping this is view total 6 irrigation 8-10 days interval required during October.
November	2 irrigation at 20-30 days interval form November to Mid December.
Dec. to Feb.	2 irrigation about 40 days interval after mid Dec. to end of February.
Remarks	Total 26 +/- irrigation requited for successfully harvest of average green fodder yield (903 q/ha/year) for three years continued from multicut perennial NB hybrid in arid region of western Rajasthan.

Weed Management

The shifting of labour from rural to urban areas, leads to scarcity of manpower in rural areas. In this scenario and with technological advancement in weed control chemicals (herbicides) became an essential component of weed management. There were no post emergence herbicides to control weeds in pulses and kharif pulses in particular in recent past, but due to researcher efforts, herbicide like imezathpyr and its mixtures are available to control mix weed flora in leguminous crops. Needless to emphasize that weeds compete with crops for space, nutrients, water and solar radiation thus adversely affecting growth, development during early periods and finally the yield and quality as well. Hence, timely control of weeds is of utmost priority Some of salient research findings of experiments conducted during 2010-11 to 2019-20 in different agro-climatic situations and field crops are given below:

▪ Weed seed bank study in clusterbean-wheat cropping system

In weed biology and physiological studies, in long term experiment (4 years) conducted at ARS, Bikaner in clusterbean-wheat cropping system, the seed bank of *Gisekia pharnaceoides, Corchorus tridense* and *Digera arvensis* increased in kharif 2013 compared to the previous years in weedy check plots. In imazethapyr treated plots minimum seed bank of *Digera arvensis* was observed while *Gisekia pharnaceoides* and *Corchorus tridense* had higher weed seed banks. *Digiteria* sp. was not observed in kharif 2013 while it was noticed in kharif 2012 in weedy check. Microbial study during *kharif* 2013 in clusterbean -wheat cropping system, the results indicated that in clusterbean, the highest total bacterial count was recorded in hand weeding at 20 and 40 DAS plots and the lowest total count was found in the treatment Imazethpyr @ 40 g/ha. At harvest, the total bacterial count in two hand weeding and imazethpyr+ one hand weeding treatments were at par to each other. In total, fungal count at 20 DAS was the maximum in weedy check plots but at harvesting highest number was recorded in the treatment imazethpyr 40 g/ha at 20DAS + one manual weeding.

▪ Post-emergence herbicide in cluster bean

✓ A field trial was conducted for consecutively for two years at Agriculture Research Station, Bikaner on evaluation of post emergence herbicide and/or their mixture to control weeds in cluster bean. The results indicated that post emergence application of imazethpyr at 40 g/ha at 15-20 days after sowing significantly controlled broad leaved weeds like *Amaranthus viridis, Digera arvensis* and recorded significantly higher yield of cluster bean as compared to weedy check in zone 1c. The results further revealed that post emergence (15-20 DAS) application of herbicide mixture imazethpyr 35% + imazamox 35% WG @ 40 g /ha significantly controlled broad leaf and grassy weeds in zone 1c.

✓ The results reveal that application of Pendimethalin @ 0.75 kg a.i/ha (pre emergence) followed by Imazethaper + Imazamox @ 40 g a.i./ha at 2-3 leaf stage (25-30 days after sowing) has found effective treatments for control of weeds in clusterbean in Sriganganagar region

✓ A field experiment was conducted at RARI, Durgapura to manage the weed in cluster bean. The results revealed that post emergence (15-20 DAS) application of Imazethapyr 35% + Imazamox 35% WG @ 52.5 g a.i./ha controlled both of broad leaf and grassy weeds and significantly increased the seed yield of cluster bean in zone IIIa.

▪ Weed management in mungbean

✓ Weeds particularly in Kharif season create more economic losses. To combat the problems of both grassy and broadleaved weeds, a field experiment was initiated for three consecutive years at Agriculture Research Station, Bikaner. The results concluded that application of Imazethapyr + Pendimethalin (2+30%) @ 2400 ml/ha (Commercial dose) in 500 litre water as pre emergence in mung bean to control both grassy and broad leaved weeds in the presence of proper soil moisture in zone 1c.

✓ In another study at ARS Ganganagar to evaluate effective post emergence herbicide to control weeds, it was concluded that application of imazethapyr @ 40 g a.i./ha found effective against weeds particularly of broad leaved weeds and increased seed yield significantly in mungbean.

✓ A field experiment was conducted at RARI, Durgapura to manage the weed in Green gram. The results indicated that post emergence application of Imazethapyr @ 40 g a.i./ha after sowing controlled weeds and increased the seed yield of in green gram in zone IIIa.

- **Weed management in groundnut**

✓ Groundnut is infested with mixed weed flora. For management of weeds in groundnut crop, an experiment was conducted at Agricultural Research Station, Bikaner. The results of the experiment indicated that 600 ml./bigha or 2.4 litre/ha imazithapyr + pendimethalin (2 + 30% pre mix company made) should be applied as pre emergence (moist soil and bright sunshine are primary condition for its affectivity) with 125 litre of water/Bigha or 500 litre water/ha to control both grassy and broad leaved weeds. The treatment gave significantly higher yield of groundnut as compared to other treatments.

✓ Another field experiment was conducted in groundnut and the results revealed that application of imazethapyr @ 40 g a.i./ha found effective against weeds and reduced dry weight of weeds significantly particularly of broad leaved weeds and increased pod yield significantly as compared to weedy check and other treatments.

- **Herbicide mixture in barley**

An experiment on herbicide mixtures in barley was conducted for three consecutively years at Agriculture Research Station, Sriganganagar. The results showed that post emergence application of isoproturon at 500g/ha +2,4- D at 250 g/ha or isoproturon at 500g/ha + metsulfuron methyl at 4 g/ha or isoproturon at 500g/ha + carfentrazone at 15 g/ha at 30-35 Days After Sowing (DAS) significantly controlled grassy as well as broad leaved weeds and increased the grain yield of barley and this technology is recommended and included in package of practices of the Zone Ib.

- **Weed management in mustard**

Weeds in mustard have created great problems particularly in irrigated areas. To combat the weed problem in mustard, an experiment was conducted for three consecutive years at Agriculture Research Station, Sriganganagar. The results revealed that the application of Pendamethalin 38.7 CS @ 0.75 kg/ ha as PPI was found appropriate for weed management in mustard in zone 1b.

- **Management of *Orobanche* in mustard**

A field experiment was conducted at farmer's fields under Agriculture Research Station, Bikaner. Two sprays of glyphosate first at 25 DAS @ 25g/ha

Orobanche infested mustard plot

Glyphosate treated (25 and 50 g/ha at 25 and 55 DAS, respectively) mustard plot

(Commercial product 60 ml) and second at 55 DAS @ 50g/ha (Commercial product 120 ml) along with 1% ammonium sulphate is recommended. The dose and time should be strictly followed for efficacy of the spray in zone 1c. The percent reduction in *Orobanche* population was in the range of 72-82 percent at four locations and consequently increased the seed yield of mustard as compared to neem cake treatment and control. The economics of these treatments also revealed that higher net return and B:C ratio was obtained in glyphosate treated plots.

- **Integrated weed management in rainfed pearl millet**

A field experiment was conducted during *kharif* 2012 and 2013 on integrated weed management in rainfed pearl millet at ARS, Bikaner. Data revealed that significantly higher yield of pearl millet is observed under the treatments atrazine @ 0.4 kg a.i./ha as post emergence followed by hand weeding at 35 DAS which was closely

followed by application atrazine @ 0.5 kg a.i./ha as pre-emergence followed by hand weeding at 35 DAS.

Integrated Weed Management (IWM) in castor

A field experiment carried out at ARS Mandor to study the weed management in castor. The results revealed that pre-emergence application of pendi methalin at 1.0 kg/ha super imposed with interculture at 40 DAS produced seed yield (3957 kg/ha) at par with weed free condition (3 weedings at 20, 40 and 60 DAS) (3860 kg/ha). Unweeded control resulted in lowest seed yield of 1197 kg/ha. Thus, integrating pendimethalin with interculture at 40 DAS was found comparable with cultural methods of weed management.

Weed Management in Cowpea:

A field experiment was conducted at RARI, Durgapura to manage the weed in cluster bean. The results revealed that post emergence application of Imazethapyr 10% SL @ 37.5 g a.i./ha is recommended in cowpea for the control of weeds in zone IIIa

Weed Management in wheat

A field experiment carried out at ARS Fatehpur to evaluate effective herbicide to control broad leaved weeds in wheat. The results revealed that the use of metsulfuron methyl @ 4g a.i /ha reduced weed density and its dry weight significantly as compared to weedy check and other treatments and produced significantly higher yield of wheat.

- **Residual effect of Imezathapyr on succeeding crop**

In some reports imezathapyr recorded residual effect on succeeding mustard crop. To verify the effects on succeeding mustard, an experiment was conducted at Agricultural Research Station, Bikaner. The results of the experiment indicated that imezathapyr as post-emergence applied in green gram crop have no residual effect on succeeding mustard crop even up to 70 g/ha.

- **Weed management in cumin and its residual effect on succeeding pearl millet**

A field experiment was conducted at ARS Mandor for two seasons to study the effect of different formulations of pendimethalin and other herbicides recommended in Cumin. The results indicated that Pendimethalin(CS) @ 484 g/ha had no residual effect on pearl millet but increased in dose above 484g/ha in cumin has residual effect on succeeding pearl millet crop in Jodhpur region(Zone Ia) .

Nutrition management of field crops

Soil fertility refer to inherent capacity of a soil to supply nutrients to plants as per requirement timely and in uninterrupted form. It means, the soil should be healthy where all physical, chemical and biological function going on in normal way. But modern agriculture and more particularly mono cropping or commercialized farming system where unbalanced use of nutrients, or fertilizer like Urea over dose than recommendations and / or excess pesticides use put agricultural system or the soil system mostly as ill for last two-three decades. Balanced fertilization for crop production is/are required to maintain the production, productivity and quality of produce as well.

Balance fertilization in Bt cotton

The maximum seed cotton yield was recorded at 120% RD of fertilizer, however, it was at par with 100% and 80% RD of fertilizer with 2% KNO_3 spray. Thus, 80% RD of NPK+2% KNO_3 foliar spray at 90 and 105 DAS was found optimum for Bt cotton. This treatment gave 15.57 per cent higher seed cotton yield over conventional method of fertilizer and irrigation application. The average water use efficiency was higher in the drip fertigated treatments as compared to flood irrigation. The maximum water expense efficiency of 3.95 kg/ha mm was recorded under T_1 (120% of RD), followed by 3.87 kg/ha mm under T_2 (100% of RD +2% KNO_3 as foliar spray at 90 & 105 DAS).

Nutrient management in Sesame

A field experiment was conducted at ARS Mandor for two seasons to study the effect of different methods of nutrients application on the seed yield & net returns of sesame. The results revealed that application of recommended dose of fertilizer super-imposed with one foliar spray of urea (2%) at flowering stage recorded

significantly higher seed yield (598 kg/ha) of sesame with net returns of Rs. 20668 compared to 100% RDF (492 kg/ha). However, one foliar application of urea (2%) with 75% RDF recorded yield as good as under 100% RDF, thereby saved 25% fertilizer dose.

Foliar feeding of nitrogen in sesame

Field experiment conducted at ARS, Mandor indicated that soil application of 75% recommended dose of nitrogen (30 kg/ha) + 25% (10 kg/ha) nitrogen as foliar spray improved seed yield and net return by 14.72 and 18.64% over crop grown with recommended nitrogen dose (40 kg/ha). Foliar feeding of nitrogen further recorded higher B:C ratio of 4.41 against 3.95 with RDN. Further, application of 2% urea (10 kg/ha) at flowering stage in addition to recommended nitrogen dose enhanced seed yield by 21.38% over soil application of RDN (40 kg/ha). The benefit of foliar application of urea was further evident by higher net return of Rs. 21,851/ha and B:C ratio of 4.51 against corresponding figures of Rs. 17,300/ha and 3.95 with RDN. Thus, foliar feeding of 10 kg nitrogen at flowering stage is found beneficial for higher seed yield and economic return.

Integrated Nutrient Management in Groundnut

A field experiment was conducted at ARS Mandor and results revealed that application of 100% RDF significantly enhanced pod yield of groundnut by 19.4 percent over 50% RDF. Further, application of biophos, mycorhizae and PSB alone did not influence the pod yield of groundnut but the combine application of all three bio-fertilizers (Biophos + Mycorhizae + PSB) significantly increased the pod yield of groundnut by 17.0% over control.

Integrated nutrient management in Lentil

A field experiment was conducted at RARI, Durgapura to investigate the effect of integrated nutrient management in Lentil. The results indicated that application of P & S enriched vermi-compost @ 2.5 t/ha + $ZnSO_4$ @ 25 kg/ha + seed treatment with sodium molybdate @ 3.5 g/kg seed significantly enhanced the productivity of lentil in zone IIIa

Managemen to sulphur in mungbean

Being a leguminous crop mungbean responds to sulphur. Experiment conducted at ARS, Fatehpur indicated that FAGM gypsum as sulphur source gave 7.75 and 8.68% higher green gram seed and straw yield over commercial gypsum (12.26, 24.19 q/ha), respectively. Further, mungbean responded upto 40 kg sulphur/ha and recorded 14.02 q/ha seed and 27.09 q/ha straw yield. Any further increase in sulphur dose could not influence mungbean production.

Potassium for enhancing cumin production

Potassium reserve in available form in soils of Rajasthan is considered high and thus the general conception is that there is no need to apply potassium fertilizer. An effort was made at ARS, Mandor to find out response of cumin to potassium. Results revealed that cumin responded to 30 kg/ha potassium and recorded 8.93 q/ha seed yield against control (7.55 q/ha) and 15 kg K_2O/ha (7.87 q/ha). Further, application of 30 kg K_2O/ha increased test weight to 4.40g as compared to control (3.96g) and 15 kg K_2O/ha (3.99 g/ha). However, K_2O application could not influence oil content.

Integrated Nutrient Management (INM)

Chickpea

A field experiment was conducted for consecutive three rabi season (2015-16 to 2017-18) at ARS, Sriganganagar to study the effect of various sources and doses of Sulphur on chickpea and results reveal that sulphur application through gypsum (@ 30 kg S/ha) recorded the highest chickpea mean seed yield of 24.44 q/ha and B:C ratio 6.64.

Dificiency of micronutrients particularliy of zinc has become wide spread affects the yield of crops.To manage the need of zinc requrement in chickpea, a field trial was conducted for consecutively for three years at Agriculture Research Station, Sriganganagar and the results indicated that foliar application of $ZnSO_4$ @0.5% was found effective for enhancing grain yield in chickpea in zone 1b.

In another study, a perusal of data revealed that application of zinc @ 24 kg $ZnSO_4$/ha through soil significantly increased the yield (16.45 q/ha) of gram over that of control (12.82 q/ha) (NP). Foliar application of iron alone non-significantly affected the gram yield, however, half of the soil application of zinc (12 kg $ZnSO_4$/ha) along with foliar application of 0.5 per cent of $ZnSO_4$ solution spray (16.9 q/ha) or foliar application of zinc sulphate @ 0.5 per cent (16.5 q/ha) and spray of 0.4% multi-micronutrient mixture (17.3 q/ha) significantly increased the grain yield of gram. The return and benefit: cost ratio also comes to be higher with, half of the soil application of zinc (12 kg $ZnSO_4$/ha) along with foliar application of 0.5 per cent of $ZnSO_4$ solution spray (1.87) followed by (1.86) foliar application of zinc sulphate @ 0.5 per cent.

Soils of arid region showed potassium deficiency in many places. To see the potassium response in sandy soils an experiment was conducted for three consecutive years at Agriculture Research Station, Bikaner. The results indicated that application of 20 kg K_2O/ha along with basal dose of fertilizers should be recommended chickpea crop in zone 1c.

Wheat

A field experiment was conducted for consecutive three rabi season (2012-13 to 2014-15 at ARS, Sriganganagar to study the effect of Urea coated by different sources (neem, zinc, USG)along with three N levels (80,100,120 kgN/ha) in wheat. The results reveal that wheat crop fertilized with 80 kgN/ha and zinc coated urea recorded the highest mean grain yield of 49.02 and 49.34 q/ha, respectively and closely followed by neem coated urea (48.45 q/)

Zinc deficiency in wheat is an common problem throughout the state. To meet out the deficiency of zinc in zone 1(b) soils, an experiment was conducted at Agricultural Research Station, Sriganganagar, The results of the experiment indicated that spray of chelated zinc at 3 g/litre of water at vegetative & flag leaf stage was sufficient to meet out the deficiency of zinc in wheat.

Barley

A field experiment was conducted for consecutive three rabi season (2015-16 to 2017-18) at ARS, Sriganganagar to study the effect of zinc fertilization on growth and productivity of barley. Result indicated that Soil application of zinc sulphate @ 24 kg/ha followed by $ZnSO_4$ 0.5% spray at vegetative and ear initiation recorded the maximum mean grain yield (52.17 q/ha) and it was closely at par with zinc sulphate @ 12 kg/ha followed by $ZnSO_4$ 0.5% spray at vegetative and earhead initiation (51.19 q/ha) while, its effect was vice versa in straw yield of barley. The yield increases in aforesaid treatments over recommended dose of NP (control, 42.42 & 50.81q/ha) were 22.75, 20.67 and 26.47, 30.58 per cent in grain and straw yields, respectively.

Pearl Millet

❖ The results of the experiment indicated that the application of 75% of RDF + PSB + Azospirillum culture (200-250 ml/ha) + 5 t FYM/ha gave significantly higher yield and net return and B:C ratio.

❖ To harvest good yields of bajra hybrids enriched with iron content, an experiment was laid out at ARS, Bikaner for two consecutive Kharif seasons (2016 and 2017).

Result showed that foliar spray of iron fertilizer @ 0.50% $FeSO_4$ + 0.1% citric acid at 25-30 DAS gave significantly higher grain and stover yields (30 &49 q/ha resp.) and maximum net return along with the highest B:C ratio in zone 1c.

Fodder Oat

Good production of grain along with green fodder of oat is aneed of the hour in arid region where economy is mainly depended ant on animals. For this, an experiment was initiated for three consecutive years at Agriculture Research Station, Bikaner to see the foliar effects of zinc in oat. The results indicated that two foliar sprays of $ZnSO_4$ @ 0.5% first at 10 days after first cutting and second at 10 days after first spray increased the yields of fodder oat in zone 1c.

Deficiency of Zinc and Iron in Sugarcane

An experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment indicated that on soil test basis under deficiency of zinc & iron, placement of 6 kg zinc sulphate /bigha (24 kg/ha) in furrows at sowing and spray of 1% ferrous sulphate in standing crop three times at weekly interval gave significantly higher yield in sugarcane and recommended in addition to NPKS.

Micronutrient in sugarcane on soil test basis

The results of a three years study conducted at ARS, Sriganganagar indicated that number of tillers, NMC, cane length, single cane weight, cane yield and sucrose per cent were influenced significantly due to different nutrient management treatments. The soil application of $ZnSO_4$ @ 25 kg/ha (94.78 t/ha) and thrice one per cent foliar spray of $FeSO_4$ at weekly interval during vegetative stage (94.91 t/ha) along with NPK gave significantly higher cane yield over NPK alone (88.15 t/ha). The maximum mean cane yield of 98.83 t/ha was obtained with the combined application of sulphur, Zn, Fe and Mn along with recommended NPK . Data further indicated that soil application of $MnSO_4$ @ 5 kg/ha could not brought significant influence on cane yield as well as sucrose per cent.

Forage production and management

Potential of Sorghum with forage legumes under varying seed rates of intercrop

A field experiment was conducted at ARS Bikaner to study the effect of varying seed rates of intercrop forage legumes on Forage production potential of Sorghum. The results indicated that the significantly higher green fodder yield was recorded under sorghum+ guar (100% SR) inter crop. Sorghum +cowpea (25 & 75% SR) and sorghum + guar (75 %SR) being at par recorded higher green fodder yield as compared to sole sorghum. Also, sorghum+ guar (100% SR) inter crop fetched the maximum net returns and B:C ratio in comparisons to other treatments.

Cutting management and nitrogen levels in dual purpose pearl millet

The experiment was conducted on dual purpose pearl millet at ARS, Bikaner on light soils during Kharif season of 2012 & 2013. Data revealed that dual purpose pearl millet variety AVKB-19 recorded the highest plant height and L:S ratio on mean data basis. While GFB-1 recorded maximum tillers per meter row length and total green fodder yield (331.74 q/ha) which was significantly higher over AVKB-19 and BAIF-1.Similarly grain yield, crude protein (per cent), CP yield and N uptake were also maximum in dual purpose variety GFB-1 . The same variety also gave higher net returns of rupees 21535 ha^{-1} along with B:C ratio 1.65.Whereas in cutting management practices, maximum green fodder yield of 421 q/ ha was recorded with two cuttings. Application of 150% RDN (Recommended Dose of Nitrogen) gave the maximum plant height, tillers per meters row length, L: S ratio, total green fodder yield, stover and grain yield as compared to 100% RDN.

Round the year green fodder production

The results of experiments conducted at ARS, Bikaner revealed that growing of perennial napier hybrid bajra in row and legume crop (gaur/ lucerne) between the rows recorded the highest green fodder yield and dry fodder yield, CP yield, net returns and B: C ratio in comparison to other treatments

Enhancing quality fodder through mixed cropping

Lucerne + oats fodder production system under irrigated condition

Results show that combination of lucerne (20 kg seed ha^{-1}) + oat (30 kg ha^{-1}) was found overall best for getting higher yield for long time with good quality fodder. This production technology is recommended for cultivation by the farmers at Bikaner and included in packages of practice of zone-1c.

For higher forage production, pearl millet should be grown in combination with clusterbean either in 1:1 or 2:2 row combinations and with cowpea in 2:2 row combinations.

4. Plant diseases and insect-pests management

Insect-pests and diseases are responsible for drastic yield losses. Pests are major limiting factors for crop production. Pest infestation is dynamic in natural condition. Thus efforts are continuously made to find out effective means for controlling pests. Generally to control these biotic stresses farmers resort to adopt chemical pesticides. Sometimes, they apply pesticides indiscriminately which in turn increase cost of cultivation, besides making produce of poor quality and rendering poor health of the soil by exerting adverse effect on macro and micro-organisms in the soil. Thus, research efforts were focused on eco-friendly and integrated plant protection measures for having quality produces, as well as, to maintain environmental sanitation and enhance soil health, rather than use of chemical alone. Salient research findings emerged during 2010-11 to 2019-20 are described below:

Diseases management

Diseases are most devastating in reducing yield of crops. Indiscriminate use of chemicals may exert adverse effect on soil health as well as crop quality. Thus efforts are being made to use bioagents and organics for controlling diseases effectively

Integrated Management of Major Diseases in Groundnut

Collar rot and tikka

Collar rot and tikka diseases are major limiting factors for achieving higher yield of groundnut. Adoption of integrated disease management practice can control diseases effectively on one hand and maintain environmental sanitation on other hand. Experiment conducted at ARS, Mandor revealed that seed treatment with *Trichoderma* (10 g/kg seed) + soil application of 2.5 kg *Trichoderma* (with 100 kg FYM) + foliar spray of carbendazim (0.1%) reduced collar rot and tikka diseases by 74.5 and 73.2%, respectively over control (22.0%, 4.1%).Further, this combination was found superior to all other combinations of carbendazim seed treatment/ foliar spray + soil application of Trichoderma in respect of diseases control. Thus, this treatment combination recorded highest pod yield of 28.75 q/ha, against 16.68 q/ha with control and rest combinations of carbendazim and Trichoderma which recorded 23.15 to 26.25 q/ha pod yield. The benefit of the treatment combination was further depicted by highest net return of Rs. 34,622/ha.

On the basis of three years data from ARSS Hanumangarh, soil drenching of hexaconazole 5 EC @1.5 ml/litre and/or propiconazole 25 EC @ 1.5 ml/litre at the time of disease initiation were effective for management of collar rot of groundnut in standing crop. These fungicides were included in package of practices for zone 1b. 201`3-14

Management of Root Rot of Groundnut

An experiment was conducted for three consecutive years at Agriculture Research Station, Sriganganagar. The results indicated that in groundnut, seed treatment with *T.viride* @ 10 g/kg + furrow application of *T. viride* @ 10 kg enriched with 250 kg FYM/ha + drenching of *T. viride* @ 5.0 gm/litre at 70-75 days after sowing has been recommended for effective management of root rot of groundnut in zone 1b.

Result of three years data (2008 to 2010) revealed that seed treatment with *T.harzianum* @10g/kg seed+ soil application of *T. harzianum* @ 4kg/ha + Soil application of Castor cake @ 250kg/ha for management of Collar rot of groundnut and Foliar Spray of Hexaconazole @ 1.0ml/lt at the initiation of Tikka disease and IInd spray after 15 days of Ist spray for control of Tikka disease of groundnut at sriganagar region.

Collar Rot and Leaf Spot

To manage the collar rot and leaf spot disease in groundnut, an experiment was conducted for three consecutive years at Agriculture Research Station, Sriganganagar. The results indicated that seed treatment with Tebuconazole 2DS @1.5 g/kg + furrow application of *T. viride* @ 4.0 kg enriched with 50 kg FYM/ha + Broadcasting of *T. viride* @ 4.0 kg enriched with 50 kg FYM/ha at 40 DAS + Two foliar spray of Tebuconazole 25.9% @1.0 ml/litre starting from initiation of foliar disease and second spray at 15 days interval was found most appropriate and effective for management of collar rot and leaf spot disease in zone 1b.

Diseases Management through Seed and Soil Treatments of Isbgol

The studies revealed that combined application of metalaxyl 30 WS @ 5 g/kg + carbendazim @ 2 g/kg as a seeds dresser and soil application of *Trichoderma* culture @ 2.5 kg/ha was found most effective to manage downy mildew, *Alternaria* leaf spot/ blight and wilt diseases of Isabgol. This treatment was closely followed

by seed treatment with mixed application of plant material i.e. Neem + Datura + *Calotropis* 1:1:1 ratio or aonla powder @ 10 g/kg seeds along with soil application of T. viride@ 2.5 kg/ha at ARS Mandore.

Management of yellow rust of barley:

A field experiment was conducted at RARI, Durgapura to mange the yellow rust of barley. The results revealed that two sprays with tebuconazole 25.9% EC @ 0.1% at disease initiation and 15 days thereafter were found good for the control of yellow rust in zone IIIa

Management of white rust in mustard:

It was concluded from the experiment that foliar spray with metalaxyl 8% + mancozeb 64% mixture (72 WP) reduced the disease in Zone Ib.

Karnal bunt disease management in Wheat

A field experiment was conducted at ARS Sriganganagar to study the effect of different seed treatments for management of karnal bunt disease in Wheat. The results revealed that Control of karnal bunt disease in PBW 343 Wheat through seed treatment of Carboxin+Thiram (37.5 per cent) @ 2 g/kg seed, followed by spray of propiconazole 10 EC on the onset of flowering (70 -75 DAS) @ 1 ml/l of water in zoneIb

Management of loose smut disease in wheat

A field study was carried out with wheat cultivar HD 2967 (Infected seeds) were dressed with different doses of fungicides at the time of sowing and sown in field at ARS, Sriganganagar. On the basis of three year pooled data minimum tiller infection (0.04%) was recorded in tebuconazole 2% DS @1.5 g /kg seed closely followed by tebuconazole 2% DS @1.0 g/kg seed (0.06%) and difenoconazole 3% WS @ 2.0 g /kg seed (0.10%). Grain yield in all the treatments was also found significantly superior over control except carbendazim 50WP @ 2.0 g /kg.

Diseases Management in Wheat

To control root rot disease of wheat, a field trial was conducted consecutively for three years at Agriculture Research Station, Sriganganagar and the results indicated that seed treatment with carboxin 37.5% + thiourea 37.5% @ 2g/kg seed followed by soil drenching of carbedazin 25% + mancozeb 50% mixture (75WP) @ 1kg/ha at time of first irrigation has been found effective against root rot in disease in wheat in zone 1b

Yellow Rust Management in Wheat:

For management of yellow rust in wheat, an experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment indicated that to control the yellow rust disease in wheat foliar spray of Propiconazol (25 EC) or Tebuconazol (25.9 EC) @ 1 ml/litre of water is recommended on appearance of the disease. If needed second spray be given at an interval of 15 days.

Bacterial blight of clusterbean:

An experiment was conducted at Agriculture Research Sub-Station Hanumangarh for management of bacterial blight of clusterbean. On the basis of two years data, two sprays of streptocycline (250 ppm)+ Blitox (0.1 per cent) at 15 days intervals followed by two sprays of *streptocycline* (150 ppm)+ SAAF (mixture of cabendazim + mancozeb) @ 2.0 ml /litre of water were effective for management of bacterial blight of clusterbean.

Bacterial Leaf Blight of Clusterbean:

To control bacterial leaf blight in clusterbean, an experiment was conducted at ARS, Sriganganagar and Bikaner. The results of the experiment indicated that *streptocycline* 500 ppm (seed soaking)+ spray of *streptocycline* 250 ppm + *copper oxychloride* (0.2%) first spray at disease appearance and second at 15 days interval was found effective against management of bacterial leaf blight in cluster bean.

Root rot complex in clusterbean:

On the basis of two years data from ARSS Hanumangarh, soil amendment with 2.5 kg *Trichoderma viride* in 100 kg FYM/ha +seed treatment with Bavistin @2.0 gm/kg seed followed by seed treatment with Bavistin @2.0 gm/kg seed were effective for management of root rot complex in Clusterbean.

Management of wilt & blight of cumin

A field experiment was conducted at RARI, Durgapura to mangewilt & blight in cumin. The results revealed that soil application of *Trichoderma viride*@ 2.5 kg/ha in 100 kg FYM + seed treatment with carbendazim @ 1 g/kg seed followed by two sprays of difenoconazole @ 0.05% at 35 and 50 days after sowing was found effective to manage wilt & blight in cumin and increased the grain yield in zone IIIa.

Management of *Anthracnose* of chilli

A field experiment was conducted at RARI, Durgapura to control *Anthracnose* disease of chilli . The results revealed that two sprays of difenoconazole @ 0. 5 ml/l of water at the appearance of *Anthracnose* disease and repeated 15 days thereafter were found effective against *Anthracnose* of chilli in zone IIIa.

Diseases management in chilli

Dieback and powdery mildew, are two major diseases of chilli in the region and affected the yield badly if not controlled in time. For the effective control of these diseases , an experiment was conducted at ARS Mandor, revealed that the foliar spray of difenconazole 25 EC at 0.05% and myclobutanil at 0.05% were found effective for management of dieback and powdery mildew, respectively in chilli.

Phyllody Management in Sesame:

To manage the phyllody in sesame, an experiment was conducted for three consecutive years at Agriculture Research Station, Sriganganagar. The results indicated that seed treatment with imidachlorprid 70 WG @ 5.0 g/kg seed + two spray of thiamethoxam @ 0.5 g/litre at 50 and 65 DAS + one spray of sterptocycline 150 ppm + copper oxychloride @ 2.0 g/litre at 75 DAS was found effective for phyllody management in zone 1b.

Root Rot and Wilt Management in Chickpea 2015-16

Soil application of *Trichoderma harzianum* + *Pseudomonas fluorescens* (2.5+2.5kg/ha) each with 100 kg vermicompost at the time of field preparation followed by seed treatment with *Trichoderma harzianum* + *Pseudomonas fluorescens* (@ 4+4 g/kg seed each) for control of root rot and wilt in chickpea. In case, *Pseudomonas fluorescens* is not available, soil application of *Trichoderma harzianum* (5kg/ha) with 100 kg vermicompost at the time of field preparation followed by seed treatment with *Trichoderma harzianum* @ 8 g/kg seed is also effective for control of root rot and wilt in chickpea in zone 1c.

Root Rot of Mothbean :

The results of the experiment indicated that *T. harzianum* + *P. fluorescens* seed treatment (4 + 4 gm./kg seed) + soil application of *T. harzianum* + *P. fluorescens* (1.25 + 1.25 kg) in 50 kg FYM each/ha.) was effective for management of root rot of mothbean in zone 1c.

Integrated Disease Management in Mustard:

For integrated disease management in mustard, an experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment indicated that seed treatment with Metalexil (35 SD) @ 6 g/kg seed & first spray of Mencozeb (75 WP) @ 2 gm/litre of water at 60 days & second spray after 15 days with Propiconazol (25 EC) @ 0.5 ml/litre of water has been recommended.

Integrated Disease Management Module against Sclerotinia rot of Mustard

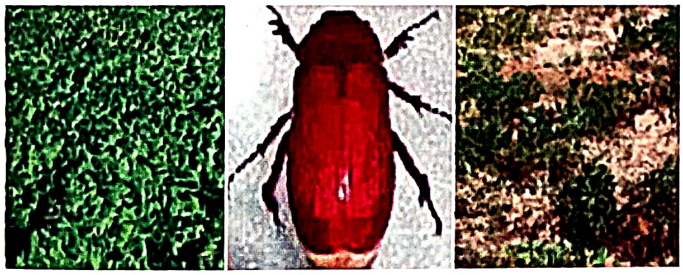
An Integrated Disease Management Module against *Sclerotinia rot* of mustard was established at ARS Navgaon-Alwar for the better management the disease. The module is as under :

Crop stage	Management practices	
Pre- sowing	i.	Destruction of diseased crop debris of previous crop by either burying or burning to avoid disease causing pathogens.
	ii.	Deep summer ploughing during summer to kill fungal spores & leveling of fields for proper drainage
	iii	Crop rotation with non host crops like wheat, barley, rice, maize etc.
	iv	Soil incorporation of *Trichoderma* based product @ 2.5kg/ha pre incubated in 50 kg FYM/ha at the time of field preparation
Sowing	i.	Follow optimum sowing time (16-31 Oct.)
	ii.	Apply recommended dose of fertilizers i.e. N:P:K:S – 80:40:40:40
	iii(a)	Seed treatment with garlic extract @ (2%)
	iii(b)	Seed treatment with *Trichoderma* @ 10 g/kg seed.
	iv.	Sowing of healthy, certified and clean seeds free from sclerotial bodies
	v.	Appropriate seed rate (4 kg/ha) to maintain the optimum plant population in field
	vi.	Variety - RRN- 505
Seedling stage	Removal of collateral host viz; *Asphodelus* (wild onion)	
Flowering and pod stage	i.	At 50% flowering need based foliar spray of *Trichoderma* @ 0.2% towards stem soon after disease appearance at 20 days interval may help to check the spread of disease.
	ii.	Excessive irrigation should be avoided (follow sprinkler irrigation)
	iii.	Removal of infected stubbles from fields after harvesting

Insect–pests management technologies of field crops

Whitegrub management in groundnut through seed treatment:

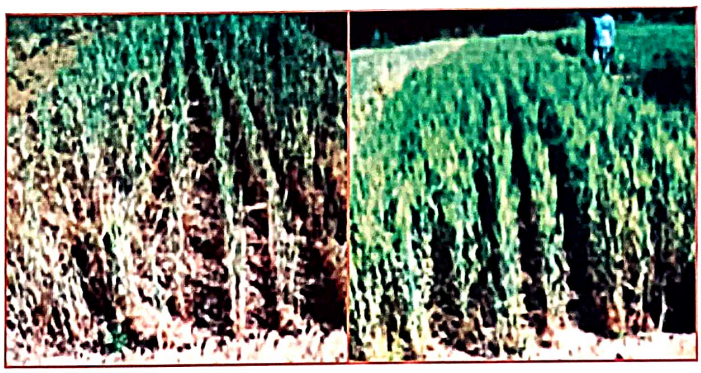
Whitegrub has come out to be one of the most limiting factor for achieving higher yield of groundnut. Experiment conducted at ARS, Durgapura revealed that seed treatment with clothianidin(dantotsu) 50 WDG @ 2 g/kg seed reduced whitegrub damage (5.47 per cent damage) against 31.51% in control. Effective control of whitegrub thus, gave higher pod yield of 22.24 q/ha against 9.68 q/ha in control. Further, reduction in damage due to seed treatment with clothianidin(dantotsu) 50 WDG @ 2 g/kg seed was at par with clothianidin50 WDG @ 3 g/kg seed (5.55% damage) and standard check imidacloprid 17.8 SL @ 3 ml/kg seed (6.19% damage). As a result, clothianidin50 WDG (2 g/kg), clothianidin 50 WDG (3 g/kg) and imidacloprid 17.8 SL (3 ml/kg) treated seed recorded at par yield of 22.24, 23.30 and 20.93 q/ha pod yield, respectively. The highest B:C ratio was recorded in seed treatment with clothianidin 50 WDG @ 3 g/kg seed (1.8) which was comparable with clothianidin 50 WDG @ 2 g/kg seed (1.7) and standard check imidacloprid 17.8 SL @ 3 ml/kg seed (1:1.6).



Healthy field | Adult stage | Infested field

Management of termite in wheat and chickpea through seed treatment:

Wheat and chickpea are most important rabi crops affected by termite frequently. Experiments conducted at ARS, Durgapura revealed that wheat seed treatment with fipronil 5 SC @ 15 ml/kg seed (0.75 g a.i./kg) recorded lowest termite damage of 3.90% against 90.45% in control. The results revealed that seed treatment with clothianidin 50 WDG @ 1.5 g/kg seed provided control of termite and increased the grain yield in wheat in zone IIIa.The results of another trial also indicated that Seed treatment with fipronil 5 SC @ 10 ml/kg seed was found good for the control of termite and increased the seed yield in chickpea in zone IIIa. However, benefit of seed treatment with fipronil 5 SC at



10 ml/kg seed recorded higher B:C ratio of 1.62 followed by higher dose of fipronil 5 SC (1.56).

Termite control in Wheat

Management of termite in wheat through seed treatment

A field experiment was conducted at ARS, Bikaner for two consecutive *Rabi* seasons 2015-16 and 2016-17 with an objective to find out suitable and effective chemical control measure for termite in wheat crop at later growth /maturity stage. Result indicated that seed treatment with imidacloprid @ 3ml / kg seed (T2) and 4ml / kg seed (T3) being at par in respect of mean values of termite damaged plants / square meter at 40DAS, grain yield (26.64 , 25.88 q/ha), however, imidacloprid @ 5ml / kg seed treatment significantly fetched the highest net gain (Rs. 8638 /ha) with 16.61 PCBR.

Termite management in wheat

An experiment was conducted for management of termite in wheat for three years (2011-12to 2013-14) at Agriculture Research Station, Sriganganagar. It was concluded that to control termite in wheat, seed treatment with imidacloprid 600 FS @ 2.5g/kg seed followed by drenching with imidacloprid 17.8 SL @ 500 ml/ha have been found suitable in zone 1b.

Management of sucking pests (whitefly and jassid) in hirsutum cotton

Eighteen Agrochemnical/ New molecules were evaluated against whitefly in cotton. Maximum thrips population reduction 67.00, 82.70, 73.73 and 55.81 per cent was observed in treatment having Pyriproxyfen 10 EC @ 1250 ml/ha at 3rd, 7th, 10th and 14th days after spray followed by Flonicamid 50 WG @ 50 g/ha (84.90, 78.81, 66.88 and 34.41 per cent), Spiromesifen 22.9 SC @ 500 ml/ha (64.13, 79.97, 56.28 and 51.26 per cent), Dinotefuron 20 SG @ 60 g/ha (78.41, 71.03, 59.98, 23.93 per cent), Diafenthiuron 50 WP @ 500 g/ha (81.11, 72.34,

Table- :-Economics of seed treatments against termite in wheat (Pooled2015-16&2016-17)

Treatments	Mean Grain yield (Q/Ha)	Treatment cost (Rs/ha)	yield increase over control	Net return (Rs/ha)	PCBR
T_1-ST with Imidacloprid 17.8 SL	23.85	380	2.30	3760	9.89
T_2 -ST with Imidacloprid 17.8 SL	26.64	520	5.09	8638	16.61
T_3 -ST with Imidacloprid 17.8 SL	25.88	660	4.33	7125	10.80
T_4 - ST with Fipronil 5% SC	24.33	584	2.78	4411	7.55
T_5- ST with Chlorpyriphos 20 EC	23.49	240	1.94	3258	13.57
T_6- Untreated control	21.55	-	-	-	-
CD at 5 %	1.71				

Note that ST= seed treatment , Cost of insecticide: Imidacloprid- Rs 1400/lit, Fipronil- Rs 1210/lit, Chlorpyriphos- Rs 310/lit ,Labor charges for seed treatment- Rs 100/ha, Cost of wheat- Rs 1800/Q

59.23 and 22.81 per cent) and Buprofezin @ 1000 ml/ha (64.39, 75.54, 66.26 and 46.28 percent), respectively.

Management of white fly in cotton

Evaluation of doses of Diafenthiuron 50 WP against white fly on cotton **:** Maximum white population reduction 60.67 per cent was noticed in Diafenthiuron 50 WP @ 1000 g/ha treated plots which was on par to Diafenthiuron 50 WP @ 750 g/ha with 55.83 per cent reduction and Diafenthiuron 50 WP @ 500 g/ha with 53.83 per cent reduction, respectively.

An experiment was conducted on bio-efficacy of some newer insecticides against sucking insect pest of cotton (whitefly, jassid and thrips) at ARS, Sriganganagar. Based on the bio - efficacy data and results during three consecutive seasons *i.e.* 2015, 2016 and 2017 it can be concluded that; flonicamid 50%WG @ 150 gm/ha found most effective against jassid and whitefly, whereas Spiromesifen 22.9 per cent OD @ 500 ml/hawas effectively control the nymphal population of whitely. The maximum seed cotton yield was recorded from Flonicamid 50%WG @ 150 gm/ha treated plots followed by Spiromesifen 22.9 per cent OD @ 500 ml/ha and Spirotetramat 15 per cent OD during all the studied years with highest B:C ratio 1:5.67, 1:5.58 and 1:4.91 respectively.

Management of sucking pests of cluster bean and Mothbean

A field experiment was conducted at ARS Bikaner to study the effect of different chemicals for management of sucking pests. The results indicated that seed treatment with fipronil (5% SC) @ 4 ml/kg seed of moth bean/ custerbean was an effective for the management of sucking pest in zone 1c.

Management of insect- pests of Greengram

A field experiment was conducted at ARS Bikaner to study the effect of different chemicals for management of pod borer in green gram. The results revealed that dusting of malathion 5% or fenvelerate 0.4% dusts @ 25 kg/ha provided effective control of pod borer and increased seed yield of green gram in zone Ia.

Clusterbean

Based on the bio - efficacy data and results of three seasons (2014, 2016 and 2017), it was concluded that; Thiamethoxam 25 WG @ 0.5 g/liter of waterfound most effective against jassid and whitefly with B:C ratio 1:4.55. The maximum grain yield was recorded from Thiamethoxam 25 WG @ 0.5 g/liter of water treated plots by Acetamprid 20 SP @ 0.4 g and Imidacloprid 17.8 SL @ 0.33 ml/liter of water during all the studied years with highest B:C ratio 1:4.55, 1:4.27 and 1:3.71 respectively.

Evaluation of Seed treatments and Foliar Sprays of Pesticides against Insect Psts of Sesame

Sesame an oilseed crop is heavily infested with insects and limiting the productivity in dry tracts of Rajasthan. Three years data from ARS Mandor on evaluation of seed treatment for the management of insect pests of sesame revealed that Seed treatment with thiamethoxam 25 WG @ 5 g/kg seeds as an alternative of imidacloprid 70 WS found effective for control of leaf webber and capsule borer (*Antigastra catalaunalis*) of sesame in zone Ia. No harmful effect on germination of sesame seed was observed after seed treated with these pesticides

Aphid Management in Mustard

Aphid infestation is an major limiting factor in mustard production.For the management of aphid,an experiment was conducted atARS, Jalore.The results revealed that the application of thiamethoxam 25WG @ 100g/ha or acetamiprid 20 SP @100g/ha were found effective against aphid in mustard

Pod borer Mangement in Chickpea

✓ Foliar application of Indoxacarb 14.5 SC @ 60 g a.i./ha followed by Rynaxapyr @ 18 g a.i./ha has been found effective.

✓ **Emamectin benzoate 05% SG @ 10 gm a.i./ha (Le. 200 g/ha) or Spinosad 45 SC @ 60 gm a.i./ha (Le. 133 ml/ha) has been recommended to control gram pod borer.**

✓ Neem oil @ 1.0 % followed by NPVHa @ 450 LE/ha + 2 kg Jaggery/ha effectively controlled the pest and this technology could be used in organic gram.

5. Research on organic cultivation & farming system

Organic productionTechnology

Performance of different crop sequences under organic manuring and INM

A long term experiment on nutrient management was conducted for 8 years at fixed site at Agriculture Research Station, Sriganganagar to explore the possibility of organic farming and to find out the best suited crop sequence among cotton-wheat, moong-wheat, mothbean-wheat and guar-wheat. Results ofthe study concluded that:

- For the production of organic wheat, the mung-wheat and guar-wheat crop rotations were found most suitable.
- The doses of FYM @ 48 & 280 q/ha were found optimum for organic Guar &Mung in *kharif* season and wheat in *rabi* season, respectively.
- For the production of organic wheat vermi compost was not found beneficial.
- After continuous application of 35 q/bigha FYM for 4 years with half dose of fertilizers, the dose of fertilizers for wheat crop can be reduced to half in succeeding years.
- Significant improvement in organic matter content was recorded with the application of organic manures as compared to alone application of fertilizers.

Management of Stem Rots in Mustrard

- A field experiment was conducted ARS, Sri-ganganager to investigate the effect of different treatments to control stem rot in mustard. The results revealed that seed treatment with *Trichoderma* mixture {*T. hamatum* + *T. viride* (1:1)} @ 10 g/kg seed + foliar spray of same mixture of bioagent @ 0.2 percent at 50 DAS is found effective and recommended to control stem rot of mustard .
- Another trial with the same objective at ARS Alwar revealed that soil incorporation of *Trichoderma* based product @ 2.5kg/ha pre-incubated in 50 kg FYM/ha at the time of field preparation significantly reduced the incidence of stem rot in mustard.

Organic Technology for vegetable production

- A field experiment was conducted at ARS, Durgapura to develop organic farming technology for *rabi* onion. The results indicated that application of 15 ton FYM+ 6 ton decomposed organic waste along with bio-fertilizer 6 kg each of *Azotobacter* & PSB/ha or apply 10 t FYM + 12 t decomposed organic waste along with bio-fertilizer 6 kg each of *Azotobacter* & PSB and 250 kg gypsum is recommended for organic production of *rabi* onion under irrigated coarse textured soil situation of Zone IIIa.
- A field experiment was conducted at ARS Durgapura to develop organic production technology in vegetable pea. The results indicated that application of 2 t vermi compost + 1.5 t decomposed organic waste along with bio-fertilizer 600 g each of *Azotobacter* & PSB is recommended for higher organic production of vegetable pea under irrigated coarse textured soil situation of Zone IIIa.
- **Various production systems on capsule yield of chilli:**

Field studies aimed at determining feasibility and economic viability of organic farming in chilli compared to organic intensive and integrated agriculture systems at ARS, Mandor indicated that organic intensive system, comprised of 100% recommended dose of nitrogen (RDN) through FYM + 250 kg gypsum/ha + 3 t/ha decomposed mustard straw residue + 5 q/ha non-edible tumba cake + one foliar spray of *streptocycline* and acephate against pests and diseases, recorded highest dry capsule yield of chilli (18.53 q/ha) against 12.74 to 18.16 q/ha with different combinations comprising of organics and chemicals. The benefit of this treatment combination was further depicted by highest net return of Rs. 88,174/ha and B:C ratio of 2.73 compared to organic and integrated agriculture systems (Rs. 64,013 to 85,999/ha, 1.84 to 2.28). This might be due to improvement in balanced availability of nutrients and better pests and diseases management through limited use of chemicals as foliar sprays only. However, under organic production system, 100% recommended nitrogen (RDN) through FYM (14 t/ha) or 75% RDN through FYM (10.5 t/ha) + 25% RDN through decomposed mustard crop residue (3.5 t/ha) along with seed treatment with *Trichoderma viride, Azotobactor*, PSB+ foliar spray of *Azadirachtin*, cow urine,

Gowshalla keet niyantrak, karanj oil and installation of yellow sticky traps produced higher mean dry capsule yield of chilli (1503/1494 kg/ha) and B:C ratio (2.20/2.28) compared to other organic treatments which were found at par with integrated agriculture.

- **Organic cotton production**

An experiment conducted at ARS Sriganaganagar during 2016-17 on organic approach for cotton and result reveal that 100% N through FYM recorded highest mean seed cotton yield followed by 50% N through FYM + 50% N through crop residue + gypsum @ 150 kg/ha.

Organic farming in Pearl millet-Chick pea cropping system

A field experiment was conducted at RARI, Durgapura to investigate organic farming feasibility in bajra-chickpea crop sequence. The result indicated that soil application of FYM @ 7.5 t/ha is recommended before sowing of bajra followed by chickpea in *Rabi* without FYM application for higher production and economic returns in zone IIIa.

Disease management through organic practices for organic groundnut cultivation

An experiment was conducted in sick plot at ARSS, Hanumangarh in kharif-2011 to 2014 for management of collar rot and leaf spot diseases of groundnut. On the basis of four year data, seed treatment with *T. viride* @10 g/kg +furrow application of *T. viride* @ 4.0 kg enriched with FYM @ 250 kg/ha+ foliar application of neem seed kernel extract@ 5 per cent at 30 and 45 DAS was included in package of practices for Zone 1b of Rajasthan for effective management of collar rot and leaf spot disease of groundnut.

Eco friendly management of gram pod borer through organic approaches

An experiment was conducted for management of gram pod borer through organic approaches for three year at Agriculture Research Station, Sriganganagar. On the basis of three years pooled data it was concluded that the treatment module T_6 comprising treatment sprays of neem oil @1% : NPVHa @ 450 LE/ha is the most suitable economical organic module followed by T_5 module (Daman A-47 : NPVHa @ 450 LE /ha) for managing gram pod borer.

Efficacy of *Rhizobium*application methodsin Lentil:

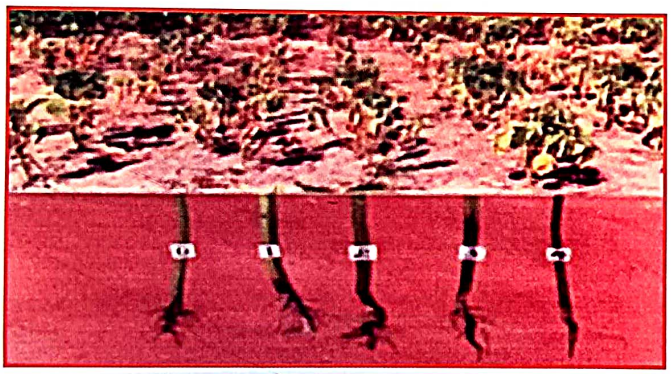
Inoculation with *Rhizobium* proved beneficial for higher nodulation and nitrogen fixation in legumes. Experiment conducted at ARS, Durgapura showed that seed treatment @ 600 g/ha gave highest seed yield (13.2 q/ha) and highest nodulation and that was at par with furrow application (12.86 q/ha) (at sowing @ 600 g/ha) and combined treatment of furrow application + broadcasting in standing crop (30 DAS @ 600 g/ha followed by light hoeing and irrigation) (13.0 q/ha). It can be concluded that *Rhizobium* inoculation can also be done through furrow application at the time of sowing @ 600 g/ha.

Organic Technology to control pests

Organic produces are in great demand all over the world. Thus, farmers are attracted towards growing crops organically. A number of crop protection technologies have been developed during the period under report. The salient features of the technologies are given here as under:

- For safe, effective mungbean organic management of sucking pests like jassid, white fly and aphid in cluster bean, a field experiment was conducted at ARS Fatehpur. The results indicated that foliar spray of cow urine 15% or cow urine fermented in sun light 10% solution was found as effective as *azadirachtine* 0.03 EC at 1500ml/ha (standard check).

- A field experiment was conducted at ARS Fatehpur for organic management of insect pests and diseases of cowpea.The results indicated that seed treatment with *Trichoderma herzianum* 10 g/kg seed followed by foliar spray of *azadirachtin* 0.03 EC (2ml/litre) or cow urine 20% or ash 25 kg/ha was done at 35 days after sowing were effective and economical to control of insect pests and diseases of cowpea.
- At ARS Mandor (Jodhpur) effort was made to control insect pests and diseases through organic means. Experimental results indicated that foliar spray of neem based insecticide (*Azadirachtin* @ 0.3%) reduced disease infestation, capsule damage and *Phyllody* to 8.4, 2.2 and 0.92% against 22.2, 13.3 and 5.32, respectively in control, which resulted in increased yield by 220.4% over control. Further, foliar spray of neem oil @ 1% reduced disease infestation, capsule damage and *Phyllody* by 55.5, 69.9 and 83.3%, respectively as compared to control. As a result neem oil treated crop gave 124.1% higher yield over control.



Organic farming of cowpea

Cowpea is grown widely in Rajasthan as rainfed *kharif* crop. Looking to the escalated demand of organic produce an effort was made to produce cowpea through organic nutrient management at ARS, Fatehpur. Three years experimentation revealed that application of 100% recommended dose of nitrogen (RDN) through FYM gave highest seed yield of 4.01q/ha and straw yield of 7.23q/ha. Application of 100% nitrogen through vermi compost or FYM in combination with organic waste recorded 3.31 to 3.90 q/ha and 6.47 to 7.18 q/ha, seed and straw yield, respectively. The benefit of nitrogen application through FYM was further evident from highest net return of Rs. 8,397/ha and B:C ratio of 1.40 against Rs. 5,159 to 7,960/ha and 0.76 to 1.33 with all other organic combinations, respectively. Further no appreciable change in soil physico-chemical properties viz., bulk density, pH, EC, organic carbon, available nitrogen, phosphorus and potash was noticed due to different organic treatments.

Management of insect pests of chilli through organics:

Organic pest and disease control is gaining importance for higher market value of organic produces. Three years experimentation at ARS, Mandor indicated that treatment comprised of soil application of neem cake @ 1.5 t/ha + seed treatment with *Trichoderma* @ 6 g/kg seed + 1st spray of cow urine @ 100 ml/ lit. + neem oil 10 ml/lit + 2nd spray of garlic mixture @ 2% + *Gowshalla keet niyantrak*, @ 30 ml/l) + 3rd spray of cow urine @ 100 ml/ lit + garlic mixture @ 2% + *Azadirachtin* @ 3 ml/lit + 4th spray of cow urine at 100 ml/ lit + garlic mixture @ 2% + *Azadirachtin* @ 3 ml/lit at fortnight interval was found effective to control termite infestation (17.93%), leaf curl incidence (20.49%), die back (12.5%) and fruit rot (6.4) in organic chilli cultivation

Organic and integrated diseases management in sesame

Alternaria leaf spot, *Phyllody* and *Macrophomina* stem and root rot have come out to be a major limiting factor for achieving higher production of sesame. Further, to maintain environment sanitation and produce quality sesame seed an effort has been made at ARS, Mandor to control sesame diseases through organic and integrated

disease management approaches. Three years research results revealed that soil application of neem cake (250 kg/ha) + seed treatment with *Trichoderma viride* (0.4%) + soil application of *T. viride* (2.5 kg/ha) + spray of *Azadirachtin* (0.3%) at 30-40 and 45-55 DAS reduced *Macrophomina* stem and root rot, *Alternaria* leaf spot and *Phyllody* by 83.3, 46.8 and 60.2% over farmers' practice, where the corresponding figures were 16.2, 15.6 and 6.4%, respectively. Effective diseases control, thus improved seed yield by 54.4% over farmers practice (4.10 q/ha). The benefit of the diseases management through organics was further manifested by higher B:C ratio of 2.29. Thus, this organic management practice has been included in package of practices.

Organic ptoduction of tomato, brinjal, bottle gourd and round gourd

Application of enriched vermicompost @ 17.5 t/ ha before transplanting of seedling and 2 t enriched vermicompost + 500 kg neem cake /ha after 30 days of transplanting and three foliar sprays of liquid organic manure (20%) starting at 40 days after transplanting at an interval of 15 days, gave significantly higher fruit yield of tomato, brinjal, bottle gourd and round gourd in Jaipur region.

Seed treatment with bioagent-

Trichoderma viride @ 5g/kg + soil application of the same @ 2kg/ha with 50kg FYM found effective in controlling root rot (disease index 8.41%) in chilli and the efficacy is comparable to chemical root rot control with carbendazim @ 2g/kg seed (5.0%) at ARS, Fatehpur-shekhawati (Sikar).

Organic Kinnow production

Changing system of livelihood and consciousness about good health of individual high income group peoples now opened a new market for cultivation of organics in the world, and developing country like India also. Therefore, there is urgent need to develop organic production technologies for field crops, vegetables and fruits. Based on three years pooled data (2014-15 to 2016-17) revealed that growth characters of organic kinnow* was found significantly improved with T4 (Vermicompost on 75% N equivalent basis RDF) + *Trichoderma harzianum* (30-40 ml/plant) + *Azadiractrum* (1% at 3-4ml/liter as spray) + *Pseudomonos* (*flourescense/striata*).

Table-: Fruit quality and fruit yield under different organic treatments at Sriganganagar

Treatment	Fruit yield (Kg/ha)			Acidity (%)			TSS(%)		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
T1	22.60	17.40	22.60	1.12	1.42	1.27	8.00	8.25	8.12
T2	30.47	24.33	30.47	1.06	1.40	1.13	8.50	10.00	9.25
T3	43.65	34.52	43.65	0.97	1.32	1.04	10.0	9.75	9.87
T4	70.10	55.32	70.10	0.81	0.83	0.82	14.0	13.75	13.87
T5	66.37	50.77	66.37	0.82	0.87	0.84	14.0	13.25	13.62
SEm±	1.71	3.93	1.71	0.04	0.06	0.06	0.43	0.72	0.35
CD at 5 %	3.74	8.56	3.74	0.09	0.14	0.14	0.95	1.57	0.76

**Age of the plant 6 years*

Where:T1: Control, **T2**: 100 per cent vermicompost (on N equivalent basis of RDF), **T3**:75 %vermicompost (on N equivalent basis of RDF) +*Trichoderma harzianum* (30-40 ml/ plant) +*Azadiractrum* (1% at 3-4ml/liter as spray), **T4**: 75% vermicompost (on N equivalent basis of RDF) + *Trichoderma harzianum* (30-40 ml/ plant) + *Azadiractrum* (1% at 3-4ml/liter as spray) +*Pseudomonos* (*flourescense/striata*),**T5** :50% Vermicompost (on N equivalent basis of RDF) +*Trichoderma harzianum* (30-40 ml/ plant) + Azadiractrum (1% at 3-4ml/liter as spray) + *Pseudomonos* (*flourescense/striata*) + *Azatobacterc hroococcum*

Organic package of practices of guar

Technology	POP for organic agriculture	POP for organic intensive agriculture
Soil treatment	Soil application of *Trichodermaharizianum* @ 5kg/ha preincubated in 100kg. FYM	Soil application of *Trichodermaharizianum* @ 5kg/ha pre-incubated in 100kg. FYM
Seed treatment	Seed treatment with *Trichodermaharzianum* @10gm/kg.+Neem oil @10ml/kg. +Azotobactor & PSB @ 5gm/kg of each biofertilizer.	Seed treatment with *Trichodermaharzianum* @10gm/kg.+Neem oil @10ml/kg. +Azotobactor & PSB @ 5gm/kg of each biofertilizer.
Nutrition	FYM @ 47 q/ha Nutrient contents: 0.6% N, 0.3% P and 0.7%K	FYM @ 36 q/ha+crop residue @ 25q/ha+ Neem cake/ caster cake @6.0q/ha.
Crop rotation	Guar-wheat	Guar-wheat
Varieties	RGC 1002	RGC 1002
Time of sowing	15 June - July	15 June – July
Insect management I – Termites II- White fly	Drenching with Neem Oil @ 4 liters/ha at II/ IIIrd irrigation Spray of Neem oil @ 2%	Drenching with Neem Oil @ 4 liters/ha at II/ IIIrd irrigation Spray of Neem oil @ 2% + 0.1% triton X or sandovit
Expected yield	8.00 qtl/ha.	8-10.00 qtl/ha.
Soil nutrient status (organic carbon)	Initial : 0.25% After harvesting : 0.38%	Initial : 0.25% After harvesting : 0.35%

Organic package of practices of mothbean

Technology	POP for Organic Agriculture	POP for Organic Intensive Agriculture	POP for Integrated Agriculture
Seed treatment with chemical/ bio-agent/ bio-fertilizer	Carbendazim@1gm/kg seed	Carbendazim@1gm/kg seed	Carbendazim@1gm/kg seed
Sources & quantity of organic amendments including green manuring & fertilizers (mention content of major nutrients)	FYM equivalent to 50 % RDF (N) + 50% through decomposed crop residue/ organic waste + bio-Fertilizers + micronutrients including S	FYM + bio-fertilizers + PP (BCA) + Gypsum + Green manure/ crop residue + cakes	50 % RDF + 50 % through FYM + bio-fertilizers + micronutrients including S
Crop rotation followed, field sanitation	Legume-cereal	Legume-cereal	Legume-cereal
PP measures: Pest management- Judicious use of pesticide and/ or organics like light traps, pheromone traps & lures, yellow sticky traps, *Trichogramma*, nutural enemies (predators & parasitoids), entomogenous fungus, Gowshalla products, botanicals, bio-pesticides, wood ash, Bt., NPV etc.	Foliar spray of cow urine (10%)+ Neem leaf extract (5%)+Garlic extract (2%)	Foliar spray of cow urine (10%)+ Neem leaf extract (5%)+Garlic extract (2%)	Foliar spray of cow urine (10%)+ Neem leaf extract (5%)+Garlic extract (2%)
Disease management- Judicious use of fungicides and/ or organics like soil application of *Trichodermma*, Plant extracts, mechanical method etc.	Followed by spray of Dimethoate (1ml/l)	Followed by spray of Dimethoate (1ml/l)	Followed by spray of Dimethoate (1ml/l)
Expected yields	300 kg/ha.	300 kg/ha.	350 kg/ha.

Organic package of practices of mungbean

Technology	POP for organic agriculture	POP for organic intensive agriculture
Soil treatment	Soil application of *Trichoderma harizianum* @ 5kg/ha preincubated in 100kg. FYM	Soil application of *Trichoderma harizianum* @ 5kg/ha preincubated in 100kg. FYM
Seed treatment	Seed treatment with *Trichodermaharzianum* @10gm/kg.+Neem oil @10ml/kg. + Azoto-bactor& PSB @ 5gm/kg of each biofertilizer.	Seed treatment with *Trichodermaharzianum* @10gm/kg.+Neem oil @10ml/kg. + Azoto-bactor& PSB @ 5gm/kg of each biofertilizer.
Nutrition	FYM @ 47 q/ha Nutrient contents: 0.6%N, 0.3% P and 0.7%K	FYM @ 36 q/ha+crop residue @ 25q/ha + Neem cake/ caster cake @6.0q/ha.
Crop rotation	Moong-wheat	Moong-wheat
Varieties	SML 668	SML 668
Time of sowing	15 June - July	15 June – July
I – Termites II- White fly	Drenching with Neem Oil @ 4 liters/ha at II/IIIrd irrigation Spray of Neem oil @ 2%	Drenching with Neem Oil @ 4 liters/ha at II/IIIrd irrigation Spray of Neem oil @ 2% + 0.1% triton - X or sandovit
Expected yield	6.00 qtl/ha.	7.00 qtl/ha.
nutrient status (organic carbon)	Initial : 0.25% After harvesting : 0.38%	Initial : 0.25% After harvesting : 0.35%

Package of practices for Organic cucurbits : Bottle gourd

Technology	POP for organic agriculture	POP for organic intensive agriculture
Soil treatment	Soil application of *Trichoderma harizianum* @ 5kg/ha preincubated in 100kg. FYM	Soil application of *Trichoderma harizianum* @ 5kg/ha preincubated in 100kg. FYM
Seed treatment	Seed treatment with *Trichoderma harzianum* @10gm/kg.+Neem oil @10ml/kg. +Azotobactor& PSB @ 5gm/kg of each biofertilizer.	Seed treatment with *Trichoderma harzianum* @10gm/kg.+Neem oil @10ml/kg. +Azotobactor& PSB @ 5gm/kg of each biofertilizer.
Nutrition	FYM @ 233 q/ha (on dry wt basis @167 qtl/ha.).Nutrient contents:0.6%N, 0.3% P and 0.7%K	FYM @175 q/ha+crop residue @ 25g/ha + Neem cake/ caster cake @6.0q/ha.
Crop rotation	Fallow - Cucurbits	Fallow – Cucurbits
Variteis	Pusa Naveen	Pusa Naveen
Time of sowing	Feb – March	Feb – March
Insect management I – Termites II- White fly	Drenching with Neem Oil @ 4 liters/ha at II/IIIrd irrigation Spray of Neem oil @ 2%	Drenching with Neem Oil @ 4 liters/ha at II/IIIrd irrigation Spray of Neem oil @ 2% + 0.1% triton X or sandovit
Expected yield	180.00 qtl/ha.	200.00 qtl/ha.
Soil Nutrient (Organic Carbon)	Initial : 0.25% After harvesting : 0.38%	Initial : 0.25% After harvesting : 0.35%

Farming system

Various Production systems for cumin:

Cumin being one of the most important seed spices, consumed directly, adoption of organic or organic intensive production system attains paramount importance for its production. Three years experimentation at ARS, Mandor revealed that 50% nitrogen through FYM (3 t/ha) + 50% nitrogen through decomposed mustard residue (3 t/ha) + 250 kg gypsum/ha + seed treatment with *Trichoderma viride*, *Azotobacter*, PSB + pests and diseases management through organics and installation of yellow stick traps recorded lowest wilt infestation of 6.5%. Thus, this treatment combination gave the highest seed yield of 4.05 q/ha. The benefit of the treatment was further evident by highest B:C ratio of 2.31. Further, under organic intensive system nitrogen through FYM, crop residue, cake + gypsum recorded higher seed yield of 4.06 q/ha and B:C ratio of 1.29. Integrated production system of 50% N through fertilizers and rest from FYM + 250 kg gypsum/ha recorded wilt incidence of 17% and seed yield 4.40 q/ha. It also gave B:C ratio of 1.68.

Production system for isabgol :

Isabgol one of the most important medicinal crops is grown extensively in Jodhpur region. Being medicinal crop, its husk is consumed directly and thus, organic production of this crop has gained importance. Experiment conducted during three years at ARS, Mandor revealed that application of 100% recommended nitrogen through FYM gave the highest seed yield of 11.69 q/ha against 100% N through vermicompost (11.25 q/ha) and different combinations of FYM, vermicompost and crop residues along with FYM + gypsum or without gypsum (9.66 to 11.25 q/ha). The benefit of 100% N application through FYM was further manifested by higher B:C ratio of 4.39. Further, integrated production system of 50% N through fertilizer and rest from FYM along with gypsum recorded higher yield of 1479 kg/ha against 11.69 q/ha in organic cultivation where total nitrogen was supplied through FYM.

6. Precision farming, climate–resilient and stress agriculture

Precision / protected agriculture

Capsicum

The experiment was laid out at ARS Bikaner to evaluate suitable variety of capsicum under shade net house and open field conditions in arid region and to study the economic feasibility of capsicum cultivation under shade net house. On the basis of pooled data (2010-13) it may inferred that shade net house is better than open field condition for cultivation of capsicum in arid hot region of Rajasthan. Among different varieties of capsicum studied Indra responded better with maximum yield of 361.26 q/ha with net return of Rs. 33148 per 1000 m^2 and B:C ratio 2.35

Low tunnels study in winter planted tomato

An experiment was conducted at Agriculture Research Station Sriganganagar during Rabi 2010-11 to 2013-14. Result indicated that 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 per cent higher fruit yield and saved 25.72 per cent irrigation water over drip irrigation at 1.0 Etc (without low tunnel) and 101.5 per cent higher fruit yield and saved 79.08% irrigation water over conventional surface irrigation. 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 I1 (0.60 Etc by drip system with low tunnel), followed by 115.5 kg/ha mm under I2 (0.8 Etc by drip system with low tunnel).

Plant Biotechnology

Studies were conductedfor identifying promising genotypes of wheat for heat tolerance using physiological and biochemical indicators through expression analysis of key enzymes/proteins. Efforts were also made for melioration of heat stress by exogenous application of thiols and other compounds. Out of 102 accessions screened for heat tolerance, three accessions (IC279317, IC335971 and IC336816) performed better under both normal and late sown conditions, which may be categorized as heat tolerant lines and may be used for further breeding programmes.

Sixteen genotypes of wheat were evaluated with two sowing dates 15 November (normal) and 15 December (late for heat stress), for four consecutive years from 2010-11 to 2013-14 for heat tolerance under warm climatic conditions. Results indicated that in general, the rate of photosynthesis, relative water content, membrane stability index, chlorophyll and carotenoid content; plant height, number of effective tillers per plant, number of spikelets per spike, grain number per spike, grain yield per plant, biological yield per plant and harvest index got reduced significantly whereas transpiration rate, stomatal conductance, internal CO_2 concentration, leaf

temperature, proline and anti-oxidants activity increased on account of heat stress. Heat tolerance index, proline and antioxidants were the highest in genotype Raj 4083 followed by Raj 4037 under both the conditions. Considering morpho-physiological, yield, biochemical and molecular indicators, Raj 4083 and Raj 4037 were found to be the most heat tolerant genotypes. Seedlings of the most heat tolerant (Raj 4083) and most heat sensitive genotype (PBW 373) were used for expression analysis by semi quantitative PCR. Expression of Hsp-70, Hsp-90, *Rubisco* and soluble starch synthase (SSS) was higher under heat stress as compared to control in both the genotypes. Genotype Raj 4083 had higher expression pattern as compared to PBW 373 in both the conditions.

Foliar sprays of thiourea (500, 1000 ppm), thioglycolic acid (100, 200 ppm) and dithiothreitol (25, 50 ppm) were applied in heat tolerant (Raj 4083) and heat susceptible (PBW 373) wheat genotypes at the time of anthesis and milking stages. Results showed a general increase in growth and yield parameters in sulphydryal treated plants under normal and heat stress conditions. Genotype Raj 4083 has higher seed production potential than PBW 373 under both conditions. Foliar application of dithiothreitol @ 25 ppm was found to mitigate the adverse effect of high temperature stress.

Climate resilient/ Stress management agriculture

Management of Heat Stress in Wheat

- A field experiment was conducted at ARS, Durgapura to investigate the effect of different chemicals to mitigate the heat stress in late sown wheat. The results revealed that spray of Salicylic acid @ 100 ppm or Thiosalicylic acid @ 100 ppm at jointing & earhead emergence stage is recommended for mitigating adverse impact of heat stress in wheat
- In another Experiment, at same station it was concluded that water spray at tillering stage of wheat is helpful to mitigate the adverse impact of heat stress in wheat.

Mitigate the Heat Stress in Wheat

Stress particularly of heat stress is a major physiological disorder in the state. Terminal heat stress is a common and serious problem in winter season crops particularly of wheat in Rajasthan. To mitigate the heat stress in wheat, an experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment revealed that foliar application of silicic acid (150 ppm) is recommended at flag leaf & milk stage in wheat for mitigation of heat stress.

In three years study Agriculture Research Station, Sriganganagar it was concluded that foliar application of silicic acid (100 ppm) + thiourea (250 ppm) has been found effective to mitigation of heat stress in wheat. In another study at same location based on three yearsresults clearly indicated that foliar spray of 1% KNO_3 at flowering and pod fillings stages has been beneficial for moister stress management in mustard in zone 1b.

Carbon intensive farming for combating stress

Results of three years (2011-2014) indicated that the maximum grain and stover yield of mustard was recorded in green manuring through cluster bean + compost @ 2.5t/ha + RDF and minimum yield was recorded under the treatment FYM@ 2.5 t/ha + castor cake 250 kg/ha. Soil properties also improved with the regular addition of the organic manure.

Frost management in mustard

For the purpose to manage the frost in N-W region, a field trial in mustard was conducted at Agriculture Research Station, Sriganganagar and it was concluded that application of sulphuric acid or di methyl sulphoxide (DMSO) @ 1 ml /litter water (0.1%) when the temperature is around 4°C or below it during the crop season was found effective and included in package of practices of the Zone Ib.

Heat stress mitigating in chickpea

During *rabi* 2012-13 and *rabi* 2013-14 Four varieties and four fertilizer management practices were tested to mitigating the heat stress in gram. Pooled data of two seasons showed that recommended dose of fertilizers along with K_2O@ 20 kg/ha through MOP and S @ 40 kg/ha through gypsum resulted in significantly higher grain yield and MSI. Further, application of potassium @ 20 kg/ha and sulphur @ 40 kg/ha along with general recommended dose of fertilizers are helpful in mitigating heat stress.

7. Research in vegetables, fruit, medicinal & aromatic plants

Horticulture

Growing demand for horticultural produce has given a potent scope to enhance farm income through crop diversification by integration of fruits, vegetables, flowers, seed spices and medicinal and aromatic crops with field crops. Horticultural crops are frequently affected by numerous insect-pests and diseases. Thus, farmers use chemicals to control these, which adversely affect crop quality as well as environmental sanitation. Quality is of paramount importance for horticultural crops. Recently horticulture has immense scope in Rajasthan for boosting farm income. Integrated and balanced use of fertilizer, testing of new varieties can play pivotal role in enhancing income of the farmers of the state. So research efforts were made to intensify the integrated and balance approach to manage nutritional and other requirement of horticultural crops. So, research efforts were being intensified to reduce indiscriminate use of chemicals and develop organic technologies for effective control of insect pest and diseases. The salient research achievements for the year 2009-10 are given below:

Optimum Crop Geometry for Drip Irrigation in Brinjal:

An experiment was conducted at ARS, Sriganganagar during Rabi 2008-09 to 2010-11 with five crop geometries (60 X 120, 60 X 75 paired, 60, 90 and 108 cm single row) for brinjal crop under drip irrigation system. On the basis of three years of experimentation, it was observed that under drip irrigation system closer row spacing of 60 cm in brinjal gave the maximum fruit yield (547.37 q/ha) , however, it was at par with 60 x 120 (511.82q/ha) and 60 x 75 (520.81q/ha) paired row spacing. The minimum fruit yield of brinjal was recorded with wider row spacing of 108 cm.

Irrigation management in Garlic

The experiment was laid outat ARS Bikaner to evaluate suitable irrigation method for Garlic in arid region. The results indicated that grow garlic under drip irrigation using 16 mm inline drip of 0.4 m, 4 lph, at a lateral spacing of 60 cm for crop geometry 15 cm x 7.5 cm having four rows of garlic per lateral and it should irrigate @ 100% ETc to obtain higher yield. A farmer can get a profit of about Rs. 70000 to irrigate the Garlic by drip method compared to surface irrigation method.

Irrigation scheduling and fertigation in Bottle Gourd

An experiment was conducted at ARS, Sriganganagar during *Kharif* 2007 to 2010 with three levels of drip (60,80 & 100% PE) and three levels of fertigation (75, 100 & 125% RD of N & K) and one surface irrigation with 100% RD of fertilizer. From results it was observed that drip irrigation gave higher fruit yield as compared to the flood irrigation treatment. In case of drip irrigation treatments, the fruit yield of bottle gourd increased significantly with every increase in the level of irrigations. Application of 125 percent N & K gave significantly higher fruit yield over 75 & 100 per cent of N&K. The highest fruit yield of bottle gourd (656.43 q/ha) was recorded in interaction effect when 125% RD of N & K were applied with I_3 irrigation level (100% PE), which was statistically superior over other treatment combinations tested.

Drip Irrigation Schedule and Fertigation in Bitter Gourd

An experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment indicated that fertigation in drip system with 80 kg N, 32 kg P_2O_5 & 32 kg K_2O/ha through water soluble fertilizers in 12 equal splits each at an interval of 11 days gave significantly higher yield in bitter gourd. In another experiment the results revealed that bitter gourd should be irrigated at 0.8 ETc (LT) for optimum yield.

Fertigation in Tomato

Fertilization along with irrigation in drip irrigation system is very important and essential component. For this, an experiment was conducted at Agricultural Research Station, Sriganganagar. The results of the experiment indicated that fertigation with 100 kg N, 40 kg P_2O_5 & 40 kg K_2O/ha through water soluble fertilizers in 9 equal splits each at an interval of 15 days produced significantly higher tomato yield than all other treatments.

Irrigation Management in Chilli:

Chilli is an important horticultural crop of Rajasthan and need good amount of water. To precise the irrigation scheduling and minimize the water requirement of the crop, a field trial was conducted for three consecutive years at Agricultural Research Station, Sriganganagar and it was concluded that drip irrigation schedule at 1.0 ETc (LT) has been found suitable to increase the fruit yield and quality of chilli in zone 1b.

Fertigation Schedule in Chilli:

An experiment was conducted for three consecutive years at Agriculture Research Station, Sriganganagar to optimise the fertigation schedule in chilli, The results indicated that 120% RD (84kg N, 60kg P_2O_5, 60kg K_2O per ha) in 9 splits at an interval of 13 days has been found most appropriate schedule in chilli for yield maximization in zone 1b.

Potassium for Onion and Cumin Production

For balance fertilization in crops, potassium application gaining importance in the state .For this, an effort was made at ARS Mandor to find out response of potessium on onion and cumin. The results revealed that application of 15 kg K_2O/ha in cumin and 50 kg K_2O/ha in onion was found effective to increase seed and bulb yield of cumin and onion, respectively.

Integrated Nutrient Management in Vegetable Pea and Rabi Onion

Application of 12.5 kg N+ 20 kg P_2O_5 + 25 kg K_2O/ha along with 2.5 t FYM, 600 gm each of Azotobacter& PSB, 250 kg gypsum and 25 kg zinc Sulphate/ha is recommended for higher production of vegetable pea under irrigated coarse textured soil situation of the Zone.Another experiment was conduted for rabi onion which revealed that application of 80 kg N+ 25 kg P_2O_5+ 80 K_2O along with 10 t FYM, 6 kg each of Azotobacter& PSB, 250 kg gypsum and 25 kg Zinc Sulphate/ha is recommended for higher production of rabi onion under irrigated coarse textured soil situation of zone IIIa.

Integrated Nutrient Management in onion:

A field experiment was conducted at RARI, Durgapura to evoulvate INM in Onion. The results revealed that application of 110:40:60:40 kg/ha NPKS + 7.5 t/ha FYM + 2.5 t/ha poultry manure + 5 kg/ha bio-fertilizers (*Azotobacter*& PSB) were recommended for higher productivity of onion in zone IIIa.

Integrated Nutrient Management in vegetable Pea:

A field experiment was conducted at RARI, Durgapura to evaluate INM invegetable Pea. The results revealed that application of 50% RDF (NPK 12.50:20:25 kg/ha) + vermin-compost @ 2.5 t/ha or poultry manure @ 2.5 t/ha or FYM @ 10 t/ha was recommended for enhancing the productivity of vegetable pea in zone IIIa.

Foliar application and fertigation of zinc and iron on sweet orange:

On basis of pooled data of experiment (From year 2011-14) conducted at ARS, Bikaner, the highest yield of sweet orange was obtained under the treatment foliar application (Zn 0.6% + Fe 0.3%) giving yield of 45.52 kg/plant which was at par with foliar application of (Zn 0.3% +Fe 0.3%), (Zn 0.3% +Fe 0.6%) and (Zn 0.6% +Fe 0.6%). In case of fertigation the highest yield of sweet orange was obtained under the treatment (Zn 0.6% + Fe 0.3%) giving yield of 40.24 kg/plant which was at par with application of Zn 0.6%, (Zn 0.3% +Fe 0.3%) and (Zn 0.6% +Fe 0.6%) whereas, the yield recorded under control plant was 38.72 kg/plant. The information obtained from these trials is helpful to design similar nutrition program according to growth and phonological cycles for other citrus areas.

Micro Nutrients Scheduling in Kinnow

An experiment was conducted at Agricultural Research Station, Bikaner for micronutrients study in kinnow. The results revealed that three foliar applications of combined solution of $FeSO_4$, $CuSO_4$, and $ZnSO_4$ each @ 0.5% is recommended for optimum yield in Kinnow before flowering stage, at fruit formation stage (ber sized fruits) and 40 days after second spray in zone 1c.

Foliar application of mironutrient on yield and quality of kinnow under drip irrigation:

A trial was conducted at ARS, Bikaner. The highest yield of Kinnow (43.45 kg/plant) was obtained under the treatment of foliar application (Fe 0.5 per cent + Cu 0.5 per cent + Zn 0.5 per cent) giving yield of 43.65kg/plant which was at par with foliar application of (Fe 0.7% + Zn 0.7 per cent), (Fe 0.7% + Cu 0.7 per cent + Zn 0.7 per cent), (Fe 0.5% + Zn 0.7 per cent) , (Fe 0.5 per cent + Zn 0.5 per cent) and (Fe 0.7 per cent + Zn 0.5 per cent) whereas, the yield recorded under control plant was 23.80kg/plant.

Fertilizer Management in Brinjal:

An experiment was conducted at Agricultural Research Station, Sriganganagar on fertilizer management in brinjal. The results of the experiment revealed that application of 80 per cent RD of fertilizers (96 kg N, 64 kg P_2O_5& 48 kg K_2O/ha) was found optimum dose for kharif brinjal. This dose should be given in 12 equal splits each at an interval of 10 days

Drip Irrigation in Brinjal:

An experiment was conducted at Agricultural Research Station, Sriganganagar on drip irrigation in brinjal. The results of the experiment revealed that drip irrigation in brinjal with mulch at 0.8 ETc was found optimum. This treatment saved 34.09 per cent of irrigation water over surface irrigation and 15.68 per cent even over drip irrigation scheduled at 1.0 ETc without plastic mulch.

Fertilizer Management in Radish:

An experiment was conducted at Agricultural Research Station, Bikaner. The results of the experiment indicated that for yield target of 300 q/ha of radish crop in this zone (1c), 40 kg N + 58 kg P2O5 + 87 kg K2O along with 25 tones per hac. FYM is required. Full dose of phosphorus and half dose of Nitrogen and Potassium as basal and remaining dose of Nitrogen and Potassium should be applied at root forming stage.

Evaluation of IPM compatible pesticides for major sucking pests in citrus (kinnow):

The observations were taken on the seasonal incidence and management of the major entomological biotic stress in citrus (kinnow) orchards at Agriculture Research Station, Sriganganagar . The entomological biotic stress recorded were mainly the citrus psylla, citrus white fly, citrus thrips, citrus mealy bug and the citrus mite. The evaluation of IPM compatible pesticides involving chemical insecticides, horticultural mineral oils, botanicals, biopesticides and the IGRs against each pest was done at appropriate time and appearance of the pest attaining ETL. The efficacy of the IPM compatible pesticides evaluated against these pests is presented as follows:

Citrus Psylla: On the basis of two years and five seasons data it was found that maximum mean per cent reduction of 78.8% was obtained by spray of diafenthiuron 50WP @ 2g/liter water and it was statistically at par with DC-tron plus @ 0.5 per cent followed by orchol -13 @ 1%. Amongst the biorationals, besides DC-tron plus@ 0.5% and orchol-13, karanj oil @ 1% was found effective.

Citrus White Fly : For the management of Citrus white fly, it was found that maximum mean per cent reduction of 82.3 per cent was obtained by spray of diafenthiuron 50 WP @2g/liter water and it was statistically at par with novaluron 10 EC @ 1ml/liter water, DC tron plus @ 0.5 per cent and karanj oil @1%.

Citrus Mealy Bug: The studies conducted during *kharif* season of 2012&2014 for the management of citrus mealy bug. The results revealed that maximum mean per cent reduction of 79.0 per cent was obtained by spray of diafenthiuron 50 WP @2g/liter water and it was statistically at par with chlorpyriphos 20 EC @ 2ml/liter water. However, amongst the bio-rationals it was the DC-tron plus which found effective.

Management of Fruit Rotting

A field experiment was conducted at ARS, Bikaner to mange the fruit rotting caused by *Aspergillusniger, Aspergillusflavus, Rhizopussp, Botryodiplodia* and *Penicilliumsp.*.The results revealed that the two spray of *Trichoderma viride* (0.1%) +*Azadiractin* (0.3%)+ date leaf cover at an interval of 15 days can be considered most suitable for minimize the fruit rotting caused by *Aspergillus niger, Aspergillus flavus, Rhizopussp, Botryodiplodia* and *Penicillium sp.*

Citrus Mite: The management of citrus mite on leaves during the two seasons sprays revealed that maximum mean per cent reduction of 75.4 per cent with Propargite 57EC @ 2.0 ml/liter water was observed and was statistically at par with Triazophos 40EC@ 2.5 ml/liter water, diafenthiuron 50WP @2g/liter,quinalphos 25EC @2ml/liter water and karanj oil @ 1.5%.

Integrated Nutrient Management in Date palm

An experiment on Integrated Nutrient Management in date palm cv. Halawy was laid out at ARS Bikaner with 10 treatments replicated thrice in R.B.D. Results showed that maximum yield per palm at *doka* recorded (60.08 kg) under 50% NPK + Biofertilizer + FYM treatment, which is significantly higher over control. The same treatment also recorded maximum fruit weight (10.13 g) and T.S.S. (31.75 per cent), which are also significantly higher over control.

DRIS (Diagnosis and Recommendation Integrated System) of Orchard Advisory included in PoP in chart form. Chart can be utilized to access the status of orchard in terms of soil and leaf nutrients content that can be used to manage optimum fruit productivity. Under this experiment, preliminary survey and identification of private orchards carried out and yield performance of those orchards were recorded. Orchards were surveyed for last 5 years i.e. 2011-12, 2012-13, 2013-14, 2014-15 and 2015-16. A total of 105 orchards were surveyed in past 5 years. Soil, fruit and leaf samples were taken and analysed for further inference. Past five year's data of 105 orchards analysed using DRIS (Diagnosis and Recommendation Integrated System) software at ICAR - Central Citrus Research Institute, Nagpur. A DRIS chart generated (Table- 1 to 3) on the basis of soil, leaf and fruit analysis data along with yield potentiality under different category of orchard. The chart can be utilized to access the status of orchards in terms of soil and leaf nutrients and nutrients can be managed to obtain optimum fruit productivity during 2017-19 at Sriganangar region.

Table-1: Variation in leaf nutrient ststus in relation to fruit yield of kinnow mandarin

Parameters	Low	Medium	High
N(%)	1.78	2.25	2.78
P(%)	0.11	0.14	0.21
K(%)	1.09	1.29	1.52
Yield (t/ha)	17.76	31.02	47.35

Table-2: DRIS based soil fertility limit for kinnow mandarin orchards in Sriganganagar

Soil properties	DRIS Indices				
	Deficient	Low	Optimum	High	Very High
pH (1:2)	<8.0	8.0-8.2	8.3-8.5	8.6-8.8	>8.8
EC (dS/m^{-1}))	<0.28	0.28-0.55	0.56-0.71	0.72-0.92	>0.92
$CaCO_3$(%)	<2.5	2.6-4.2	4.3-7.5	7.6-8.9	>8.9
Organic C (%)	<0.25	0.5-0.42	0.43-0.58	0.59-0.71	>0.71
Available Nitrogen (Kg/ha)	<95.1	95.2-112.3	112.4-123.4	123.4-136.1	>136.1
Available phosphorous (Kg/ha)	<14.2	14.2-23.2	23.3-28.1	28.2-36.1	>36.1
Available potassium (Kg/ha)	<228.4	228.4-272.3	272.4-301.4	301.4-334.1	>334.1
Fruit yield (t/ha)	<14.5	14.5-20.2	20.3-35.8	35.9-45.2	>45.2

Table-3: DRISbased leaf nutrient standards for kinnow mandarin orchards in Sriganganagar

Nutrients	DRIS Indices				
	Deficient	Low	Optimum	High	Excess
Nitrogen (%)	<1.68	1.68-2.10	2.11-2.48	2.48-2.72	>2.72
Phosphorous (%)	<0.10	0.11-0.13	0.14-0.16	0.17-0.22	>0.22
potassium (%)	<1.18	1.18-1.34	1.35-1.48	1.48-1.68	>1.68
Fruit yield(t/ha)	<14.5	14.5-20.2	20.3-35.8	35.9-45.2	>45.2

Management of Date Palm Scale Insect

For effective management of datepalm scale insect *Parlatoria blanchardii*, an experiment was conducted at ARS,Bikaner which revealed that two sprays of Acetamiprid 20SP @ 0.3g/litre or Imidacloprid 17.8SL @ 0.3 ml/litre of water is recommended for higher yield and better quality of date fruits.

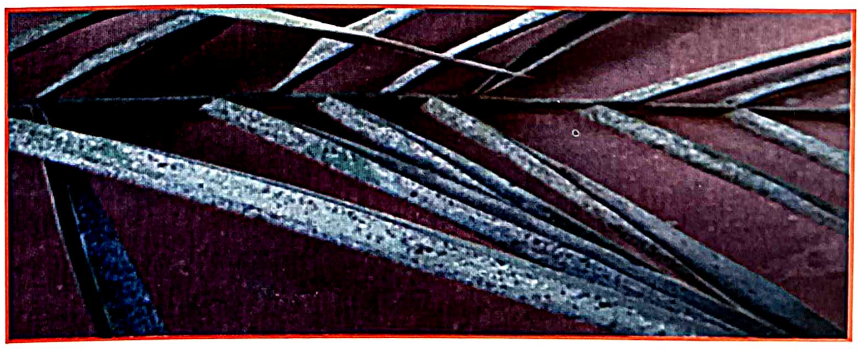


Fig: Datepalm leaflets infested by scale insect

Date Palm

Nutritive value

- Highly nutritious with **high calorific value** (3150 calories /kilogram of fresh fruits)
- **Sugars**: 60–65%
- **Fiber**: 2.5%
- **Protein**: 2%
- **Fat** : less than 2%
- **Minerals** : 2% (iron, potassium, calcium, copper, magnesium, chloride, sulphur and phosphorus etc.)

Status

Date palm is grown on 275 hectare area in Bikaner district.

Date palm in India does not attain *pind* (soft date) stage on trees due to **rains coinciding the ripening period of fruits** (June end to September).

Therefore, mostly fruits are harvested at *doka* stage (hard ripe stage).

Lack of market facility and spoilage of fruits during rains is major problem in date palm growing in Rajasthan.

Under a RKVY Project various processed products of date palm were prepared at SKRAU, Bikaner.

Products developed

- **Pickle** (with aloe vera, green mango, ginger)
- **Squash** (with guava, mango)
- **Sauce** (with tomato)
- **Jam** (with mango, pineapple, apple, ginger, papaya)
- **Health bar** (with dry fruits)
- ***Chhuara*** and ***pind khajur***

Bajra (Pearl Millet)

- Bajra has high nutritive value and is staple food of arid region.
- It is a rich source of calcium, iron, dietary fiber and micro nutrients.
- Nutritive value (Per 100g)

Energy: 361 Kcal.
Protein: 11.6 g
Fat: 5.0 g
Fiber: 1.0 g
Carbohydrate: 67.5 g
Ca: 42.0 mg.
Fe: 8.0 mg
P: 296. mg.
ZN: 3.1 mg.

Status

More than 50% of area under Bajara cultivation is in Rajasthan.
Peal millet is not under consumption in the urban population.
Also pearl millet flour is having low shelf life and develop rancidity.

Pearl millet can be subjected to various processing techniques like blanching, germination, soaking to overcome problems of poor digestibility, bitter taste and rancidity.

Products developed

- Bajra biscuit (sweet)
- Bajra cookies
- Bajra cake
- Bajra kurkure
- Bajra khakra
- Bhakarvadi
- Idli/dosa/upma
- Donuts
- Nankhatai
- Burfi
- Thepla

Olive

The olive, (*Olia europaea*), is a species of small of small tree in the family Oleaceae.

Nutritive value of olive

Energy: 146 K Cal
Carbohydrate: 3.84 g
Sugars: 0.54 g
Fiber: 3.3 g
Total fat: 15.32g
Saturated fat: 2.02 g
Mono unsaturated fat: 11.31g
Poly unsaturated fat: 1.30 g
Protein: 1.03g
Beta Carotene: 20 mg
Vit. E: 3.81 mg

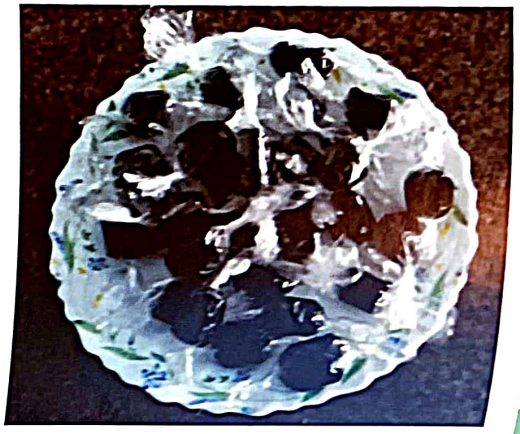
- Olive is a rich source of calcium, iron, vitamin-E, vitamin-A, vitamin-K, magnisium, copper, potasium and amino acids
- Olive have been associated with many health benefits, especially for heart health and cancer prevention.

Status

Olive is planted on 182 ha. area in Government farms in Rajasthan. With increasing plantation of olive in the state of Rajasthan there was need for development of technology for value addition in Olive.

Products developed

- Olive tea
- Olive pickle
- Olive mouth freshner
- Olive toffee
- Olive cake
- Olive biscuit
- Pizza
- Olive cookie



9. Farm implements & machinery testing and training

Farm Implements & Machinery Testing and Training Centre

To increase efficiency in utilization of natural resources including energy and reduce human drudgery, farm implements have been invented to enhance on- farm productivity. Taking cue, a number of manufacturers are involved in the fabrication of agricultural implements in the region However, their competence in the field can be assessed and appraised of only through precise, methodical and technical testing and evaluation of prototype development for large scale production and utilization is also a must for commercialization. With this view a Farm Implements & Machinery Testing and Training Centre was sanctioned to the university in 2011 by the Government of Rajasthan. The establishment of this centre at Bikaner improved the quality of manufacturing as per the standard of Bureau of Indian Standard (BIS).

Objectives

- Check material specification, durability and reliability of the farm equipments
- Assess the functional performance such as quality, output and energy/power requirement of the farm equipments.
- Maintain the quality of the farm machinery being subsidized by the Government.
- Suggest modification and improvements on the basis of test result for batter performance, ease in handling and adjustment on the basis of feedback from farmers.
- Impart training on different type of farm equipments to farmers, small scale manufacturers and extension workers.

The centre got accredited by the Division of Agriculture & Cooperation, Ministry of Agriculture & Farmer Welfare, Govt. of India, New Delhi vide Addendum No. 8-1/2004-MY(I & P) dated July 09, 2012 The centre was also awarded ISO 9001:2015 in December 2016 for three year & subsequently renewed in December 2019.

Further ISO 14001:2015 was also awarded to the centre in the February 2020.

Achievements

Since its inception in 2012, more than 1500 manufacturers have applied for the testing of following types of equipments:

- Tillage
- Land Development
- Sowing
- Intercultural
- Harvesting
- Gardening

Year	Nos.	Rs in Lakhs
2012-13	73	54.0
2013-14	85	51.0
2014-15	56	35.0
2015-16	84	40.0
2016-17	71	45.0
2017-18	73	45.0
2018-19	74	55.0
2019-20	91	100.0
Total	**607**	**425.0**

Training conducted

In all 432 farmers participated in the training programs related to *"Vibhinn Krishi Machinery evam Tractor ka Rakh-Rakhav", "Tractor Rakh-Rakhav evam Krishi Yantro ki Jankari"& "Krishi Machinery me Urja Sanrakshan evam Suraksha".*

Student Training		**(Nos.)**
• 2013 – 14	:	10
• 2014 – 15	:	07
• 2015 – 16	:	10
• 2016 – 17	:	17
• 2017 – 18	:	27
• 2018 – 19	:	32
• 2019 – 20	:	30
Total	**:**	**133**

- Machine in Lab

- Machine in Field

- Training

10. Research recommendations

2010-11

- Sulphur application @ 40kg /ha found optimum for chickpea and it gave 23.47q/ha seed yield and Rs. 16,688/ha net return (ARS, Fatehpur) zone IIa.
- Two irrigations at 21-30 DAS and 70 DAS found optimum for chickpea (ARS, Fatehpur).
- Highest pod yield (116.25 q/ha) and B:C ratio of 2.79 in cowpea cv. RCV- 7 was recorded with the application of poultry manure @ 2.5t/ha + half of recommended dose of NPK (12.5:20:20 kg/ha) ,and it is recommended for Jaipur region.
- Three years of research results revealed that spray of 0.2% $ZnSO_4$ +100 ppm ascorbic acid at vegetative and flowering stage increased grain yield by 28.44% over the control in clusterbean (ARS, Navgaon) zone IIIb.
- Row to row spacing of 135cm gave 28.50 q/ha castor seed yield, which was at par with 101cm (28.22 q/ha) and 67.5cm (27.34 q/ha) row spacing and thus, recommended for general practice in Sriganganagar region zone Ib.
- 75 kg N + 40 kg P_2O_5/ha found optimum for mustard in Sriganganagar zone.
- Application of potash @ 40 kg/ ha at the time of sowing in potash deficient soils increased the yield of wheat (ARS, Navgaon) zone IIIb.

2011-12

- It has been recommended in Zone IIa (ARS,Jalore) that foliar spray of thiourea 500 ppm at flowering and grain filling stages enhances grain yield of barely.
- It has been recommended in Zone Ib (ARS Sriganga-nagar) that optimum crop geometry of 60 cm x 120 cm is recommended for Bt cotton.
- It has been recommended in Zone Ib (ARS Sriganga-nagar) that seed rate @ 60 kg/ha is recommended for late sown chickpea.
- It was recommended in Zone IIIa. ARS, Durgapura that paired row planting of pearl millet and cluster bean in 2:1 row ratio is recommended for inter cropping in the zone.
- Different field experiments were conducted at farmer fields for the refinement of package of practices (POP) under RKVY Project in Zone-Ib. The results revealed that the fertilizer schedule for Barley in canal irrigated light to medium soils and Ghagger flood plain soils and salt affected soils was 80 kg N + 30 kg P_2O_5/ha whereas, for canal irrigated heavy soils: 100 kg N + 40 kg P_2O_5/ha.
- Application of 0.5% $FeSO_4$ +0.1% citric acid in groundnut reduced the chlorosis and increased the pod and kernel yield of ground nut (Zone Ia).
- Soil application of murate of potash (MOP) at the rate of 20 kg/ha is recommended for nutrient management in groundnut in Zone 1b.
- Application of half dose of FYM is optimum to be applied either in Kharif or Rabi season for economical organic wheat production if full dose of FYM is not available (Zone 1b).
- Different field experiments were conducted at farmer fields for the refinement of package of practices(POP) under RKVY Project in Zone-IIb. The foliar spray of 1% urea, DAP and soluble NPK (19:19:19) was applied at tillering and flowering stages in wheat crop at farmer fields irrespective of agro-ecological situation. Results revealed that foliar application of all three chemical fertilizers i.e. urea, DAP and soluble NPK (19:19:19) enhanced wheat production by 9.88, 12.62 and 16.83%, over control practice respectively
- Different field experiments were conducted at farmer fields for the refinement of package of practices(POP) under RKVY Project in Zone-Ib .The results revealed that fertilizer schedule for Castor crop in canal irrigated light to medium textured soils & Salt affected soils was 60 kg N + 40 kg P_2O_5 + 200 kg gypsum/ha.

2012-13

- Soil application of potassium @ 20 kg/ha is recommended for cultivation of wheat under irrigated situation in zone IIb.
- Sowing of pearl millet at 60 cm row spacing was found more appropriate for rain fed situation of zone IIb.
- Foliar spray of 0.2% K_2SO_4 + 100 ppm ascorbic acid

at grain development stage was recommended for rain fed pearl millet in zone IIb

- Mungbean seeds treated with emamectin benzoate 5 SG @ 40 mg/ kg seed can safely be stored for one year in jute bags under ambient conditions, maintaining the seed germination as per minimum seed certification standard in zone IIIa.
- Seed treatment with imidacloprid 600 FS @ 8.75 ml/kg seed followed by dusting of fenvelerate 0.4% @ 20 kg/ha at 35 days after germination is effective for the management of shoot fly and stem borer of pearl millet in zone IIIa.
- Seed treatment with Topsin –M @ 2 g/kg followed by seedling dip in 0.1% solution of Topsin-M at transplanting time to control the pink root rot of onion in zone IIa.
- 80% of the recommended dose of N & P fertilizers through drip in 12 equal splits on 10 days interval was recommended in vegetable brinjal for zone Ib.
- Optimum irrigation schedule for brinjal through drip was found at 1.0 ETc. Distance between dripper to dripper is 30 cm and water trickle down @ 2 liter/hour. To establish plantation run drip 2 hours/day for 4 days. In low tunnel irrigate once in a week and after lifting tunnel irrigate on alternate days in zone Ib.

2013-14

- Crop geometry of 67.5 cm x 90 cm gave significantly higher Bt cotton yield in all the years in Zone Ib.
- Application of sulphuric acid or di methyl sulphoxide (DMSO) at the rate of 1 ml /litter water (0.1%) in mustard should be applied when the temperature is around 4 °C or below it during the crop season in Zone Ib.
- Variety RSG 945 of chickpea can be recommended for late sown condition to mitigate terminal heat stress in chick pea in zone 1b.
- Application of K_2O @ 20 kg/ha and sulphur @ 40 kg/ha along with general recommended dose of fertilizers are helpful in mitigating heat stress in gram crop in zone 1b.
- For management of bacterial leaf blight (BLB) of clusterbean, application of *Streptocycline* @ 1 g/kg seed as seed soaking & two foliar spray of copper oxychloride @ 0.2% (mixed ½ hour before sowing) in zone 1c.
- Foliar spray with metalaxyl 8% +mancozeb 64% mixture (72 WP) reduced the white rust disease of mustard in Zone Ib.
- Post emergence application of isoproturon at 500g/ha +2-4 D at 250 g/ha or isoproturon at 500g/ha + metsulfuron methyl at 4 g/ha or isoproturon at 500g/ha + carfentrazone at 15 g/ha at 30-35 Days After Sowing(DAS) significantly controlled grassy as well as broad leaved weeds and increased the grain yield of barley in Zone Ib.

2014-15

- Application of nitrogen 90 kg /ha, half basal and rest at 45 days after sowing in dual purpose fodder variety GFB-1 of bajra for better production in zone 1c.
- Two sprays of sulfo-salicilic acid (254 ppm) in cluster bean at vegetative and flowering stage gave more production under stress conditions in Zone 1c.
- For sowing of sewan grass, apply seed @ 4-5 kg /ha having spacing of 100 X 50cm with a depth of 2-3 cm in zone 1c.
- Seed soaking of sewan grass with 100 ppm salicylic acid or 500 ppm thio urea for better germination and growth in zone 1c.
- Post-emergence application (15-20 DAS) of atrazine 0.4 kg a.i/ha found effective to control weeds in standing crop of pear millet in zone 1c.
- For the control of broad leaves weeds in cluster bean, spraying of imezathapyr 40 g/ha 20 DAS found effective. Spraying of imezathapyr + imezamox (40g/ha 20 DAS) found effective against both grassy and broad leaves weeds in zone 1b&1c.
- Seed treatment with *T.viride* @10 g/kg seed +furrow application of *T.viride @ 4 kg* enriched with FYM 250kg/ha (added 15 days prior to its application and kept in shade) + foliar application of neem seed kernel extract @ 5 per cent at 30 and 45 days after sowing found effective for management of collar rot and leaf spot diseases of groundnut and this recommendation was added in package of practices for zone-1b.
- Seed treatment with Carbendazim @ 2.0 g/kg seed + soil amendment with 2.5 kg *Trichoderma viride* in 100 kg FYM/ha (added 15 days prior to its application and kept in shade) at the time of sowing was found effective for management of root rot complex in clusterbean caused by *Fusarium* sp. and

Macrophomina-phaseolina and this recommendation was added in package of practices for zone-1b.

- To control termite in wheat, seed treatment with imidacloprid 600 FS @ 2.5g/kg seed followed by drenching with imidacloprid 17.8 SL @ 500ml/ha have been recommended in zone 1 b.
- For integrated disease management of alternaria blight and stem rot in mustard, seed treatment with carbendazim 50WP@ 2 g/kg followed by 2 foliar spray of carbendazim12% + mancozeb 63% mixture have been recommended in zone 1b.
- Sprinkler irrigation to oat at IW/CPE 1.1 (three irrigations) 25, 50 and 80 DAS was found optimum and recommended in zone 1 b.
- Drip irrigation schedule at 0.8 ETc (LT) for tomato was found optimum and recommended in zone 1 b.

2015-16

- To control the yellow rust disease in wheat foliar spray of Propiconazol (25 EC) or Tebuconazol (25.9 EC) @ 1 ml/litre of water is recommended on appearance of the disease. If needed second spray be given at an interval of 15 days.
- Foliar application of silicic acid (150 ppm) is recommended at flag leaf stage & milk stage in wheat for mitigation of heat stress.
- Spray of chelated zinc @ 3 gm/litre of water at vegetative & flag leaf stage to meet out the deficiency of zinc in wheat.
- For integrated disease management in mustard seed treatment with Metalexil (35 SD) @ 6 g/kg seed & first spray of Mencozeb (75 WP) @ 2 g/litre of water at 60 days & second spray after 15 days with Propiconazol (25 EC) @ 0.5 ml/litre of water has been recommended.
- On soil test basis under deficiency of zinc & iron, placement of 6 kg zinc sulphate / bigha in furrows at sowing and spray of 1% ferrous sulphate in standing crop three times at weekly interval has been recommended for sugarcane in addition to NPKS.
- Fertigation with 100 kg N, 40 kg P_2O_5& 40 kg K_2O/ha through water soluble fertilizers in 9 equal splits each at an interval of 15 days has been recommended for tomato.
- Fertigation with 80 kg N, 32 kg P_2O_5& 32 kg K_2O/ha through water soluble fertilizers in 12 equal splits each at an interval of 11 days has been recommended for bitter gourd.
- Bare root transplanting in kinnow may be done successfully in month of September, October & February with the treatment of 200 mg IBA + 1 g carbendanzim with wetted moss grass up to 48 hours. This technology significantly reduces cost of transportation.
- For yield target of 300 q/ha of radish crop in this zone (1c), 40 kg N + 58 kg P_2O_5 + 87 kg K_2O along with 25 tones/ha FYM is required. Full dose of phosphorus and half dose of Nitrogen and Potassium as basal and remaining dose of Nitrogen and Potassium should be applied at root forming stage.
- Standardization of production technology for round the year cultivation of Cucumber under Polyhouse

2016-17

- Pendamethalin extra @ 0.75kg a.i./ha as PPI+ one hoeing was found effective in controlling the weeds in *hirsutum* cotton.
- Growth regulators Ethrel @ 8.5 µmols at square initiation followed by MH @ 500 ppm at 95 DAS significantly enhanced the productivity of american cotton
- Foliar spray of Maleic hydrazide (MH) (6 hydroxy-3-(2H) Pyrizihone) @ 500 ppm at 75 & 125 DAS or Cycocel (CCC) @ 100 ppm at 75 DAS and 125 DAS were found effective in increasing the seed cotton yield.
- First irrigation at vegetative stage (25-30 DAS) and second at grain development stage (60-65 DAS) was appropriate in clusterbean for optimum production.
- Seed soaking in Streptocycline 500 ppm (SS) thereafter foliar spray of Streptocycline 200 ppm + Copper Oxychloride (0.2%) at 15 days interval significantly managed bacterial leaf blight in cluster bean
- Application of 80 per cent RD of fertilizers (96 kg N, 64 kg P_2O_5& 48 kg K_2O/ha) was found optimum dose for *kharif* brinjal. This dose should be given in 12 equal splits each at an interval of 10 days
- Drip irrigation at 0.8 ETc in brinjal with mulch was found optimum. This treatment saved 34.09 per cent of irrigation water over surface irrigation and 15.68 per cent even over drip irrigation scheduled at 1.0 ETc without plastic mulch.

- Raised bed with plastic mulch gave significantly higher seed cotton yield as compared with rest of the treatments with or without plastic mulch. Irrigation with drip at 0.8 ETc was found optimum irrigation schedule. In case of canal closer or some other reasons if sowing is not possible in time then the crop may be raised in plastic bags and transplanted in field up to 30th May with drip irrigation without any yield loss.
- In organic approach treatments, 100% N through FYM recorded highest mean seed cotton yield followed by 50% N through FYM + 50% N through crop residue + gypsum @ 150 kg/ha.
- *Streptocycline* 500 ppm (seed soaking)+ *Streptocycline* 250 ppm + copper oxychloride (0.2%) first spray at disease appearance and second at 15 days interval is effective against management of bacterial leaf blight in cluster bean.
- In rainfed areas, sowing of clusterbean at 60 cm row spacing followed by earthing by hand plough or running wheel hoe at 25 and 35 DAS is beneficial for moisture conservation and sustaining yields.
- *T. harzianum* + *P. fluorescens* seed treatment (4 + 4 gm./kg seed) + soil application of *T. harzianum* + *P. fluorescens* (1.25 + 1.25 kg) in 50 kg FYM each/ha.) is effective for management of root rot of mothbean.
- Integrated nutrient management for pearl millet the application of 75% of RDF + PSB + *Azospirillum* culture (200-250 ml/ha) + 5 t FYM/ha gave significant higher grain, straw yield, net return and B:C ratio.
- For management of weeds in groundnut crop, 600 ml. imazithapyr + pendimethaline (2 + 30% pre mix company made) should be applied as pre emergence (moist soil and bright sunshine are primary condition for its effectivity) with 125 litre of water/bigha.
- Irrigation scheduling for NB Hybrid fodder cultivation (DWi = 60 mm) at 1.0 IW/CPE ratio recommended for arid western Rajasthan

2017-19

- For management of weeds in clusterbean, spray of Pendimethaline @ 0.75 kg a.i/ha as pre emergence followed by Imazethaper + Imazamox @ 40 g a.i./ha at 2-3 leaf stage (25-30 days after sowing) has been recommended.
- In sugarcane on soil test basis under deficiency of zinc & iron, placement of 6 kg zinc sulphate/bigha in furrows at sowing and spray of 1% ferrous sulphate solution in standing crop three times at weekly interval has been recommended.
- DRIS (Diagnosis and Recommendation Integrated System) of Orchard Advisory included in PoP in chart form. Chart can be utilized to access the status of orchard in terms of soil and leaf nutrients content that can be used to control optimum fruit productivity.
- Organic Kinnow production can be practiced for optimum production with the application of 75% Vermicompost (on N equivalent basis of RDF) + *Trichoderma harzianum* (30-40 ml/plant) + *Azadiractrum* 1% (3-4 ml/liter) spay + *Pseudomonas* (50 g/tree).
- For the control of sucking pest of cotton two new chemicals viz; Flonicamid 50 WG @ 150/ha (0.30 gm per liter of water) and Spiromesifen 22.9 SC @ 500 ml/ha has been recommended.
- In clusterbean, for the management & control of sucking pest (white fly &jassids) Thiamethoxam 25 WG @ 0.5 g/liter of water has been recommended.
- Planting Nappier bajra hybrid (NBH var. Co-4/Co-3) at 60 x 60 geometry in rows and perennial Lucerne (var. Krishana, RL-88 or any other) between two NBH row spaced 3.6 meter (ratio 1:6 A/A) in sequence, resulting significantly higher green fodder (862 q/ha) and dry fodder (233 q/ha) annually as compared to other fodder crop sequence. The aforesaid treatment also fetched the maximum net returns (Rs. 90334/ ha) and B:C ratio (3.61) in comparison to less than 2.0 in prevailing fodder cropping sequences, NBH fertilized @150:40:20 as N:P:K doses and irrigation management for Lucerne crop (intervals o 5-10 days at establishment and summer and 10-15 days during winter growth periods) fulfills the water requirement of Napier bajra hybrid as well.
- Irrigation of wheat at ETc 0.8 along with application of 120 kg N/ha was found suitable to get better yield and water productivity in hot arid region.
- To achieve targeted yield under IPNS for which fertilizer needs of cabbage was recommended after soil test values. For this following generated fertilizer prescription equations were computed as :

- Fertilizer Nitrogen (kg/ha) = 1.31 target yield -0.715 soil Nitrogen – 1.09 FYM/Compost
- Fertilizer Phosphorus (kg/ha) = 0.81 target yield - 1.99 soil phosphorus – 1.0 FYM/Compost
- Fertilizer Potash (kg/ha) = 1.42 target yield -0.56 soil potash – 1.09 FYM/Compost

  Here, target yield in q/ha, soil nutrient in kg/ha and available nutrients in organic matter in kg/ha
- Organic matter is used for increase the efficiency of nitrogen, phosphorus and potash fertilizer is recommended. Use of above generated fertilizer prescription equations, decrease the doses of fertilizer after incorporation of organic matter.
- Soil application of 10 kg/ha *Trichoderma harzianum / Psudomonas fluorescens* mix with 400 kg vermi compost in gram and mustard crop was found effective for the control of wilt and root rot disease of gram and mustard.
- Maps of Bilara and Pipar city tehsils of Jodhpur district were prepared on the basis of irrigation water quality and also study the effect of irrigation water on soil properties and suggested safe use of irrigation water.
- Seed treatment of wheat with Imidacloprid 17.8 SL @ 3 ml/kg seed is found effective for the management of termite
- Foliar application of iron at the rate of 0.50% $FeSO_4$+ 0.1% citric acid at 25-30 DAS gave significantly higher yields of pearl millet along with net return & B: C ratio.
- Late sowing of pearl millet at 25July ±5 days can result in better yields as compared to very late sowing on August 10±5 days
- Application of RDF + 5 t FYM + 0.5% foliar spray of NPK (19:19:19) at 20-25 days after sowing. In case FYM is not available then treatment 125% RDF gave significantly higher grain yield, net return and B:C ratio of pearl millet under late sown conditions
- **Fertilizer adjustment equations for moong bean**

Fertilizer nitrogen =14.195 target yield – 0.745 soil available nitrogen – 0.86 organic nitrogen

Fertilizer phosphorus = 11.91 target yield – 2.025 soil available phosphorus – 1.625 organic phosphorus

Fertilizer potassium = 17.785 target yield –0.51 soil available potassium – 1.14 organic potassium

Here, target yield in q/ha, soil available nutrients in Kg/ha, Organic nutrients in Kg/ha and fertilizer nutrients in Kg/ha.

- Seed soaking of cluster bean for 1 hour with *Streptocycline* @ 500 ppm + seed dressing with Carbendazim @ 2g/kg seed along with seed treatment with Fipronil 5% SC @ 4 ml/kg seed followed by two foliar sprays with *Streptocycline* @ 250 ppm + Copper oxychloride @ 0.2% and Thiamethoxam 25 WG @ 0.3g/litre followed by *Streptocycline* @ 250 ppm + Copper oxychloride @ 0.2% with Acetamiprid 20 SP @ 0.2 g/litre at 15 days interval was found most effective against diseases (Bacterial blight and dry root rot) and insect pests (aphid, jassid and whitefly) in cluster bean.
- Sowing of 20 kg lucerne mix with 30 kg oat seeds per ha obtained higher and nutritive green fodder
- for a longer period-Deep tillage and application of FYM @ 5 t/ha are suitable to get higher yield of wheat and Indian mustard in Bikaner region.
- For the late sown condition (15 to 30 Nov.) the NPJ-93 & NRCDR-2 varieties are better for higher yield under high temperature condition.
- Cultivation of onion under drip irrigation system increased 36% yield and save 32% irrigation water.
- Wheat can be cultivated successfully without reduction in yield from saline water (4.0 dS/m) through drip irrigation.
- 15 For integrated pest management application of 250 gm/ (Bioagents) *Verticilium leecuvai* followed by methyl-dematon 25 EC or Diamethoide 30 EC, 125 ml/ Begha at 7 days interval gave effective control of aphid in mustard crop at Sriganganagar.

2019-20

- Deep summer ploughing with mould board plough + Soil application of *Trichoderma* @ 4 kg/ ha enriched in 250 kg FYM/ha + Seed treatment with Tebuconazole 2DS@ 1.5 g/ kg of seed followed by Seed treatment with PGPR @625g/ ha of seed + Soil application of *Trichoderma* @ 4 kg/ ha enriched in 250 kg FYM/ha at 35 and 80 DAS for effective control of collar rot incidence in groundnut
- **Fertilizer adjustment equations developed for Cowpea.**

Fertilizer nitrogen =9.70 target yield – 0.66 soil available nitrogen – 1.05 Organic N

Fertilizer phosphorus = 2.44 target yield – 4.11 soil available phosphorus – 3.36 organic phosphorus

Fertilizer potassium = 12.66 target yield –0.53 soil available potassium – 1.63 organic potassium

Here, target yield in q/ha, soil available nutrients in kg/ha, organic nutrients in kg/ha and fertilizer nutrients in kg/ha.

- Two sprays of Profenophos 50 Ec @ 1.0 ml/liter water at an interval of 15 days can be done to manage the scale insect on datepalm.
- Seed treatments with a combination of *T. harzianum* + *P. fluorescens* seed treatment (4+4 g/kg seed) along with soil application of *T. harzianum* + *P. fluorescens* (1.25 +1.25 kg in 50 kg FYM for each/ha) for effective control of root rot incidence in Clusterbean.
- Application of straw mulch + 7.5 kg/ha Hydrogel gave maximum grain and straw yield and it was closely followed by straw mulch + 5.0 kg/ha hydrogel treatment.
- Application of green vegetative mulch gave significantly higher grain and straw yield of pearl millet, net returned and B:C ratio closely followed by straw mulch treatment.
- Drip irrigation at 0.8 ETc was found optimum irrigation schedule & 45 or 60 cm single row spacing found optimum row spacing for pigeon pea.
- Seed treatment of moth bean with imedacloprid 600 Fs @ 5ml/kg seed before sowing followed by foliar spray of thiamethoxam 25 WG @ 0.3 g/lit is found effective and economical against sucking pests.
- Sowing of Groundnut at a depth of 5-7 cm reduces the incidence of diseases and increases the yield
- In tube well irrigated area where water salinity is around 4 ds/m, groundnut could be cultivated successfully using drip system without any significant reduction in yield as compare to best available water. The total water requirement of groundnut crop is about 534 mm. Farmers are advised to schedule the irrigation at 0.8 PE using drip geometry as 60x30 cm which would result in 20% saving of water thereby reducing the salt accumulation in the soil profile
- In cotton the tube well irrigated area where water is moderately saline, cotton could be cultivated successfully using drip system with about 15% reduction in yield as compared to good quality water.
- Under irrigated conditions, the cluster bean isabgol and cluster bean - Indian mustard are more profitable and water productive than cluster bean - wheat cropping system. These systems gave 25-30% more profit along with saving of 35-47% of irrigation water. In
- Integration of Dhaman grass, clusterbean, cowpea and Tinda crop in equal proportion in integrated agricultural production system with planted ber and khejari at 10 meter spacing under rainfed and supplemental irrigation through harvested rain water from 1000 spm meter pucca catchment increased the productivity by 57-63 and 118-120 per cent, respectively over sole custerbean system

11. Researchable issues and Thrust area for future research

Research issues and way forward

1. Genetic improvement

The existing potential of the arid horticultural crops are being utilized by developing appropriate horticultural practices for their production. However, the need of the hour is to develop new cultivars / varieties by introduction of specific genes either by conventional breeding or by creating of variability using mutagens. In this pursuit, attempts will be made to identify the genes in the existing germplasm for development of resistant and high potential varieties as:

A. Salinity tolerance
B. Drought hardy species and rootstock
C. Frost tolerance
D. Selection of varieties for better bio efficiency
E. Selection for non conventional uses

2. Production for export

Since arid zone agro climate offers a great potential for production of high quality produce , there is great opportunity for production for export . There is a need to initiate research on priority basis on export – oriented production of crops . Standardization of grading and packing requirement for indigenous and foreign markets with reference to size , color and quality parameters should be done . Survey and identification of indigenous flora for export market will find place in the export market.

3. Value added products

There is great scope for developing high value products from the indigenous produce. In order to generate appropriate technologies for post harvest management, government interventions through policy directions are needed. Promoting establishment of processing units in production centers based on cluster village concept to process excess produce for export is required.

4. Cropping Systems

The high solar radiation resource in the arid areas provides an opportunity for its harvesting by optimization of cropping system models incorporating multi –layer receptor crops, etc.

5. Agro – based industries

The advanced agro – techniques development for crops suitable for arid ecosystem have resulted in increasing the production. This provides an opportunity to establish agro based industries in the region, which will avoid gluts of produce in the markets, generate employment and income to the inhabitants. Value chain development in major arid crops will be attempted.

6. Assessment of Climate change scenario

The change in climate parameters over past few years are yet to be assessed in terms of the impact it will bring in on production potential of the arid and semi arid crops. In view of this, opportunities exit to assess the impact of climate change and work out new crops models for recommendation in arid and semi arid regions.

7. Off season crop production

Arid and semi arid regions are bestowed with harsh environment, yet the protocols of protected cultivation provide ample opportunities to work out technologies for off season crop production in this region. by doing so, the cropping intensity and high value crop production can be initiated in arid and semi arid regions.

8. Crop diversification

Being unique environment for crop production, opportunities exist for developing multiple cropping models to harness the natural resources and provide economic returns to the farmers throughout the year.

9. Post harvest value addition

The region is bestowed with unique characteristics such as low humidity, ample sunshine, low rainfall family labor, vast land area, etc. which are important for processing of agricultural produce. Hence, this region provides an ample opportunity for establishment of agro based cottage industries which can produce value added products using strengths of this region.

THRUST AREAS FOR FUTURE RESEARCH

Short Term

- Agro-technology for organic farming in mandate crops including medicinal plants.
- Developmentof in-situ moisture conservation technology.
- Development of farming system modules for raising economic status of farmers.
- Enhancement of seed production of mandate crops with particular emphasis on pearl millet, groundnut, mothbean, clusterbean, chickpea, mustard and vegetables.

- Enhancement of medicinal plant cultivation. Management of weeds in standing crops
- New Sowing windows in resilience with climate Change
- Management of insect pests and diseases through eco-friendly techniques and the use of bio-pesticides/ herbal products.
- Development of bio-agents for various pest controls.
- Isolation of Pheromones for eco-friendly pest management.
- Suitable storage technology for reducing losses in different mandate crops.
- Establishment of model demonstration-cum-HRD.
- Development of package for organic farming in different crops.
- Development of suitable processing techniques for value addition in different crops.

Long Term

- Development of heat and moisture stress tolerance in wheat, barley, chickpea, pearl millet, groundnut and other *kharif* crops.
- Development of varieties in mandate crops resistant to various diseases and pests.
- Development of dual purpose (grain and fodder) varieties in pearl millet and barley.
- Development of high quality malt varieties in barley.
- Quality development in seed spices for export purpose.
- Molecular characterization of varieties.
- Characterization of drought tolerance mechanism in chickpea and pearl millet.
- Studies on quality characteristics in wheat.
- Developing climate resilient technologies against heat stress, frost and moisture stress.
- Development of Integrated Farming System Module for small and marginal farmers.
- Development of technology for use of Nano fertilizers and elements for production enhancement and reduction in costs of cultivation.
- Find out suitable chemicals and technology for locust control in western part of Rajasthan
- A major research thrust is warranted in areas of balance and site- specific nutrient supply and efficient water management strategies.
- Integrated Pest Management (IPM) needs greater emphasis.
- In horticulture, the research agenda needs to emphasize survey of indigenous biodiversity for resistance to various biotic and abiotic stresses for improvement in production, productivity, and quality of produce.

Annexure-1

List of All India Coordinated Research Projects during 2019-20

S.No.	Name of Project	*Location*	Funds Provisions	Year of Start
01.	AICRP on Cotton	ARS,Sriganganagar	75% ICAR and 25% State share basis	1976
02.	AICRP on Sugarcane	ARS,Sriganganagar	75% ICAR and 25% State share basis	1976
03.	AICRP on Oilseeds (R&M)	ARS,Sriganganagar	75% ICAR and 25% State share basis	1988
04.	AICRP on Pulses (chickpea)	ARS,Sriganganagar	75% ICAR and 25% State share basis	1988
05.	AICRP on Water Management	ARS,Sriganganagar	75% ICAR and 25% State share basis	1980
06.	AICRP on Tropical Fruits (Citrus)	ARS,Sriganganagar	75% ICAR and 25% State share basis	2009
07.	AICRP on Groundnut	ARS, Bikaner	75% ICAR and 25% State share basis	1988
08.	AICRP on Arid Legumes	ARS, Bikaner	75% ICAR and 25% State share basis	1982
09.	AICRP on Datepalm	ARS, Bikaner	75% ICAR and 25% State share basis	1978
10.	AICRP on Soil Salinity	ARS, Bikaner	75% ICAR and 25% State share basis	1980
11.	AICRP on Pearl millet	ARS, Bikaner	75% ICAR and 25% State share basis	1995
12.	AICRP on Forage	ARS, Bikaner	75% ICAR and 25% State share basis	1995
13.	AICRP on Soil Test Crop Response	ARS, Bikaner	75% ICAR and 25% State share basis	1995
14.	AICRP on Breeder Seed Production	ARS, Bikaner	75% ICAR and 25% State share basis	1979

Other projects funded by Government of India (GOI)

S. No.	Name of project	Finance Agency	Operating Center	Year of start
1.	Integrated Agro-met Advisory Services (GKMS)	GOI	ARS, Sriganganagar	1996
2.	Integrated Agro-met Advisory Services (GKMS)	GOI	ARS, Bikaner	1995
3.	FASAL Project (IMD)	GOI	ARS, Bikaner	2011
4.	Precision Farming Development Centre	NCPAH	ARS, Bikaner	1995

Annexure-II

List of Rashtriya Krishi Vikas Yojna Projects (As on 31.03.2020)

S.No.	Title of the project	Location
01.	ICT Enabled Agricultural Knowledge Management in North Western Plain Zone-I-b of Rajasthan	ARS, Sriganganagar
02.	Developing Agri-entrepreneurship among rural youth through mushroom cultivation	ARS, Sriganganagar
03.	"Evaluation of high yielding strains and post harvest management of Mushroom"	ARS, Sriganganagar
04.	Role of wool waste as a source of nutrient for crop production and soil improvement in Torripsamments	ARS, Bikaner
05.	Studies on post harvest technology and processing of date palm	ARS, Bikaner
06.	Mitigating Limitations of groundnut Production in Hyper Arid Region of Rajasthan	ARS, Bikaner
07.	Crop weather relationship, impact assessment and awareness for negative weather calamities in arid region (zone Ic)	ARS, Bikaner
08.	Broom Rape (*Orobanche ramose*) management in Mustard in light soil	ARS, Bikaner
09.	Training cum demonstration on pulses for quality seed production and seed storage technologyat farmer's fields	COA, Bikaner
10.	Developing package of water-saving agro-technologies for improving water use efficiency and productivity of Dill (*Anethum graveolens* L.) under Western Rajasthan	COA, Bikaner
11.	Standardization of Pressurized irrigation system in marigold for arid region of Rajasthan	COA, Bikaner
12.	Molecular Indexing of Drought Tolerance in Pearl Millet	DOR, SKRAU
13.	"Dissemination of post harvest technologies of arid foods for doubling the farmers income"	DOR, SKRAU
14.	Exploring Enterpreneurship Potentials for Farm Women in Animal Husbandry in Rajasthan	DEE, SKRAU
15.	Development of Economically Viable Indigenous Cow Based Farming System for Arid Regions	KVK, Bikaner
16.	"Documentation of farming system and evaluation of varieties and nutrient management in gram & wheat crops in khadin areas of Jaisalmer district of Rajasthan"	KVK, Jaisalmer
17.	Development and Nutrient Evaluation of value added products of Olive	C H.Sc., Bikaner
18.	Krishi IQ: Digital Dissemination of Agriculture Practices of Cluster bean and Gram in hyper arid partially irrigated western plain zone of Rajasthan	IABM, Bikaner
19.	Metal Composition Lab at Farm Implements & Machinery Testing and Training Centre	Central Workshop, Bikaner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