

**Major Achievements of Decade
(2011-2020)
at
ICAR-CAZRI RRS, Bikaner**



ICAR-Central Arid Zone Research Institute
(ISO 9001:2015)
Jodhpur 342 003 (India)



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उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)

Dr. Suresh Kumar Chaudhari

Deputy Director General (Natural Resource Management)

Foreword



The Indian hot arid landscape, where a major portion of drylands occurs, has witnessed some major changes during past few decades. A sharp growth in human and livestock population and the rapid developmental activities have exerted tremendous pressure on the slender natural resource base of the region, with the apprehension of sustainability being at stake. Highly undulating topography, scanty and erratic precipitation, high temperature, high wind speed and high potential evapotranspiration, extreme temperature peaks, and very poor soil conditions makes it a challenging task to develop and adopt different technological interventions in response to changing scenarios. Moreover there is a wider array of plant and animal diversity in hot arid regions having various potential uses which needs to be explored and harvested.

ICAR-Central Arid Zone Research Institute (CAZRI) has the distinction of being one of the first institutes in the world devoted to arid zone research and development for the past six decades with an objective to develop technologies for sustainable development of arid regions. CAZRI has five Regional Research Stations for addressing location-specific problems and developing suitable technologies.

Regional Research Station, Bikaner was established specifically to develop area specific farming systems, increasing water productivity of irrigated and rainfed production systems and management of range grasses and shrubs. In recent times, the station has undertaken intensive and multi-disciplinary research involving alternative farming systems, enhanced water productivity, developing suitable combinations of various agro-forestry components and managing abiotic stresses in field crops. The bulletin covers various aspects of research and extension activities carried out by this station during last decade. I hope this compilation will benefit all stakeholders sharing a stake in arid zone research and development. I would like to congratulate whole dedicated team of RRS, Bikaner for this meaningful and praise worthy efforts.

(S.K. Chaudhari)

Deputy Director General



Rajbir Singh

ADG (AAF&CC)

Message



Arid zones are characterized by their limited water supply, low and highly variable rainfall and recurrent droughts. Inhabitants of arid zone have learned to cope with their harsh climatic conditions through appropriate practices. The arid landscape in India is spread over 32 million hectare and accounts for approximately 12% of country's total geographical area. The area has witnessed some major changes in past few decades. With fragile natural resource base, achieving food security in arid lands has been a great challenge. ICAR-Central Arid Zone Research Institute (CAZRI) is engaged in research related to problems of arid region.

The Regional Research Station Bikaner has conducted intensive and multi-disciplinary research on diverse and alternative farming systems, crop water productivity, irrigation scheduling, developing suitable silvi-pastoral, horti-pasture and agri-horti-pasture systems. This document consists on major decadal achievements to all aspects of research and extension activities carried out by this station during 2011-2020. I hope this compilation will benefit all stakeholders sharing a stake in arid zone research and development. I congratulate to whole devoted scientific team of Bikaner Station for their effort.

(Rajbir Singh)

Assistant Director General (AAF & CC)



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डॉ. ओम प्रकाश यादव
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Dr. O.P. Yadav
Director

Message



In India, arid regions are spread in the north-western part of the country, mostly lying in western Rajasthan and Gujarat. The most important challenge face by the people of arid regions is to achieve sustainable agricultural production while conserving land, water and biodiversity. To deal with these issues, ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur is engaged in research to develop technologies for sustainable development of arid regions.

ICAR-CAZRI Regional Research Station, Bikaner situated in most arid part of western Rajasthan, is working on the development of area specific farming system, improving the crop and water productivity, stabilizing crop production in rainfed areas and management of range grasses and shrubs. The report consists of summary of achievements in research, development and outreach activities taken up by the station during 2011-2020. I congratulate the Head and his dedicated team for nice compilation of achievements and hope this may be very useful to the scientists and stakeholders working for the region.


(O.P. Yadav)
Director

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Historical Background

The Indian hot arid zone covers about 12% of the country's geographical area. The region is characterized by inhospitable climatic conditions and scarce natural resources. Rainfall varies from less than 100 mm to 500 mm, and is highly erratic and unpredictable. The region experiences extremes of temperature (-2 to 51°C), high insolation, high wind speed (35-40 km h⁻¹) and high evapotranspiration (1500-2000 mm year⁻¹). Nearly 41-85% of groundwater is saline. Crop yields under rainfed conditions are low and animal husbandry is the major source of survival of the people. These low-yielding systems are perpetually under stress due to ever rising human and livestock population, frequent drought and desertification. Hence, to address the problems of arid areas, Central Arid Zone Research Institute (CAZRI) was established in October 1959 by the Government of India which was later brought under the ICAR in April 1966. The institute is carrying out systematic research on survey and management of natural resources, sustainable farming systems, livestock production and management, and related rural livelihood issues for the last six decades to generate location specific technologies that can provide solution to the problems of arid zone agriculture and to control desertification.

The Regional Research Station of CAZRI was established at Bikaner in 1957 with the aim to act as a center for demonstration, experimental afforestation and soil conservation. The station was given the responsibility of sand dune stabilization in three areas viz., Sri Kolayatji, Udairamser and Shiv-Bari. Gradually, the center was strengthened by creating the necessary facilities for laboratory and field studies during 5th and 6th plan and it was designated as Regional Research Station which functioned as an integral part of Division of Plant Studies under CAZRI up to September 1986, which was then given

independent status of Regional Research Station of CAZRI, Jodhpur.

Thrust Areas

- Development of area specific farming systems;
- Increasing water productivity of irrigated and rainfed production systems; and
- Management of range grasses and shrubs

Location

The CAZRI Regional Research Station, Bikaner is located near the Lalgarh railway station about 5 km away from the Bikaner city. Bikaner region falls under hot arid eco-system and is characterized by low and erratic rainfall (average 230 mm yr⁻¹). May-June are the hottest months (mean maximum temperature 42.9°C and mean minimum temperature 29.6°C) and December-January are the coldest months (mean maximum temperature 23.7°C and mean minimum temperature 8.9°C). The soils of the region are light in texture having poor water retention capacity and are affected by the process of land degradation, particularly soil erosion, ultimately leading to desertification, which is one of the serious impediments in crop production.

Facilities

Research Farm

The station has ~141 ha farm area representing typical arid ecosystem. An area of ~20 ha has irrigation facilities with canal and tubewell water which is mainly used through sprinkler and drip irrigation systems. To utilize the canal water for irrigation, a water reservoir of 25 lakh liter capacity has been constructed at research farm. In addition, two tubewells were energized to irrigate the experimental crops. To support the field experiments, the farm is moderately equipped with farm machinery like tractor, seed-cum-fertilizer drill, power tiller, etc.



Library and ARIS cell

The station has a collection of over 1000 books on different subjects. The library subscribes to 15 national journals related to various disciplines of agriculture. An agricultural research information system having 13 computers with internet facilities is available.

Laboratories

Basic facilities for soil, plant and water analysis are available at the station. The labs are moderately equipped with the instruments such as kjeltech distillation and digestion assembly, spectrophotometer, flame photometer, water potential meter, leaf area meter, ceptometer, infrared

thermometer, TDR meter, autoclave, laminar flow, pH meter, conductivity meter, centrifuge, incubator, deep fridge etc.

Meeting hall

To conduct various meetings and farmers trainings, the research station has one meeting hall equipped with state of the art presentation facilities with a seating capacity of 40 persons.

Weather station

The station has an automatic as well as a manual weather station to record basic weather parameters like soil and air temperatures, relative humidity, wind speed, sun-shine hours, rainfall etc.

Research Achievements

Integrated Arid Land Farming System Research

Tree-crop interaction in sprinkler irrigated agri-horti-silvi systems

Sixteen years old plantations of citrus and shisham intercropped with mung bean, clusterbean, *Aloe vera* and cactus pear in sprinkler irrigation showed that the tree height of citrus and shisham was 9-28% and 12-23% higher, respectively in intercropping system over their sole cropping. Highest fruit yield (6.12 t ha^{-1}) of citrus was recorded with intercropping of *Aloe vera* and it was 43.5% higher over sole citrus. Mung bean and clusterbean with shisham gave 16.33 and 8.60% higher grain yield, respectively over citrus. The *Aloe vera* produced 6.93% higher green pad yield with shisham as



Aloe vera intercropped with citrus



Experiment visit by ADG (Agroforestry) and Director (CSSRI, Karnal)

compared to citrus. In rabi crops, the intercropping of linseed with shisham yielded 37.8% higher yield over intercropping with citrus, but the yield of safflower was 55.2% higher with citrus. Highest land equivalent ratio (LER) was recorded with *Aloe vera* (2.09) and safflower (1.94) intercropping with citrus in sprinkler irrigation (Fig. 1a).

Tree-crop interaction in drip irrigated agri-horti systems

The study conducted in 16 years old drip irrigated citrus, bael and gonda intercropped with rainfed crops viz., *Lasiurus indicus*, moth bean, clusterbean and *Aloe vera* showed that plant height, collar diameter and canopy of citrus was highest with intercropped of *Aloe vera* whereas the plant height of bael and gonda was highest with intercropping of moth bean. The *L. indicus*, *Aloe vera* and clusterbean intercropping with citrus produced 51.6 & 17.2%, 16.4 & 17.5% and 3.6 & 25% higher yield over bael and gonda, respectively. Among all the systems, the highest LER (1.67) was recorded with bael + clusterbean intercropping and the lowest with bael + *L. indicus* system in drip irrigated fruit plants with rainfed cropping (Fig. 1b).



L. indicus intercropped with citrus

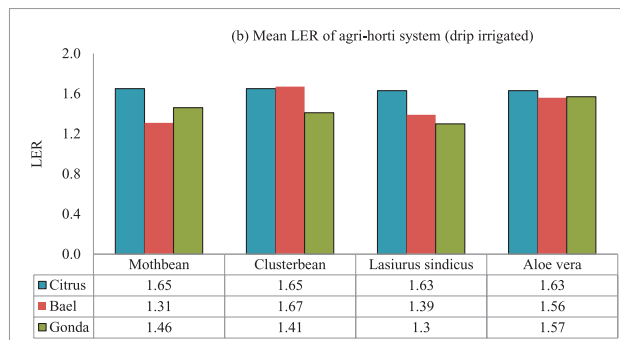
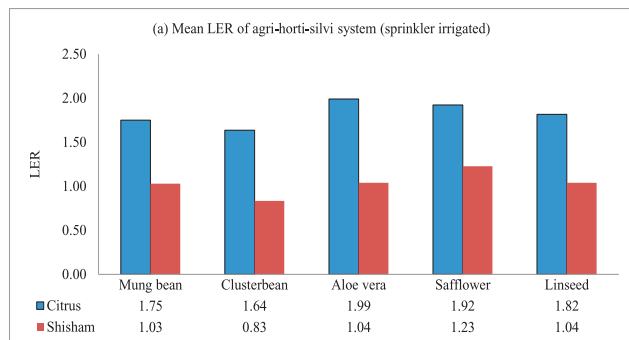


Fig. 1 Mean LER of agri-horti-silvi systems in (a) sprinkler (b) drip irrigation

Vector analysis in agri-horti-silvi systems

When mung bean was intercropped with shisham, an increase in biomass and uptake of NPK and decrease in concentration of NPK in mung bean was observed when compared with the sole mung bean (Fig. 2). This indicated antagonism and competition for nutrients in intercropping systems compared to sole cropping. When intercropped with shisham and citrus, safflower increased biomass and uptake of NPK. The vector represents a typical growth dilution response, indicating improved growing conditions due to intercropping.

Effect of tree-crop interaction on soil properties

In sprinkler irrigated agri-horti systems, the soil pH and EC was higher with intercropping of

clusterbean in citrus and lower in shisham. The soil organic carbon (SOC) was higher with mung bean and *Aloe vera* intercropping with citrus as compared to shisham. In drip irrigation, the soil pH and EC were higher in moth bean intercropped with gonda. Intercropping of *Lasiurus sindicus* with all the trees lowered the soil EC and pH with maximum reduction in citrus + *L. sindicus* system. The SOC, available nitrogen, available P and available K was higher under drip irrigation with perennial intercrop components in the system. Microbial activities were observed to be higher in *Aloe vera* strips and also in between trees and grass strips. In agri-horti system, higher dehydrogenase activity in soil was observed in intercropping of *Aloe vera* both in drip as well as in sprinkler irrigated systems.

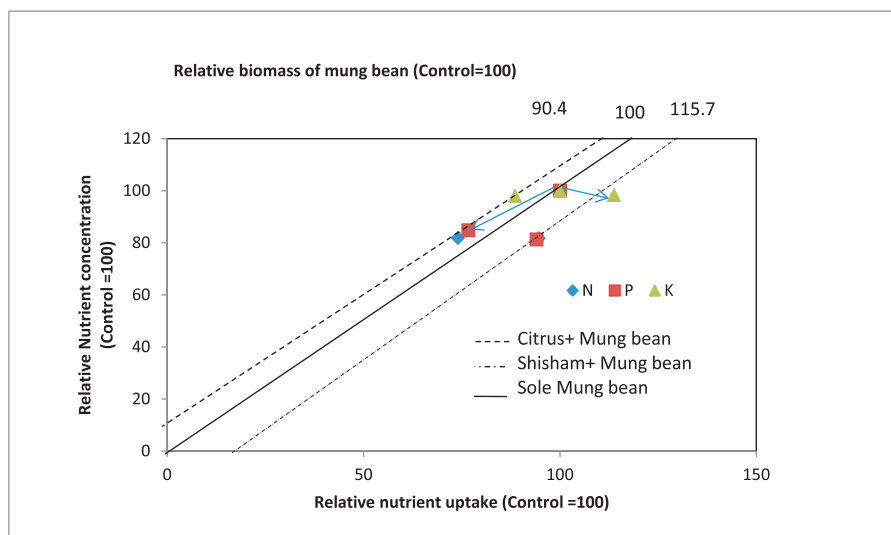


Fig. 2 Vector analysis on mung bean intercropping with trees

Clusterbean based cropping systems

Three clusterbean based cropping systems [clusterbean-wheat (CB-W), clusterbean-Indian mustard (CB-IM), and clusterbean-isabgol (CB-IG)] with two tillage [conventional (CT), and deep tillage (DT)] systems, and three FYM application rates (0, 5, and 10 t ha⁻¹) were evaluated for yield, returns and water productivity. The alternative cropping systems (CB-IM and CB-IG) had 28-37% lesser irrigation requirement, 7-31% higher economic returns, and 49-112% higher water productivity (WP) but had 29-48% lower yield than conventional CB-W cropping system. Using DT instead of CT increased yield (11.1 to 15.8%), economic return (12.1 to 24.8%), WP (10.8 to 15.7% physical irrigation WP, 11.8 to 24.8% economic irrigation WP) and nitrogen use-efficiency (NUE) (10.9 to 16.1%) of cropping systems in comparison to CT. Addition of FYM @ 5 t ha⁻¹ increased yield, economic return, physical irrigation WP, economic irrigation WP and NUE by 18.4 to 26.3%, 13.8 to 29.0%, 18.2 to 26.1%, 13.5 to 28.7% and 61.3 to 97.0%, respectively over no FYM application. The CB-IG with DT and FYM addition offered the best balance of yield, profit, saving of irrigation water and resource use efficiency.

Oleri-horti cropping system under drip irrigation and mulching

Two irrigation methods (drip and furrow) and three mulching materials (plastic mulch, i.e. black polyethylene-25 micron), hessian cloth (50% shade jute cloth), indigenous plant material i.e. Kheep (*Leptadenia pyrotechnica* @ 10 t ha⁻¹) and their interactions on yield of pea and okra in ber-based cropping system were evaluated. The mean yield of pea was 18% higher under drip than furrow irrigation. Mulching improved the pea yield from 40 to 72% over no mulch. Among different mulching materials, the plastic mulch showed the highest improvement in yield followed by hessian cloth and indigenous plant material mulch. Drip irrigation recorded 14 to 15% higher yield of okra compared to furrow irrigation.

Plastic mulch, hessian cloth and indigenous mulch resulted 45, 31 and 22% higher okra yield over no mulch.



Pea with drip and mulch

Squash melon (*Citrullus vulgaris* var. *fistulosus*) response to mulching, FYM and supplemental irrigation

Yield response of squash melon (*Citrullus vulgaris* var. *fistulosus*) to different mulching materials [no mulch, straw mulch (local vegetation i.e. senia (*Crotalaria burhia*) @ 10 t ha⁻¹ and plastic mulch (black polyethylene-25 micron) and four FYM doses (0, 20, 30 and 40 t ha⁻¹) showed significant improvement in yield up to 30 t FYM ha⁻¹, respectively. The yield of squash melon increased by 43, 84 and 87% with application of 20, 30 and 40 t FYM ha⁻¹. Plastic and straw mulch had 25 and 42% higher yield, respectively than no-mulch. Yield of squash melon increased by 21% with the supplemental irrigation of harvested rainwater in the event of long dry spells.



Squash melon under mulching and FYM

Integrated agricultural production systems with harvested rainwater

Integrated agricultural production systems viz., agri-horti (ber + clusterbean), agri-horti (ber + cowpea), horti-oleri (ber + squash melon), horti-pastoral (ber + *Cenchrus ciliaris*), traditional horticultural (ber+fallow), agri-silvi (khejri + clusterbean, khejri + cowpea), silvi-oleri (khejri + squash melon), silvi-pastoral (khejri + *Cenchrus ciliaris*), and traditional silvicultural (khejri + fallow) systems were evaluated under rainfed and life-saving irrigation through harvested rainwater. Among various production systems, the maximum biomass yield was obtained in agri-horti/silvi (ber/khejri + cowpea) followed by agri-horti/silvi (ber/khejri + clusterbean). Supplemental irrigation at the critical stage of the crops improved system productivity of integrated production systems. Maximum system productivity in terms of clusterbean equivalent yield was obtained with khejri based supplemental irrigation system (1143 kg ha^{-1}) followed by ber based system (1131 kg ha^{-1}) as compared to sole clusterbean (498 kg ha^{-1}). However, maximum economic returns were obtained in horti/silvi-oleri (ber/khejri + squash melon) production systems. In a comparison between khejri + squash melon and ber + squash melon, it was found that ber + squash melon system gave higher net return and B:C ratio (Rs. 55721 ha^{-1} and 2.94, respectively) as compared to khejri + squash melon system (Rs. 54034 ha^{-1} and 2.88, respectively).

Productivity of kinnow based oleri-horticultural systems

Productivity and economic performance of kinnow based oleri-horticultural systems in seven years old plantation of kinnow mandarin (*Citrus reticulata*) with five treatment combinations i.e., (i) kinnow + onion (*Allium cepa*) - squash melon (*Citrullus lanatus* var. *fistulosus*), (ii) kinnow + radish (*Raphanus sativus*) - cowpea (*Vigna unguiculata*), (iii) sole onion - squash melon, (iv) sole radish - cowpea and (v) sole kinnow were evaluated at farmer's field. The annual system productivity in terms of onion equivalent yield (OEY) increased by 2.81 and 7.58



Kinnow+onion oleri-horti system

times in kinnow + (radish-cowpea) respectively and kinnow + (onion-squash melon) respectively as compared to sole kinnow. Water productivity in terms of economic yield (WP_{EY}) was improved to 4.23 and 1.86 kg m^{-3} in intercropping system of kinnow + (onion-squash melon) and kinnow + (radish-cowpea), *Cenchrus ciliaris* as compared to sole kinnow (0.62 kg m^{-3}) (Fig. 3a). Similarly, the water productivity in terms of gross return (WP_{GR}) was improved to Rs. 22.7 and Rs. 9.5 m^{-3} in kinnow + (onion-squash melon) and kinnow + (radish-cowpea), respectively as compared to Rs. 4.98 m^{-3} in sole kinnow (Fig. 3b). The B:C ratio of kinnow + (onion-squash melon) and kinnow + (radish-cowpea) improved to 3.65 and 2.06 as compared to sole kinnow (B:C ratio of 1.50), respectively.

Pomegranate based agri-horti systems

Yield, water productivity and return of pomegranate-based intercropping system during the establishment phase of pomegranate were evaluated with five treatment combinations i.e. sole pomegranate, pomegranate + (fenugreek-clusterbean), pomegranate + (wheat-groundnut), sole fenugreek-clusterbean and sole wheat-groundnut at farmers' field. Intercrops showed positive effect on height, girth and canopy spread of pomegranate over sole plantation. In agri-horti systems, the productivity of fenugreek, wheat, clusterbean and groundnut were higher by 20.5, 15.1, 16.4 and 14.9%, respectively in grain and 18.0, 15.0, 31.6 and 12.4%, respectively in straw/stover, as compared to sole cropping. The

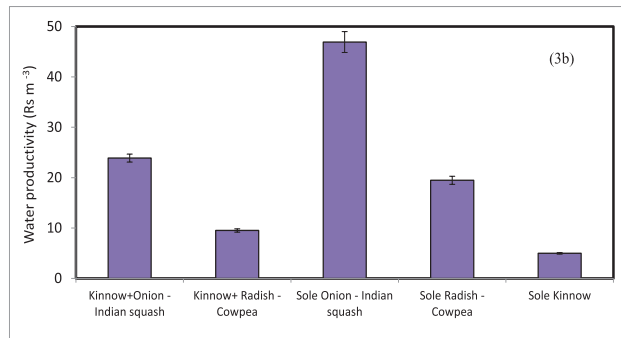
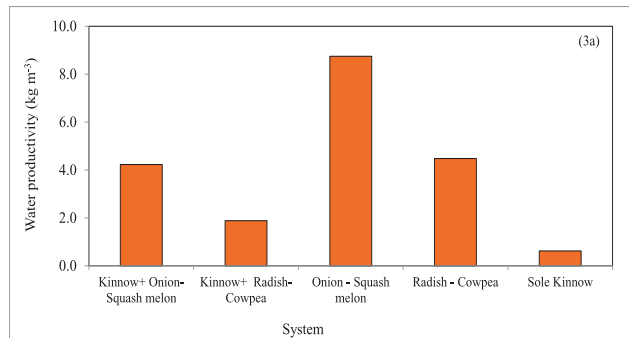


Fig. 3 Water productivity in terms of economic yield (3a), and gross return (3b) in different kinnow based oleri-horti and sole cropping systems

increase in productivity in agri-horti systems may compensate the area sacrificed by canopy coverage of trees up to some extent. Wheat-groundnut intercropped with pomegranate produced higher system productivity (5376 kg ha⁻¹) over fenugreek-clusterbean intercropped with pomegranate as well as sole fenugreek-clusterbean (Fig. 4). Water productivity of sole orchard can be improved to 0.21 and 0.39 kg m⁻³ in terms of economic yield (WP_{EY}), 0.64 and 0.99 kg m⁻³ in terms of biological yield (WP_{BY}) and Rs.108.8 and Rs. 151.1 ha⁻¹ mm⁻¹, respectively in monetary terms by incorporating fenugreek-

clusterbean and wheat-groundnut intercropping systems, respectively.

Carbon Sequestration

Silviculture systems (rainfed)

In 28 years old tree species, *Acacia tortilis* produced the largest biomass stocks of carbon (16.09 t ha⁻¹) followed by *Acacia senegal* (11.89 t ha⁻¹) and *Colophospermum mopane* (8.27 t ha⁻¹) under rainfed conditions. Soil organic carbon (SOC) density for a meter of soil profile was 2756, 2580 and 2284 g m⁻² under *A. tortilis*, *A. senegal* and *C. mopane*, respectively as compared to 877.5 g m⁻² under long

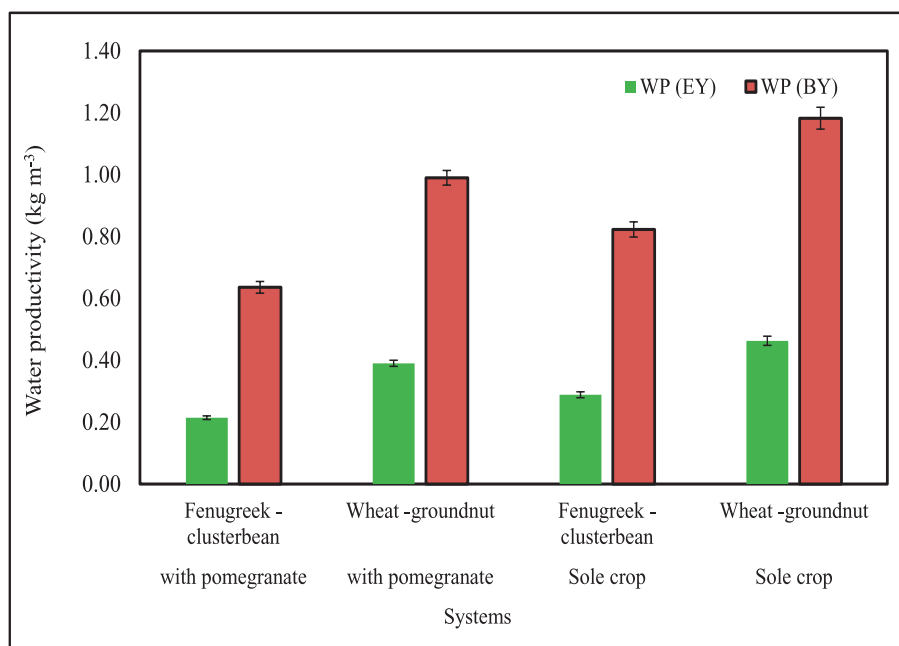


Fig. 4 Water productivity (WP) in terms of crop yield (EY = economic yield and BY = biological yield) of pomegranate-based agri-horti and sole cropping systems

fallow. The SOC density increased by 210, 190 and 157% in *A. tortilis*, *A. senegal* and *C. mopane*, respectively over long fallow. These tree species could sequester 18.68, 16.91 and 13.95 t C ha⁻¹ in soil system.

Agri-silvi systems (rainfed)

The rate of carbon sequestration through vegetative biomass in shrub-based agroforestry system was more in *Calligonum polygonoides* + clusterbean (0.36 t C ha⁻¹ yr⁻¹) and *C. polygonoides* + moth bean (0.35 t C ha⁻¹ yr⁻¹) as compared to *Haloxylon salicornicum* + clusterbean (0.19 t C ha⁻¹ yr⁻¹) and *H. salicornicum* + moth bean (0.21 t C ha⁻¹ yr⁻¹) systems. Approximately 1.73, 1.79, 1.61, 1.41 t ha⁻¹ soil organic carbon was sequestered in *C. polygonoides* + clusterbean, *C. polygonoides* + moth bean, *H. salicornicum* + clusterbean and *H. salicornicum* + moth bean systems, respectively. The *C. polygonoides* based cropping system can sequester 0.50 t C ha⁻¹ yr⁻¹ in comparison to *H. salicornicum* based systems, which can sequester 0.34 t C ha⁻¹ yr⁻¹.

Agri-pasture systems (rainfed)

In ten years old grass-based agri-pasture systems, the *Lasiurus indicus* + clusterbean sequestered maximum carbon (0.058 t C ha⁻¹ yr⁻¹) through vegetative biomass over rest of grass combinations. About 4.03, 3.47, 3.38 and 3.06 t ha⁻¹ soil organic carbon was sequestered in *L. sinducus* + clusterbean, *L. indicus* + moth bean, *Cenchrus ciliaris* + clusterbean and *C. ciliaris* + moth bean

systems, respectively as compared to their sole cropping. Among all the treatments, *L. indicus* + clusterbean sequestered maximum soil organic carbon (0.40 t C ha⁻¹ yr⁻¹). The *L. indicus* + clusterbean system sequester maximum carbon (0.42 t C ha⁻¹ yr⁻¹) as compared to other treatments. The *C. ciliaris* + moth bean system mitigate minimum carbon (0.38 t C ha⁻¹ yr⁻¹).

Agri-horti systems (irrigated)

Among the three fruit tree based systems, *Aegle marmelos* + clusterbean sequestered maximum vegetative biomass carbon (0.60 t C ha⁻¹ yr⁻¹) followed by *A. marmelos* + moth bean (0.52 t C ha⁻¹ yr⁻¹) and minimum in *Cordia myxa* + moth bean system (0.29 t C ha⁻¹ yr⁻¹). In all the systems, the size of soil C pools was greater than that of plant C pools. Of the total carbon pool, soil accounts about 74.6-80.9% in different systems. About 5.03, 4.99, 4.28, 4.02, 3.30, 3.0 t C ha⁻¹ soil organic carbons was sequestered in *Citrus aurantifolia* + clusterbean, *C. aurantifolia* + moth bean, *A. marmelos* + clusterbean, *A. marmelos* + moth bean, *C. myxa* + clusterbean and *C. myxa* + moth bean systems, respectively. Among different systems, *A. marmelos* + clusterbean can sequester maximum C (0.84 t C ha⁻¹ yr⁻¹) followed by *C. aurantifolia* + clusterbean (0.80 t C ha⁻¹ yr⁻¹). Among different treatments combinations *C. myxa* + moth bean sequester minimum C (0.47 t C ha⁻¹ yr⁻¹).



Agri-pasture system of *Cenchrus ciliaris* + moth bean



Agri-horti system of *A. marmelos* + clusterbean

Agri-silvi systems (irrigated)

In irrigated agri-silvi systems, *Melia dubia* + chickpea showed maximum carbon sequestration rate ($6.07 \text{ t C ha}^{-1} \text{ yr}^{-1}$) followed by *Ailanthus excelsa* + *Aloe vera* ($3.62 \text{ t C ha}^{-1} \text{ yr}^{-1}$) in the active growth stage.



Melia dubia + chickpea agri-silvi system

Carbon sequestration in shelterbelts

The 1-row shelterbelt of *Dalbergia sissoo* with different crops showed that the shelterbelt of *D. sissoo* + wheat accumulated maximum vegetative carbon ($4.6\text{-}5.8 \text{ t C ha}^{-1}$) as compared to the shelterbelts of *D. sissoo* + fenugreek ($1.13\text{-}2.05 \text{ t C ha}^{-1}$), *D. sissoo* + mustard ($1.03\text{-}1.38 \text{ t C ha}^{-1}$) and *D. sissoo* + chickpea (0.99 t C ha^{-1}). The 1-row shelterbelt of *D. sissoo* with wheat crop sequestered maximum vegetative carbon ($0.48\text{-}0.67 \text{ t ha}^{-1} \text{ yr}^{-1}$) as compared to this shelterbelt with mustard ($0.28\text{-}0.34 \text{ t ha}^{-1} \text{ yr}^{-1}$), fenugreek ($0.23 \text{ t ha}^{-1} \text{ yr}^{-1}$) and chickpea ($0.20 \text{ t ha}^{-1} \text{ yr}^{-1}$) crops.

Rooting patterns of mopane in agroforestry systems

Root architecture of 12-year old mopane (*Colophospermum mopane*) along a soil depth gradient of up to 2.5 m was studied with a focus to record the below ground development and biomass production. More than 70% roots were confined to the upper 60 cm soil layer. The root spread was 2.48 fold higher than the crown spread. The angles of primary roots were more than 66° . The total root biomass varied from $5.13\text{-}13.80 \text{ kg tree}^{-1}$ and average root: shoot ratio



Root system of *Colophospermum mopane*

was 0.20. It was concluded that the deep rooted system of *C. mopane* is suitable for dry and hot regions of the country. However, its lateral spread and accumulation of secondary roots in the upper 60 cm soil layer may lead to competition with agricultural crops and may not be suitable in agri-silvi systems. Hence, it may be grown for greening of wastelands or on sand-dunes in desert areas of Rajasthan.

Impact of shelterbelts on crop production

To study the prevalence of tree species as shelterbelts and their impact on crop production, about 78 shelterbelts were surveyed in Bikaner district. Shisham (*Dalbergia sissoo*) was the most common tree species (49% sites) for shelterbelt used by the farmers (Fig. 5) in irrigated conditions. Crop production was adversely affected by shelterbelts and the per cent yield reduction depends upon the distance from tree line and the tree species. At most sites, crop growth

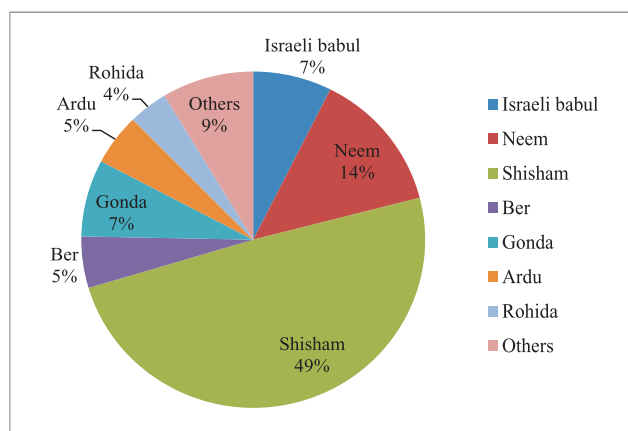


Fig. 5 Prevalence of trees in shelterbelts

was meager up to 1-2 m from tree line. The yield reduction was mainly due to shading, competition for moisture and damage by birds mainly at germination stage. The neem (*Azadirachta indica*) was noted to exert comparatively more negative effect on the crop, followed by ber (*Ziziphus mauritiana*), shisham, gonda (*Cordia myxa*) and ardu (*Ailanthus excelsa*).

Performance of agroforestry trees under different spacings

In *Ailanthus excelsa* and *Prosopis cineraria* based agroforestry system under different plant spacings viz., 4 m × 4 m, 6 m × 6 m and 8 m × 8 m, the maximum basal diameter (154.5 mm) and maximum height (407.1 cm) of *A. excelsa* was observed at 8 m ×

8 m spacing at 36 months after planting (MAP) which was at par with 6 m × 6 m. Minimum tree growth was observed at 4 m × 4 m spacing. In *P. cineraria*, no significant difference was observed in basal diameter and tree height under the three spacings (Fig. 6 and Fig. 7). Tree volume in *A. excelsa* was higher i.e. 0.015 and 0.014 m³ tree⁻¹ at wider spacings i.e., 8 m × 8 m, 6 m × 6 m, respectively. Maximum leaf fodder and fuelwood of *A. excelsa* was produced at 8 m × 8 m (Fig. 8 and 9). Clusterbean gave significantly higher yield (21%) when grown with *A. excelsa* at 6 m × 6 m spacing as compared to 8 m × 8 m spacing. When grown with *P. cineraria*, the clusterbean yield at 6 m × 6 m was significantly higher than that at 4 m × 4 m spacing.



Intercropping of clusterbean with *Ailanthus excelsa*



Field visit in *Ailanthus excelsa* based agro-forestry system

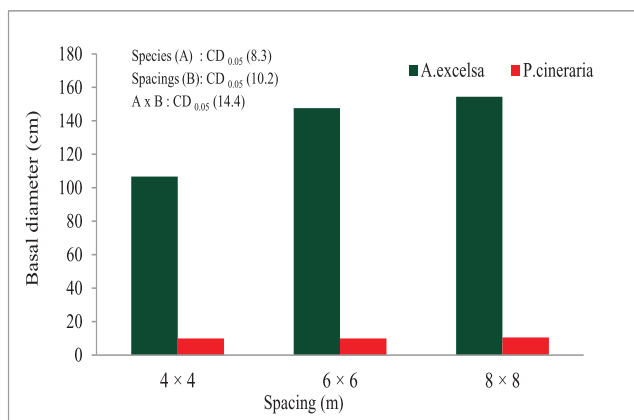


Fig. 6 Average basal diameter of trees

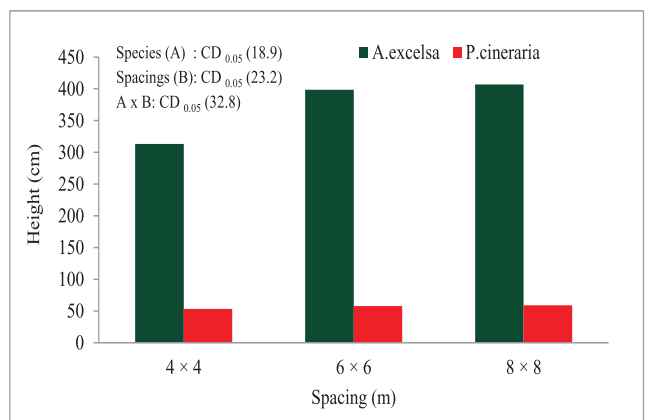


Fig. 7 Average height of trees

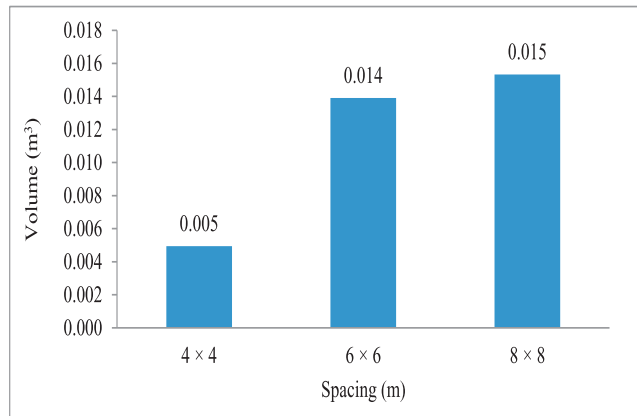


Fig. 8 Volume of *Ailanthus excelsa*

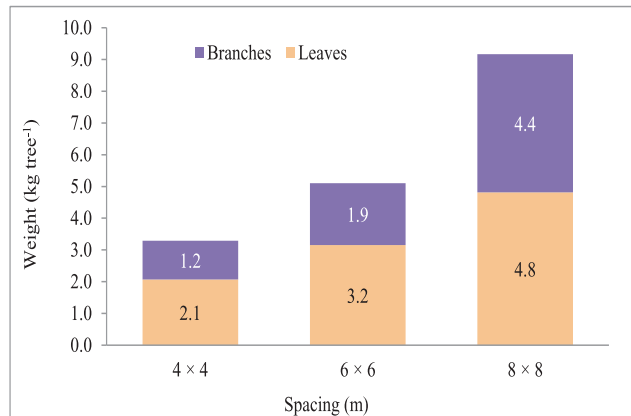


Fig. 9 Leaf fodder and fuelwood from *Ailanthus excelsa*

Evaluation of prickly pear cactus (*Opuntia ficus-indica*)

Growth and yield performance of seven accessions viz., 1269, 1270, 1271, CAZRI Botanical Garden, Mount Abu, 1458 and AHCP-2 of prickly pear cactus (*Opuntia ficus-indica*) was evaluated at the station with the aim to find out most suitable accessions for this region. The accession CAZRI Botanical Garden produced maximum number of cladodes per plant (14.4) followed by the accession 1458 (5.4), 1270 (5.0) and 1271 (4.2) in pots within a period of nine months. Highest green cladodes production (1260.7 g plant⁻¹) was recorded in the accession CAZRI Botanical Garden followed by accession 1270 > accession 1458 > accession 1271.

To bring the cactus pear in existing cropping system, the intercropping of clusterbean with cactus



Prickly pear intercropped with clusterbean

pear was assessed under rainfed condition. The accessions CAZRI Botanical Garden produced the highest biomass (19.3 t ha⁻¹) followed by 1458 (18.2 t ha⁻¹), 1269 (12.7 t ha⁻¹) and 1270 (9.2 t ha⁻¹) in intercropping system with rainfed crops. Accessions AHCP-2, 1271 and Mexico were inferior in terms of cladode yield under pot as well as field conditions. Effect of different accessions of cactus pear was not observed on crop growth and yield. However, the seed yield of different crops was observed to the tune of 324.0, 293.3, 284.0 and 143.7 kg ha⁻¹ in moth bean, mung bean, clusterbean and cowpea, respectively.

Dynamics of litter decomposition

Chemical composition of leaf litter

Total N concentration in the leaf litters varied from 0.99% in *Colophospermum mopane* followed by *Dalbergia sissoo* (1.51%), *Acacia senegal* (1.76%) and maximum of 2.18% in *Acacia tortilis*. The lignin content (34.1%) was maximum in *C. mopane* and minimum in *A. senegal* (12.6%). In fruit tree species, the total N concentration in the leaf litters varied from a minimum of 0.93% in *Cordia myxa* followed by *Aegle marmelos* (1.66%) and a maximum of 2.17% in *Citrus aurontifolia*. Maximum lignin (45.5%) and C:N ratio (53.1%) was observed in the *C. myxa*. Among different shrubs and grasses, the total N concentration in the leaf litters varied from 1.22% in *Haloxylon salicornicum* followed by *Cenchrus ciliaris* (1.62%), *Lasiurus indicus* (1.76%) and (2.52%) in *Calligonum*

polygonoides. The lignin content was maximum in the *H. salicornicum* (14.05%) and minimum in *C. ciliaris* (7.52%).

Chemical composition of tree roots

Total N concentration in the roots of fruit trees varied from 0.77% in *C. aurantifolia* followed by *A. marmelos* (0.98%) and 1.11% in *C. myxa*. Lignin was maximum in *C. aurantifolia* (14.4%) and minimum in *A. marmelos* (11.8%). The C:N ratio was also maximum in *C. aurantifolia* (59.4) followed by *A. marmelos* (44.5) and lowest in *C. myxa* (38.5). Among tree species, maximum C:N ratio was observed in *C. mopane* (85.7) followed by *D. sissoo* (72.07). Lignin content in tree roots was found in the order *D. sissoo* > *A. senegal* > *C. mopane* > *A. tortilis*.

Decomposition of leaf litter of trees

Decomposition under field conditions

Leaf litters of *C. aurantifolia* decomposed fastest and followed the order *C. aurantifolia* > *A. marmelos* > *C. myxa* in buried and surface placed litters. About 51% of *C. aurantifolia*, 34% of *A. marmelos* and 21% of *C. myxa* litter disappeared in surface and 59% of *C. aurantifolia*, 36% of *A. marmelos* and 24% of *C. myxa* disappeared in buried condition within 60 days. The *C. aurantifolia* released the nutrients rapidly as compared to *A. marmelos* and *C. myxa*. The N release in *C. aurantifolia*, *A. marmelos* and *C. myxa* during the cropping season (July to October) was 54.1, 47.6 and 11.4% of their total



Collection of leaf litters of trees in litter traps

nitrogen content in surface and 70.5, 54.7 and 23.1% in buried condition, respectively. The study suggested that leaf litters of *C. aurantifolia* and *A. marmelos* constitute comparatively good sources of readily available N and they could be suitable for meeting partial nitrogen requirement by intercrops.

Among the tree species, the wider C:N ratio (55:1), high lignin (34.1%) and lower N content (0.99%) of *C. mopane* as compared to *A. tortilis*, *A. senegal* and *D. sissoo* resulted in lower decomposition rate of *C. mopane* and less nutrient release.

Decomposition under different moisture conditions

Among the litters of fruit tree species, the mass loss followed the order *C. aurantifolia* > *A. marmelos* > *C. myxa* at both moisture levels (Field Capacity and 50% field capacity). The half-lives at field capacity was lowest (34 days) for *C. aurantifolia* and highest (96 days) for litter of *C. myxa*. The mass loss of leaf litters of tree species followed the order *A. tortilis* > *A. senegal* > *D. sissoo* > *C. mopane* at both moisture levels (field capacity and 50% field capacity). The half-life or time required for 50% decay at field capacity was lowest (54 days) for *A. tortilis* and highest (81 days) for litter of *C. mopane*. For 99% decay, litter of *A. tortilis*, *C. mopane*, *D. sissoo* and *A. senegal* would require 390, 588, 510 and 485 days at field capacity and 495, 746, 675 and 568 days at 50% field capacity, respectively. For 99% decay, litter of *A. tortilis*, *C. mopane*, *D. sissoo*, *A. senegal*, *C. myxa*, *A. marmelos* and *C. aurantifolia* would require 390, 588, 510, 485, 694, 328 and 246 days at field capacity and 495, 746, 675, 568, 847, 409 and 328 days at 50% field capacity, respectively (Table 1).

Decomposition of leaf litters of shrubs and grasses

Leaf litters of *Calligonum polygonoides* decomposed rapidly as compared to *Haloxylon salicornicum*. The relative rate of decomposition in surface placed litters of *C. polygonoides* in dry and rainy season was 2.35 and 10.69 mg g⁻¹ day⁻¹, respectively while in *H. salicornicum* it was 2.15 and

Table 1 Daily decay rate coefficient ($k_D \times 10^{-3}$) and time (days) required for 50% decomposition (t_{50}) and 99% decomposition (t_{99}) of leaf litter of various tree species

Species	Field capacity			50% field capacity		
	$k_D \times 10^{-3}$	t_{50}	t_{99}	$k_D \times 10^{-3}$	t_{50}	t_{99}
Trees						
<i>Acacia tortilis</i>	12.8	54.1	390.6	10.1	68.6	495.0
<i>Colophospermum mopane</i>	8.5	81.5	588.2	6.7	103.4	746.2
<i>Dalbergia sissoo</i>	9.8	70.7	510.2	7.4	93.6	675.6
<i>Acacia senegal</i>	10.3	67.2	485.4	8.8	78.7	568.1
Fruit trees						
<i>Cordia myxa</i>	7.2	96.2	694.4	5.9	117.4	847.4
<i>Aegle marmelos</i>	15.2	45.5	328.9	12.2	56.8	409.8
<i>Citrus aurantifolia</i>	20.3	34.1	246.3	15.2	45.5	328.9

9.42 mg g⁻¹ day⁻¹, respectively which was significantly lower than buried condition which was 5.24 and 16.78 mg g⁻¹ day⁻¹ for *C. polygonoides* and 4.26 and 13.12 mg g⁻¹ day⁻¹ for *H. salicornicum* in dry and rainy seasons, respectively.

Between the two grasses, decomposition was higher in *Cenchrus ciliaris* as compared to *Lasiurus indicus*. The relative rate of decomposition of surface placed litters of *L. indicus* in dry and rainy seasons was 2.83 and 11.69 mg g⁻¹ day⁻¹, respectively, whereas in case of *C. ciliaris*, it was 3.31 and 13.20 mg g⁻¹ day⁻¹, respectively which was significantly lower than that in buried condition which was 6.21 and 19.21 mg g⁻¹ day⁻¹ for *L. indicus* and 8.21 and 21.21 mg g⁻¹ day⁻¹ for *C. ciliaris* in dry and rainy seasons, respectively. The release of nitrogen was faster in grasses as compared to shrubs.

Decomposition of tree roots

Unlike leaf litters, the roots of *C. myxa* decomposed more rapidly followed by *A. marmelos*

and *C. aurantifolia*. Among the roots of fruit tree species, the half-lives were the lowest (0.42 years) for *C. myxa* and highest (0.76 years) for *C. aurantifolia*. Among the tree species, the half lives of roots was the lowest for *A. tortilis* (1.12 years) and the highest (1.73 years) for *D. sissoo*.

Effect of leaf litters on crop yield

Leaf litters of *C. aurantifolia*, *A. marmelos* and *D. sissoo* proved better in increasing the grain yield and total dry matter of clusterbean and moth bean. The residual effect of litter on the successive mustard and oat crops was also found significant for *C. aurantifolia*, *D. sissoo* and *A. marmelos* leaf litters as compared to other species. The increase in seed yield of mustard was 13.5, 15.5 and 14.6% with the leaf litters of *C. aurantifolia*, *D. sissoo* and *A. marmelos*, respectively. Similarly the increase in seed yield of oat was 16.1, 13.4 and 14.0% with the leaf litters of *C. aurantifolia*, *D. sissoo* and *A. marmelos*, respectively.

Land and Water Resources Management

Deficit-irrigation schedule to improve crop-water productivity

Groundnut (*Arachis hypogaea*)

Six deficit irrigation (DI) levels (DI_0 , DI_{10} , DI_{20} , DI_{30} , DI_{40} and DI_{50} , with irrigation amount of 100, 90, 80, 70, 60 and 50% of ET_c , respectively) and four N application rates (N_0 , N_{10} , N_{20} and N_{30} , with 0, 10, 20 and 30 kg N ha⁻¹, respectively) were evaluated for yield, quality, net return (NR) and water productivity (WP) of groundnut in hot arid region of western Rajasthan. Compared to DI_0 , DI_{20} increased WP by 17.1%, economic benefit by 2.6%, but reduced yield by 3.2%. The DI_{40} and DI_{50} significantly reduced the yield (40.2-62.1%), economic benefit (70.8-118.5%), WP (8.2-33.0%) and kernel oil content (KOC) (7.5-11.9%). Application of N augmented yield, KOC, NR and WP. Among all treatments, DI_0N_{30} had maximum yield and NR; $DI_{20}N_{30}$ had maximum WP and KOC. Overall $DI_{20}N_{30}$ was optimal in terms of best balancing of yield, NR, quality and WP of groundnut.

Wheat (*Triticum aestivum*)

Six deficit irrigation (DI) levels (DI_0 , DI_{10} , DI_{20} , DI_{30} , DI_{40} and DI_{50} , with irrigation amount of 100, 90, 80, 70, 60 and 50% of ET_c , respectively) and four N rates [0 (N_0), 40 (N_{40}), 80 (N_{80}), and 120 (N_{120}) kg ha⁻¹] rates were evaluated for yield, WP and nutrient use efficiency (NUE) of wheat. Moderate deficit irrigation (DI_{20}) had highest WP and caused 17% water saving with only 5% reduction in yield compared to full irrigation (ET_m). The N application improved yield and WP. The NUE declined with a reduction in water application and an increase in N rates. A significant increase in grain yield was recorded with N_{120} at DI_0 and DI_{10} , with N_{80} at DI_{20} and DI_{30} , and with N_{40} at DI_{40} and DI_{50} irrigation levels. The significant increase in

WP was recorded with N_{80} at DI_0 , DI_{10} , DI_{20} and DI_{30} , and with N_{40} at DI_{40} and DI_{50} irrigation levels. The results suggested that moderate deficit irrigation (DI_{20}) along with 120 kg N ha⁻¹ could ensure satisfactory grain yield and WP of wheat in arid regions. The study also indicated that the adoption of an appropriate deficit irrigation and N rate combination can be the effective means to save water, achieve higher yield, and improve WP and NUE of wheat in an arid environment.

Evaluation of Cropsyst Model for crop water productivity

CropSyst model was calibrated in flood irrigated (IGNP-I) and sprinkler irrigated (IGNP-II) condition and validated in the successive years for biomass, yield and water productivity of crops using the experimental data of crop parameters, soil profile and observed daily weather parameters of experimental site. The model was calibrated and validated successfully for various parameters of crops cultivated in both flood and sprinkler methods of irrigation.

Simulation (Calibration) of CropSyst model for crop yield and water productivity

In flood irrigated conditions (IGNP Stage-I), cotton produced higher above ground biomass (AGB) and economic yield (EY) than clusterbean during kharif season, and wheat produced higher above ground biomass and economic yield during rabi season. The economic yield of cropping systems ranged from 3741-6514 kg ha⁻¹. The economic yields were higher for cotton-wheat, intermediate for clusterbean-wheat and lower for cotton-mustard and clusterbean-mustard cropping system. The calibrated CropSyst model predicted the green area index (GAI),

yield and water balance of crops reasonably well. It predicted above ground biomass, green area index and economic yield better than N-uptake and water balance. Among the tested crops, the model is better suited for clusterbean and mustard as compared to other crops.



Scientists interaction at farmers field in IGNP-I

In sprinkler irrigated condition (IGNP Stage-II), highest seed yields were observed with groundnut-wheat cropping system followed by groundnut-mustard. Lowest crop yields were recorded with clusterbean-chickpea cropping system. Highest WP was recorded with clusterbean-chickpea cropping system (0.49 kg m^{-3}) followed by groundnut-wheat (0.47 kg m^{-3}) and groundnut-mustard (0.46 kg m^{-3}). Lowest WP (0.33 kg m^{-3}) was recorded with groundnut-cumin cropping system. The simulated GAI, AGB, EY and N-uptake matched closely with the observed values for groundnut and clusterbean during kharif season and wheat, mustard, chickpea, cumin and isabgol during rabi season reasonably well within the permissible range of relative error. The CropSyst model calibrated GAI, EY and AGB of groundnut, clusterbean, wheat, chickpea and psyllium accurately but N uptake moderately.

Validation of CropSyst model for yield and water productivity

The yield and WP of different crops were validated at four levels of nitrogen with three levels of irrigation as per the recommendations of different crops. In IGNP Stage-I (Flood irrigated condition),

with increase in 33% irrigation (400-600 mm) in cotton, the lint yield is increased by 8.6%. Water productivity of cotton was highest at N_{150} with I_{200} (higher by 10% over I_{600}). In clusterbean, with the increase in N from 0-60% the increase in yield was 34% at I_{300} and 42% at I_{200} . Highest WP was observed at $N_{60} + I_{200} \text{ mm}$ (0.33 kg m^{-3}). During rabi season in wheat, WP was highest at $N_{100} + I_{200}$ which was 50 and 20% higher over I_{600} and at I_{400} irrigation level, respectively. The mean Index of Agreement (IA) ranged from 0.96-0.98. In mustard, highest WP (0.81 kg m^{-3}) was recorded in $N_{80} + I_{100}$ treatment, which was 63% more over N_0 level. The root mean square error (RMSE) and IA varied from 7.0 to 31.3 and 0.97-0.99, respectively. The economic yield and total biological yield was highest in cotton-wheat system but higher systems WP was with clusterbean-mustard cropping system.

In IGNP Stage-II (sprinkler irrigated condition), the highest WP in clusterbean was recorded in $N_{60} + I_{200}$ treatment, which was 16.6% higher than $N_{60} + I_{300}$ treatment. In groundnut, WP decreased with increase in irrigation and N levels. The highest WP (0.53 kg m^{-3}) was observed in $N_{40} + I_{250}$ treatment which was at par with $N_{60} + I_{250}$ treatment. During rabi season, the highest yield of wheat was recorded in $N_{150} + I_{600}$ treatment. The increase in N by 50% at I_{600} irrigation level increased the wheat yield by 16.5%. Highest WP was recorded in $N_{150} + I_{200}$ treatment, which was 52% higher than that in $N_{150} + I_{600}$ irrigation level at same level of N. The mean relative root mean square error (RRMSE) was 14.7 with index of agreement of 0.97-0.99. In mustard, highest crop yield was recorded at N_{120} at I_{400} level but WP was maximum (0.80 kg m^{-3}) at $N_{80} + I_{100}$. The mean RRMSE was 12.0 with index of agreement of 0.99. The total system economic yield of groundnut-wheat rotation was the highest with 0.60 kg m^{-3} water productivity (Fig. 10), which was higher over clusterbean-mustard cropping system WP (0.34 kg m^{-3}).

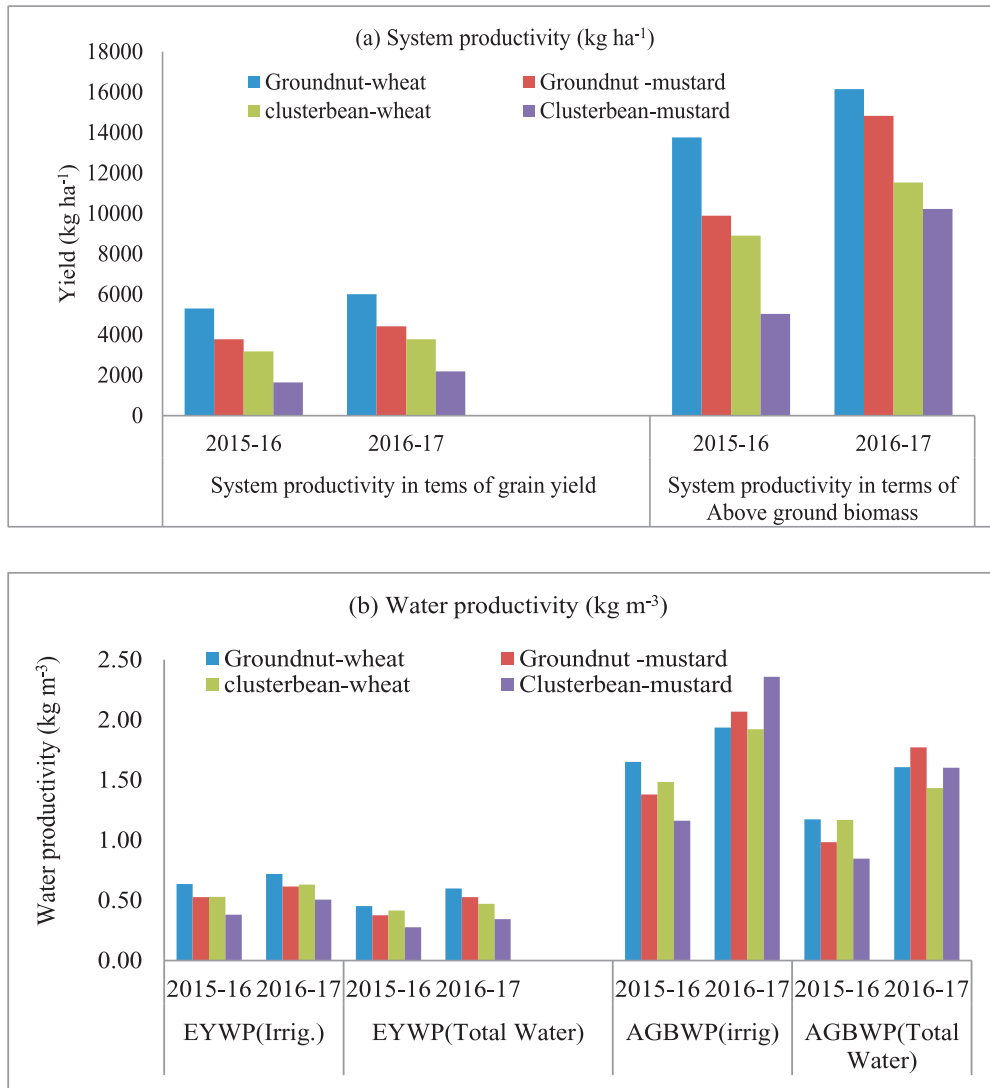


Fig. 10 System productivity (a) and water productivity (b) in sprinkler irrigated systems (IGNP Stage-II)

Stress Management

Sulphydryl compounds applications in arid legumes

Foliar application of sulphydryl compounds in clusterbean increased membrane stability index, chlorophyll content, antioxidant enzyme activities and net photosynthetic rate by 11-18, 18-30, 17-57, 25-47%, respectively, whereas the malondialdehyde (MDA) content was 10–19% lower compared to control. The application of thioglycolic acid (TGA) @ 400 ppm, thio urea (TU) @ 1000 ppm, TGA @ 300 ppm, TU @ 750 ppm, TU @ 500 ppm and TGA @ 200 ppm produced 212, 202, 190, 188, 154 and 142 kg ha⁻¹ (14 to 22%) higher seed yields, respectively over untreated plants.



Clusterbean with spray of TGA @ 400 ppm

In moth bean, foliar application of sulphydryl compounds increased membrane stability index, total chlorophyll content, antioxidant enzyme activities, and net photosynthetic rate by 10-14, 17-25, 16-74, 14-37%, respectively; whereas the malondialdehyde (MDA) content was 12-21% lower than that in control. Averaged across the years, application of sulphydryl compounds gave 13 to 20% higher seed yields than that in control. Thus foliar application of TU @ 1000 ppm or TGA @ 400 ppm could be used as a potential bioregulator for improving yield of clusterbean and moth bean under water stress condition.



Moth bean with spray of TGA @ 400 ppm

Salicylic acid (SA) compounds application

Field experiment was conducted to assess efficacy of salicylic acid (SA) and its derivatives [thiosalicylic acid (TSA) and 5-ulfo-salicylic acid (SSA)] each with three concentrations i.e. (0.5, 1.0 and 1.5 mM), along with water spray as control on membrane stability, antioxidant defence mechanism and yield of clusterbean under water stress condition in hot arid region. The SA and its derivatives had significant influence on growth and yield attributes of clusterbean with 12-26% higher net assimilation rate (NAR). The foliar application of SA and its derivatives had 13-20, 10-22, 9-14, 14-52% higher membrane stability index, chlorophyll content, carotenoid content, and activities of anti-oxidant enzymes compared to control, respectively. Exogenous application of SA and its derivatives brought 9-19% improvement in seed yield being the highest with 1.0 mM SSA followed by 1.0 mM SA and 1.0 mM TSA. These results suggest that foliar application of SA and its derivatives had potential to diminish the negative effects of water deficit on clusterbean. These compounds could be used as a potential bioregulator for improving yield of clusterbean under water stress condition.

Performance of mustard cultivars under high temperature stress

Five mustard (*Brassica juncea*) cultivars (Varuna, NRCDR-2, NPJ-93, RGN-48 and RGN-229) were evaluated for physio-biochemical and yield parameters under three planting dates [normal (30 October), late (15 November) and very late (30 November)] and two temperature conditions (ambient condition and high temperature stress). High temperature stress was given by polythene sheet at the time of pod initiation stage. Mustard cultivars varied significantly in terms of membrane stability index (MSI), guaiacol peroxidase (GPOX), test weight and seed yield. Averaged across temperature conditions and planting dates, the NPJ-93 had the highest GPOX activity, test weight and seed yield. The MSI was the highest in NRCDR-2 cultivar.

Effect of temperature stress on physio-biochemical attributes and seed yield

Thermal stress versus cultivar interaction was found significant for MSI, GPOX, test weight and seed yield. Under elevated temperature stress, the reduction in MSI, test weight and seed yield was recorded by 10-23%, 9-13% and 16-30%, respectively over ambient temperature (Fig. 11 and 12). Under elevated temperature, the decline in MSI, test weight and seed yield was resulted as the maximum with RGN-229, RGN-48, Varuna and as the minimum with NPJ-93 and NRCDR-2. It may be concluded that under late and very late (15 November to 30 November) conditions, NPJ-93 and NRCDR-2 cultivars are suitable for terminal heat stress in Bikaner.



Experiment visit by Director, ICAR-CAZRI, Jodhpur



Thermal stress imposed through polythene sheets

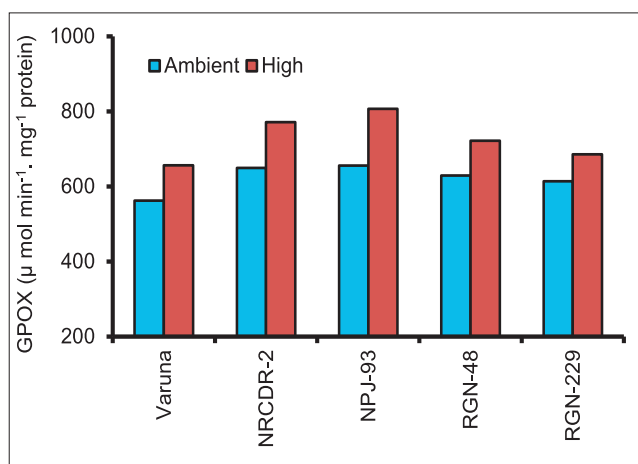


Fig. 11 Effect of temperature stress on physio-biochemical attribute of mustard cultivars

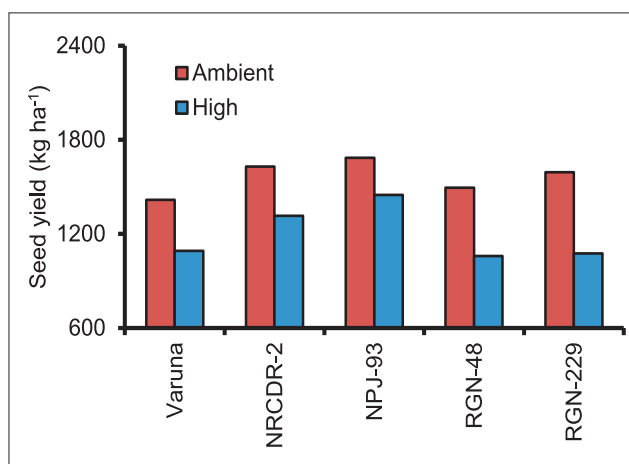


Fig. 12 Effect of high temperature stress on seed yield of mustard cultivars

Socio-economic Evaluation

People's participation in management of common property resources (CPRs)

Socio-economic status of farmers

The majority (73.33%) of farmers were having low, followed by moderate (20.0%) and high (6.67%) level of socio-economic status in selected villages of Kolayat tehsil of Bikaner. Whereas, 51.67, 41.67 and 41.67% farmers were having moderate, low and high level of socio-economic status in Chhattargarh tehsil of Bikaner, respectively. In Bhaniyana tehsil of Jaisalmer, 58.3% farmers were having moderate, 23.3% low and 18.3% high level of socio-economic status. The pooled data revealed that 46.10, 43.32 and 10.55% farmers were having low, moderate and high level of socio-economic status in selected villages of Kolayat, Chhattargarh and Bhaniyana tehsils, respectively.

Attitude of farmers

The majority of farmers (70.0%) were having favourable, 16.67% more favourable and 13.33% less

favourable attitude towards common property resources (CPRs) in selected villages of Kolayat tehsil. In Chhattargarh tehsil, 53.33, 33.33 and 13.33% farmers were having more favourable, less favourable and favourable attitude towards CPRs, respectively. In Bhaniyana tehsil, 75.0, 21.7 and 3.3% of farmers were having more favourable, favourable and less favourable attitude towards CPRs, respectively. The pooled data revealed that 48.33, 35.01 and 16.65% farmers were having more favourable, favourable and less favourable attitude towards CPRs in selected villages of Kolayat, Chhattargarh and Bhaniyana tehsils in Bikaner district, respectively.

People's participation

The study showed that maximum 61.78% participation was exhibited by farmers in development stage of CPRs, followed by 56.61% participation in maintenance stage of CPRs and 54.17% participation in planning stage of CPRs in villages of Kolayat tehsil. The overall 57.52% participation was exhibited by local people in management of CPRs. Maximum



Scientist interacting with farmers about CPR management

52.89% participation was exhibited in development stage, followed by 52.5% in maintenance stage and 46.5% in planning stage of CPRs in villages of Chhattargarh tehsil. The overall 50.59% participation was exhibited by local people in management of CPRs in villages of Chhattargarh tehsil. Maximum 74.39% participation was exhibited in development activities followed by 65.67% in planning stage and 64.44% in maintenance stage of CPRs in villages of Bhaniyana tehsil. The overall 68.17% participation was exhibited by local people in management of CPRs in villages of Bhaniyana tehsil.

Maximum 63.02% participation was exhibited by respondents in development stage,

followed by 57.85% in maintenance stage and 55.45% in planning stage of CPRs. According to PPI index value, the overall extent of people's participation in sustainable management of CPRs was 58.76% in the villages of Kolayat, Chhattargarh and Bhaniyana tehsils of western Rajasthan.

Benefits derived from CPRs

Availability of average pond water was 9.3 months in all 3 tehsils. On an average, 7 animals household⁻¹ day⁻¹ had access to grazing and drinking water in CPRs. The cropping intensity in nearby farms increased by 30.3%. An average of 32.2 kg food material household⁻¹ year⁻¹ was collected from CPRs.

Technologies Included in State Package of Practice

The following technologies developed by the station were presented in the ZREAC meeting and included in POP of Rajasthan State Agriculture Department.

Deficit Irrigation schedule for higher crop and water productivity in wheat

Deficit irrigation schedule was developed for improving crop water productivity in wheat. Irrigation of wheat at 0.8 ET_c along with application of 120 kg N ha⁻¹ is suitable to get better yield and water productivity in Bikaner region. About 20% irrigation water can be saved through this technology without any significant effect on wheat yield.

Irrigation management in groundnut

Sprinkler irrigation at 0.8 ET_c is suitable for getting better yield and water productivity of groundnut in Bikaner region.

Tillage management in wheat and Indian mustard

Deep tillage and application of FYM @ 5 t ha⁻¹ are suitable to get higher yield of wheat and Indian mustard in Bikaner region.

Cropping systems for water saving in hot arid region

Over exploitation of groundwater for irrigation has led to many ecological and environmental problems and is posing serious threat to sustainable crop production in north-western hot arid region of India. Clusterbean-wheat is an important cropping system in groundwater-irrigated regions of NW hot arid India. Replacing high water requiring crops with crops having low water requirement is an effective option to save the irrigation water, and

thus, to reduce the pressure on groundwater resource. Clusterbean-isabgol cropping system saved 35-47% irrigation water and gave 25 to 30% more profit as compared to clusterbean-mustard and clusterbean-wheat cropping systems.

Mustard cultivars for terminal heat stress

Extreme heat stress during the crop reproductive period can be critical for crop productivity. Heat stress reduces mustard growth by upsetting various physio- biochemical processes and the developmental stage. Identification of suitable mustard cultivars tolerant to terminal heat stress is required for the region to sustain the crop productivity and increase the income of farmers. Experiment conducted to evaluate the effect of temperature stress on physio-biochemical attributes and yield of different cultivars of mustard under different planting dates i.e. normal (30 October), late (15 November), and very late (30 November) and two temperature conditions (ambient condition and high temperature stress) in mustard proved that NPJ-93 and NRC DR-2 cultivars were having better thermo-tolerance and suitable to grow under late and very late (15 November to 30 November) conditions with minimum yield reduction as compared to ambient temperature.

Water harvesting based integrated agricultural production system

Water harvesting based integrated agricultural production systems (IAPS) comprising buffel grass, squash melon, cowpea and clusterbean with *Ziziphus mauritiana* (ber) and *Prosopis cineraria* (khejri) were evaluated to enhance the productivity and profitability of arid region. Harvested rainwater was used to provide supplemental irrigation through drip system to

the squash melon at the most crucial stages of water stress to ensure the better production and generate better remuneration. The system with buffel grass proved its superiority in exceptionally low rainfall year. But in normal rainfall years, squash melon provided the additional income. Integration of buffel grass, squash melon, cowpea and clusterbean in equal proportion with planted ber and khejri at 10 m spacing

under rainfed and supplemental irrigation through harvested rainwater from 0.1 ha area increased the productivity by 57-63 and 118-120%, respectively over sole clusterbean system. The net return was increased from Rs. 18200 in sole clusterbean to 29000 in rained IAPS and Rs. 39700 in supplemental irrigation IAPS systems.

Outreach

Farmers' trainings

Thirty six farmers training programs were organized on improved technologies of crops, vegetables, fruits and natural resource conservation and management which were sponsored by State Agriculture Department, PD (ATMA) and Scheduled Caste Sub Plan (SCSP) program. About 940 male farmers, 140 female farmers and 40 krishi mitras got benefitted by these training programs. The main objective of these trainings was to make the farmers learn and adopt improved technologies of crop production and increase their income.



Farmers-Scientists interface meetings

Fourteen farmers-scientists interface meetings on innovative agricultural technologies for improving crop yield, fruit production, vegetable



production and resource conservation were organized which were sponsored by State Agriculture Department, PD (ATMA), network project, institute fund and SCSP program. About 450 farmers including krishi mitra were benefitted through these interface meetings. The main objective of these meetings was to discuss the problems of the farmers during crop cultivation and suggest the innovative techniques and solutions.

Kisan Diwas

To showcase the improved production technologies at the station a Kisan Diwas was organized on October 09, 2013. More than 110 farmers from various villages nearby Bikaner participated and benefitted through visits and deliberations on various aspects of production technologies for improving the crop yield, water saving and managing soil health.



Farm School

Three farm schools on improved cultivation practices for kharif crops were organized in 2016 in three different villages in Bikaner. In each farm schools, 25 farmers participated to learn the improved technologies of kharif crops. Both theoretical and practical aspects on scientific cultivation of moth

bean, mung bean and clusterbean were discussed in detail through different lectures delivered by subject matter specialists and field demonstrations on various agricultural operations such as seed treatment, fertilizer doses and method of application, weed management, pest management etc.



Demonstrations

A total of 111 demonstrations sponsored by State Agriculture Department were carried out under "Mera Gaon Mera Gourav" program to showcase the performance of high yielding varieties of moth bean, mung bean and cowpea in rainfed and irrigated areas



of Bikaner. About 111 beneficiaries from 9 villages were benefitted by these demonstrations. A significant improvement in yield of moth bean and mung bean at farmers' fields was observed due to the cultivation of improved varieties and scientific management practices.

Mega Field Day

To showcase the improved production technologies at the station, a Mega Field Day was organized on February 27, 2020 on the theme "Innovations in arid agriculture to increase income of farmers". Total 158 farmers and farm women participated from nine villages of Bikaner district. The farmers enriched their knowledge on production technologies for improving the crop yield, water saving and managing soil health through various demonstrations by subject matter specialists and field visits of crop cafeteria and experimental area.



Farmer-Scientist Sangosthi

Two days Farmer-Scientist Sangosthi on "अनार उत्पादन प्रौद्योगिकी एवं उत्पादन में आ रही समस्याएँ" was conducted from June 25-26, 2018 with the financial support from ATMA DOA, Bikaner. Thirty



seven farmers having pomegranate orchards in Bikaner district participated in sangosthi. The program provided the farmers basic information and addressed their concerns on pomegranate cultivation in Bikaner through 8 lectures under three technical sessions on broad topics of improved cultivation methods, plant protection and post-harvest management. The compilation of lectures was published in the form of a technical bulletin.

Distribution of inputs under Scheduled Caste Sub Program (SCSP)

To ensure the supply of critical inputs to the farmers of SC community, the research station distributed various inputs such as crop seeds, fertilizers, improved breed rams, multi nutrient mixture, lemon seedlings and Napier grass cuttings to 404 SC farmers of 9 villages and organized demonstrations and FLDs in their fields under SCSP during the year 2019-20. Similarly, the agricultural inputs such as improved varieties of crop seeds, fertilizers, multi nutrient mixture, lemon & ber seedlings and Napier grass cuttings were distributed to 580 SC farmers of 11 villages to organize demonstrations and FLDs in their fields under SCSP program during the year 2020-21. A total of 1630 kg seeds, 785 bags fertilizer, 5 improved breed of ram, 400 seedlings of fruit plants, 666 kg multinutrient mixture and 5000 cuttings of Napier hybrid amounting Rs. 4,89,700 in 2019-20 and 2356 kg seeds, 1110 bags fertilizer, 600 seedlings, 1000 kg multinutrient mixture and 20000 cuttings of Napier hybrid amounting Rs. 7,55,756 were distributed to the SC farmers of Bikaner district.



Workshop on Gum production

One-day workshop on gum production in trees using CAZRI gum inducer was organized on March 26, 2019 under network project on Harvesting, Processing and Value Addition (HPVA) of Natural Resins and Gums. About 29 farmers having different gum producing trees in Bikaner district participated in the workshop. An introduction to the CAZRI Gum Inducer technique and its proper method of use and application was explained through lectures, followed by field demonstration of the technique where selection of trees, the injection process, precautions to be taken and how to collect the expressed gum was explained. The trees (*Acacia senegal*, *Acacia tortilis*, *Moringa oleifera*), which were already yielding gum after use of the gum inducer were also shown.



Farmers visit

About 51 groups of farmers and farm women from various parts of Rajasthan visited the station and acquired technical know how about arid zone farming. These visits were facilitated by various NGOs, PD (ATMA) and state agriculture department with the aim to demonstrate and adopt agricultural technologies suitable for arid region.



Crop cafeteria

Promising cultivars of clusterbean, moth bean, mung bean, sesame, pearl millet and groundnut during kharif season and wheat, Indian mustard, chickpea, cumin, fenugreek, isabgol and safflower in rabi season were demonstrated from 2019 in “Crop cafeteria” with recommended package of practices. The major objectives of the program were to showcase diversity and choice of cultivars available for different crops. About 500 farmers and stakeholders from line departments including state department of agriculture, IGNP, agricultural university visited the crop cafeteria.



Fodder production

Intensive fodder production using waste water has been undertaken from 2019. About 30 t of fodder of Napier hybrid, pearl millet and oat has been produced. In addition, 25000 cuttings of Napier hybrid were made available for distribution among the farmers of this region.



Seed production

A program for quality seed production (TFL seed) for clusterbean and cumin has been executed under mega seed project of the Institute. About 1.5 t of clusterbean and 0.5 t of cumin seed have been produced. New areas for *Cenchrus ciliaris* and *Lasiurus indicus* were developed for quality seed production.



Farmers Training Organized

Duration	Title of training	Number of farmers	Sponsoring agency
November 02-05, 2011	सब्जी उत्पादन की नवीनतम तकनीकें	25 women farmers	PD (ATMA), Jhunjhunu
November 02-05, 2011	शुष्क एवं अर्धशुष्क क्षेत्रों में फलोत्पादन	25 women farmers	PD (ATMA), Jhunjhunu
November 14-18, 2011	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 farmers	PD (ATMA), Jaisalmer
December 27-31, 2011	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 farmers	PD (ATMA), Jaisalmer
January 30-31, 2012	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	57 farmers	DHDS & AD (Ag), Jaisalmer
February 06-10, 2012	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 women farmers	PD (ATMA), Jaisalmer
February 13-17, 2012	कृषि उत्पादन वृद्धि हेतु संसाधन प्रबंधन	40 krishi mitra	PD (ATMA), Bikaner
February 21-25, 2012	फसलोत्पादन की नवीनतम तकनीकें	20 farmers	PD (ATMA), Jhunjhunu
February 14-15, 2013	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 women farmers	PD (ATMA), Jaisalmer
February 19-23, 2013	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 farmers	DHDS&AD (Ag.), Jaisalmer
March 18-19, 2013	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 farmers	PD (ATMA), Jaisalmer
March 19-23, 2013	सब्जियों एवं फलों के उत्पादन की उन्नत तकनीकें	30 farmers	DHDS & AD (Ag.), Jaisalmer
January 16-20, 2014	फलों, सब्जियों एवं मसालों की आधुनिक खेती	30 farmers	PD (ATMA), Jaisalmer
January 25-29, 2014	फलों, सब्जियों एवं मसालों की आधुनिक खेती	30 women farmers	PD (ATMA), Jaisalmer
December 30-31, 2014	फलों, सब्जियों एवं मसालों की आधुनिक खेती	50 farmers	NHM, Jaisalmer
January 05-09, 2015	शुष्क क्षेत्रों में बागवानी एवं मसाला फसलों की खेती	30 farmers	PD (ATMA), Jaisalmer
March 08-12, 2016	शुष्क क्षेत्रों में खरीफ कृषि उत्पादकता वृद्धि हेतु नवाचार	30 farmers	PD (ATMA), Jaisalmer
August 10-11, 2017	शुष्क क्षेत्रों में खरीफ कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां	33 farmers	PD (ATMA), Bikaner
September 25-26, 2017	शुष्क क्षेत्रों में खरीफ कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां	30 farmers	PD (ATMA), Bikaner
October 27-28, 2017	शुष्क क्षेत्रों में रबी फसल प्रबंधन एवं विविधीकरण की उन्नत तकनीकें	32 farmers	PD (ATMA), Bikaner
November 24-25, 2017	शुष्क क्षेत्रों में रबी फसल प्रबंधन एवं विविधीकरण की उन्नत तकनीकें	30 farmers	PD (ATMA), Bikaner
January 24-25, 2018	शुष्क क्षेत्रों में वर्षा जल संरक्षण एवं बारानी खेती	30 farmers	PD (ATMA), Bikaner
February 23-24, 2018	शुष्क क्षेत्रों में वर्षा जल संरक्षण एवं बारानी खेती	25 farmers	PD (ATMA), Bikaner
February 27-28, 2018	शुष्क क्षेत्रों में चारागाह विकास एवं पशु प्रबंधन	34 farmers	PD (ATMA), Bikaner
March 15-16, 2018	शुष्क क्षेत्रों में चारागाह विकास एवं पशु प्रबंधन	30 farmers	PD (ATMA), Bikaner
March 20-21, 2018	शुष्क क्षेत्रों में समन्वित कृषि प्रणाली एवं उद्यान प्रबंधन	28 farmers	PD (ATMA), Bikaner

Duration	Title of training	Number of farmers	Sponsoring agency
March 22-23, 2018	शुष्क क्षेत्रों में समन्वित कृषि प्रणाली एवं उद्यान प्रबंधन	31 farmers	PD (ATMA), Bikaner
December 17-21, 2018	शुष्क क्षेत्रों में कृषि उत्पादन बढ़ाने हेतु एकीकृत खेती प्रणाली प्रबंधन	30 farmers	PD (ATMA), Jaipur
March 07-08, 2019	शुष्क क्षेत्रों में कृषि उत्पादन बढ़ाने हेतु एकीकृत खेती प्रणाली प्रबंधन	30 farmers	PD (ATMA), Bikaner
March 13-14, 2019	शुष्क क्षेत्रों में कृषि उत्पादन बढ़ाने हेतु एकीकृत खेती प्रणाली प्रबंधन	30 farmers	PD (ATMA), Bikaner
March 18-19, 2019	शुष्क क्षेत्रों में कृषि उत्पादन बढ़ाने हेतु एकीकृत खेती प्रणाली प्रबंधन	30 farmers	PD (ATMA), Bikaner
July 27, 2019	शुष्क क्षेत्रों में खरीफ मौसम में कृषि उत्पादकता हेतु नवीनतम तकनीकियां	30 farmers	SCSP program ICAR-CAZRI, RRS, Bikaner
July 31, 2019	शुष्क क्षेत्रों में खरीफ मौसम में कृषि उत्पादकता हेतु नवीनतम तकनीकियां	30 farmers	SCSP program ICAR-CAZRI, RRS, Bikaner
August 01, 2019	शुष्क क्षेत्रों में खरीफ मौसम में कृषि उत्पादकता हेतु नवीनतम तकनीकियां	30 farmers	SCSP program ICAR-CAZRI, RRS, Bikaner
August 07, 2019	शुष्क क्षेत्रों में खरीफ मौसम में कृषि उत्पादकता हेतु नवीनतम तकनीकियां	30 farmers	SCSP program ICAR-CAZRI, RRS, Bikaner
August 08, 2019	शुष्क क्षेत्रों में खरीफ मौसम में कृषि उत्पादकता हेतु नवीनतम तकनीकियां	30 farmers	SCSP program ICAR-CAZRI, RRS, Bikaner

Farmer-Scientist Interaction

Date	Title and venue	Sponsoring agency
October 28-29, 2014	Farmer-Scientist Sangosthi on "रबी मौसम के दौरान समन्वित कृषि प्रणाली: समस्याएं एवं निवारण"	PD (ATMA), Bikaner
July 12-13, 2016	Farmer-Scientist Interaction Workshop	PD (ATMA), Bikaner
June 25-26, 2018	Farmer-Scientist Sangosthi on "अनार उत्पादन प्रौद्योगिकी व उत्पादन में आ रही समस्याएं"	PD (ATMA), Bikaner
July 18, 2018	Interface Meeting of Scientists & Auditor CAG, Jaipur with Farmers of Lakhuser and Bajju	ICAR-CAZRI, RRS, Bikaner
March 12, 2019	Interface Meeting of Scientists with Women Farmers in Gajner village under MGMG scheme	ICAR-CAZRI, RRS, Bikaner
March 26, 2019	Farmers Scientists Workshop on "Gum Production in Trees Using CAZRI Gum Inducer – Principles and Techniques" at ICAR-CAZRI, RRS, Bikaner	Network project on gum and rasin production
October 14-15, 2019	Interface Meeting of Farmers with Scientists on "शुष्क क्षेत्रों में रबी फसल प्रबंधन एवं समेकित कृषि प्रणालियां"	PD, ATMA, Bikaner
November 06, 2019	Farmer - Scientist Sangosthi on "शुष्क क्षेत्रों में रबी कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां"	SCSP project ICAR-CAZRI, RRS, Bikaner
November 07, 2019	Farmer - Scientist Sangosthi on "शुष्क क्षेत्रों में रबी कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां"	SCSP project ICAR-CAZRI, RRS, Bikaner

Date	Title and venue	Sponsoring agency
November 08, 2019	Farmer - Scientist Sangosthi on "शुष्क क्षेत्रों में रबी कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां"	SCSP project ICAR-CAZRI, RRS, Bikaner
November 22, 2019	Farmer - Scientist Sangosthi on "शुष्क क्षेत्रों में रबी कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां"	SCSP project ICAR-CAZRI, RRS, Bikaner
November 23, 2019	Farmer - Scientist Sangosthi on "शुष्क क्षेत्रों में रबी कृषि उत्पादकता वृद्धि की नवीनतम तकनीकियां"	SCSP project ICAR-CAZRI, RRS, Bikaner

Farm Schools Organised

Name of training	Duration /Season	Venue	No. of participants
Farm School on Moth bean	Kharif 2016	Village: Dharnok, Panchayat samiti: Panchu, Bikaner	25
Farm School on Clusterbean	Kharif 2016	12 KJD, Panchayat samiti Khajuwala, Bikaner	25
Farm School on Mung bean	Kharif 2016	Village: Nokha Gaon, Panchayat samiti: Nokha, Bikaner	25

Farmers Training Course Organized

Subject	On campus		Off campus		Total	
	No. of courses	No. of trainees	No. of courses	No. of trainees	No. of courses	No. of trainees
Horticulture	14	427 (Male) 30 (Female)	--	---	14	427 (Male) 30 (Female)
Agronomy	25	826 (Male)	12	300 (Male)	37	1126 (Male)
Resource management	1	40 (Male)	--	---	1	40 (Male)
Total	40	1363	12	--	52	1623

Field Demonstrations

Thematic area	Demonstrations	Beneficiaries
Kharif Crops (Moth bean)	37	37
Kharif Crops (Mung bean)	37	37
Kharif Crops (Cowpea)	37	37

Participation in Farmers' Fare, Exhibition etc.

Date	Occasion
July 16, 2014	ICAR Foundation Day at Jalwali, Bikaner
October 03, 2014	Kisan Mela at Lunkaransar, Bikaner
October 03, 2015	Launch Function of “Mera Gaon Mera Gaurav” at Kalasar, Bikaner
February 27, 2016	Kisan Mela at RAJUVAS, Bikaner
February 18-20, 2017	Western Regional Agriculture Fair at SKRAU, Bikaner
October 06, 2017	Kisan Mela on “Agriculture and Animal Science” at PD, ATMA, Bikaner
October 07, 2017	Kisan Mela on “Groundnut” at ICAR-CSWRI, Arid Region Campus, Bikaner
March 17, 2018	Kisan Mela on “Arid Horticulture” at ICAR-CIAH, Bikaner
July 05, 2018	Foundation Day of ICAR-National Research Centre on Camel, Bikaner
September 13-15, 2018	Farmer Fair cum Farm Innovation at ICAR-CAZRI, Jodhpur
October 02, 2018	KRISHIFEST-2018 at ICAR-National Research Centre on Camel, Bikaner
October 27, 2018	National Conference on “Arid Horticulture for Enhancing Productivity & Economic Empowerment” at ICAR-CIAH, Bikaner
January 27, 2019	Ber Diwas at ICAR-CIAH, Bikaner
March 07, 2019	Kisan Mela at KVK (SKRAU), Lunkaransar, Bikaner
April 04, 2019	Foundation Day of ICAR-CSWRI at ICAR-CSWRI, ARC, Bikaner
July 05, 2019	Foundation Day of ICAR-National Research Centre on Camel at ICAR-National Research Centre on Camel, Bikaner
August 30, 2019	Kisan Mela at ICAR-Central Institute for Arid Horticulture, Bikaner
September 16, 2019	Kisan Mela at ICAR-Central Arid Zone Research Institute, Jodhpur



Meetings and Events Organised

Workshop on "Climate change: Mitigation and adaptation in Hot Arid Regions"

A workshop on changing climate scenario and technological options to mitigate its adverse effect on crops was organised in 2016 under NICRA project. The workshop was attended by 126 participants representing various ICAR research institutes, Swami Keshwanand Rajasthan Agricultural University, Rajasthan state agriculture department, RAJUVAS, Dungar college, MGS university, Hydrology and water management institute, IGNP etc. Lectures related to various issues on climate change scenario and its impact on arid agriculture, changing landuse and livelihood in arid region, climate resilient cropping systems and agronomical practices, evolving horticultural production systems in climate change of arid region, managing soils productivity under changing climate elevating adverse effects climate induced environmental stress and strategies on mitigation and adaptation through IFS systems in arid regions were presented and discussed.



Brainstorming on improving crop water productivity in IGNP canal command area

A brainstorming session on Improving Crop Water Productivity in Indira Gandhi Canal Command Area was organized on August 19, 2013 under ICAR-



ICARDA collaborative project with the objective to discuss the issues like the losses of water in IGNP and interventions and technologies required to improve water productivity. About 40 participants from different ICAR institutes (viz. CAZRI Jodhpur, CAZRI RRS Bikaner, CAZRI RRS Jaisalmer, CIAH Bikaner, NRCC Bikaner, CSWRI Bikaner, NRCE Bikaner), Swami Keshwanand Rajasthan Agricultural University, IGNP and NGO from Bikaner actively participated. After thorough discussion on various issues, it was concluded that our efforts should be to minimize the losses of irrigation water by adopting suitable water saving technologies, checking conveyance losses by suitable lining material, providing incentives to the farmers growing low water requiring crops, enhancing the support price for the low water requiring crops and develop suitable integrated farming system models with adequate ratio of livestock and tree/woody components to improve water productivity.

Workshop on "Improving crop and water productivity in IGNP areas"

A workshop on improving crop and water productivity in IGNP areas was organised during August 21-22, 2014 with the objectives to share the experiences of scientific institutions, state government

departments and agricultural university to identify critical research gaps for improving crop and water productivity. The workshop was attended by 80 participants representing various ICAR research institutes, Swami Keshawanand Rajasthan Agricultural University, Rajasthan State Agriculture department, Hydrology and water management institute, IGNP etc. The workshop was inaugurated by Dr. S.K. Sharma, Director, CIAH, Bikaner. After the presentations of lead lectures, group discussions and the research outcomes of ICAR-ICARDA collaborative project, the recommendations emerged that there is a need of fine tuning of CropSyst model by field experiments under different crop management options i.e. method, rates and time of irrigation and nutrient (nitrogen) application, moisture conservation techniques etc.

Workshop on "Improving water productivity in IGNP: Expanding dimensions"

A workshop was held on March 02, 2016 with the objective to improve agricultural water productivity in canal command areas of IGNP. The workshop was attended by 40 participants representing various ICAR research institutes, Swami Keshawanand Rajasthan Agricultural University, Rajasthan State Agriculture department, IGNP etc. The workshop was inaugurated by Dr. S.K. Sharma, Director, CIAH, Bikaner. Renowned speakers from ICARDA and CAZRI on valuation of economic services to improve agricultural water management, challenges and opportunities to improve crop, livestock, nutritional and economic water productivity in arid region.



Brainstorming on "Enhancing crop water productivity in hot arid regions: Challenges and opportunities"

A brainstorming session on 'Enhancing crop water productivity in hot arid regions: Challenges and opportunities' was organised on February 26, 2018 under ICAR-ICARDA collaborative project phase II. The objective of the brainstorming was to discuss the challenges and the ways to enhance crop water productivity in IGNP areas. Approximately 45 participants from different ICAR institutes (viz. CAZRI Jodhpur, CAZRI RRS Bikaner, CIAH Bikaner, NRCC Bikaner, CSWRI Bikaner, NRCE Bikaner), Swami Keshwanand Rajasthan Agricultural University, IGNP, State Agriculture Department etc. actively participated in the brainstorming session.



Workshop on "Status and strategies for enhancing crop water productivity in IGNP area"

A workshop on "Status and strategies for enhancing crop water productivity in IGNP area" was organized on November 11, 2018 in ICAR-ICARDA

project. The workshop was attended by 62 participants representing various ICAR research institutes, Swami Keshawanand Rajasthan Agricultural University, Rajasthan State Agriculture department, Hydrology and water management institute, IGNP etc. The issues on global scenario of water resources, groundwater resources of western Rajasthan, water flow status in IGNP canal command area, approaches and policies of state agriculture department for enhancing water productivity of crops through soil and water management approaches were discussed.



Training on CropSyst crop model

Six days specialised training programme on “CropSyst crop model” was organised during November 5-10, 2012 under ICAR-ICARDA Collaborative Research Project #8 with the objective to get a hand-on practice to use CropSyst model. The training was coordinated by Dr. Mariya Glazirina



(Crop modeling expert) and Dr. Vinay Nangia (Hydrologist) from ICARDA. Twelve participants from CAZRI and SKRAU participated in the training. The training comprised of basic theory, practical and hands on practices on familiarization with the concept, installation of CropSyst model, creation of different input files related to weather, soil, crop & management, soil organic matter, nitrogen, salinity, crop phenology, crop growth data, soil hydraulic properties etc.

Cleanliness drive

The station organized the cleanliness drive near office premises, surrounding areas of the institute and other public places time to time. To give a message of the importance of cleanliness among the local people, the station organized a solid and liquid waste management (SLWM) drive from September 11, 2019 to October 27, 2019 on the occasion of 150th birth anniversary of Rashtrapita Mahatma Gandhi under Swachh Bharat Mission. All the officers and staff of the station cleaned the RIICO dividing road and made it free from polythene and other trash material.



Field day

A field day was organized on March 22, 2011 under FPARP project at farmers field in village Gigasar, Bikaner. More than 50 farmers from various villages nearby Gigasar participated and benefited through field visits on improved cultivars of different rabi crops, suitable cropping systems and improved technologies for rejuvenation of ber orchards and its

improved technologies in agri-horti systems for higher production. The farmers also got benefited through deliberations on various aspects of production technologies by subject matter specialists for improving the productivity of crops, horticultural crops and soil health.

The International Yoga Day

The International Yoga Day was celebrated on June 21 in 2019 and 2020 together by all the central government institute including ICAR institutes, Banks, BSNL, NCC wings etc. The scientists, technical and administrative staff of the station and participants from other organizations took part in this program. The trainers from *Yog avam Prakratik chikitsa kendra*, Bikaner imparted Yoga training on various yogasanas.



हिन्दी दिवस/हिन्दी सप्ताह/हिन्दी पखवाड़ा

इस दशक में प्रत्येक वर्ष 14 सितम्बर को हिन्दी दिवस व उस अवधि के दौरान हिन्दी सप्ताह व हिन्दी पखवाड़े का आयोजन किया गया। कार्यक्रम के दौरान बीकानेर में उपस्थित जाने माने हिन्दी विद्वेता व हिन्दी अधिकारियों के व्याख्यान आयोजित किये गए। इस दौरान हिन्दी प्रश्नोत्तरी, वाद-विवाद, अन्ताक्षरी, आशुभाषण, निबंध प्रतियोगिता, वैज्ञानिक विचार गोष्ठी आदि कार्यक्रमों का आयोजन किया गया, जिसमें संस्थान के सभी अधिकारियों व कर्मचारियों ने सक्रिय रूप से भाग लिया। हिन्दी के प्रसार के लिए हिन्दी में कार्य करने वाले कर्मचारियों को सम्मानित किया गया।



Institute Development

New farm office

One new farm building with a seating capacity of four rooms for officer-in-charge, farm supervisor and technical persons, and a store for keeping the seeds and fertilizers was constructed and inaugurated on August 19, 2013 by Dr. M.M. Roy, Director, CAZRI, Jodhpur in presence of Dr. S.K. Sharma, Director CIAH and officers and staff of the station.



Repair and renovation of office building and office premises

Civil works of approx. Rs. 92.00 lakhs were executed for the repair of office building, renovation of conference hall, laboratory, fencing of experimental



area, road recarpeting, repair of water supply line, animal fodder store, and replacement of conventional lights with energy efficient LEDs etc. One roof top water harvesting structure to collect the rainwater from the roof top of office building was constructed during 2019. One tubewell has been constructed in the farm area to irrigate the crops.

Consultancy

A consultancy was provided for Development Plan for Plantation/Greenbelt at Super Thermal Power Station, RVUN, Suratgarh amounting Rs. 25.00 lakhs. The objective of the consultancy was to suggest suitable plant species and their plantation geometry; advice on plant residue management, use of recycled water for irrigation of plantation and post plantation maintenance and care. In a six months time frame, the team came out with a development plan as per MOU and suggested the suitable plants for greenbelt development, their planting technique, irrigation management, optimum planting density, pruning and training management, residue management, use of recycled water etc.



Linkages and Collaborations

International

- International Centre for Agricultural Research in the Dry Areas (ICARDA)

National

- Swami Keshwanand Rajasthan Agricultural University, Bikaner
- ICAR-Indian Institute of Pulses Research, RRS, Bikaner
- ICAR-Central Sheep and Wool Research Institute, Arid Region Campus, Bikaner
- ICAR-National Research Centre on Camel, Bikaner
- ICAR-Central Institute for Arid Horticulture, Bikaner
- Krishi Vigyan Kendra, SKRAU, Bikaner
- Krishi Vigyan Kendra, SKRAU, Lunkaransar
- Agriculture Research Station, SKRAU, Bikaner
- Directorate of Research, Command Area Development, Government of Rajasthan, Bikaner
- Project Directorate, ATMA, Bikaner
- Technoserv NGO, Bikaner
- URMUL Trust NGO, Bikaner
- National Food Security Mission, Department of Agriculture, Bikaner
- Department of Agriculture, Bikaner
- Hydrology and Water Management Institute, Bikaner

Capacity Building

Workshops, Symposium, Brain Storming Session and Trainings Organised

Duration	Title of training course and venue
August 19, 2013	Brain Storming Session on Water Productivity at ICAR-CAZRI, RRS, Bikaner
August 22-23, 2014	Workshop on Improving Crop and Water Productivity in IGNP Areas at ICAR-CAZRI, RRS, Bikaner
February 26, 2016	Workshop on Climate Change Mitigation and Adaptation in Hot Arid Region at ICAR-CAZRI, RRS, Bikaner
March 2, 2016	Workshop on Improving Water Productivity in IGNP- Expanding Dimensions at ICAR-CAZRI, RRS, Bikaner
February 26, 2018	Brainstorming Session on Enhancing Crop Water Productivity in Hot Arid Regions: Challenges & Opportunities at ICAR-CAZRI, RRS, Bikaner
November 14, 2018	Workshop on Status and Strategies for Enhancing Crop Water Productivity in IGNP Area, Phase-II at ICAR-CAZRI, RRS, Bikaner

Training Attended International

Duration	Title of Training Course and Venue	Name of Participants
October 26-November 14, 2013	Water Productivity of Agricultural Systems. ICARDA, Amman, Jordan	N.D. Yadava
October 19-November 06, 2014	Improving Water Productivity in Agricultural Systems with Emphasis on Rainfed Agriculture. ICARDA, Amman, Jordan	V.S. Rathore

National

Duration	Title of Training Course and Venue	Name of Participants
April 05-18, 2011	National Training on Climate Change, Carbon Sequestration and Carbon Credits at ICAR-ISSS, Bhopal	S. Bhardwaj
December 12-15, 2011	International Training Workshop on Ecosystem based Disaster Risk Reduction organised by National Institute of Disaster Management, Ministry of Home Affairs, GOI and Partnership for Environment and Disaster Risk Reduction United Nations, New Delhi	V.S. Rathore
January 16-21, 2012	Training Program on Data Analysis Using SAS Software at MPUA&T, Udaipur	N.S. Nathawat S. Bhardwaj
November 05-10, 2012	Specialized Training Course on CropSyst Crop Model organized by ICARDA in Cooperation with CAZRI at ICAR-CAZRI, RRS, Bikaner	N.D. Yadava M.L. Soni V.S. Rathore Birbal N.S. Nathawat S. Bhardwaj

Duration	Title of Training Course and Venue	Name of Participants
April 12-May 12, 2013	Orientation Training at ICAR-CAZRI, Jodhpur	R. Ravi
May 14-August 13, 2013	Professional Attachment Training at ICAR-NRC for Agroforestry, Jhansi	R. Ravi
March 24-28, 2014	National Training Course on Drought Mitigation and Management at ICAR-CAZRI, Jodhpur	R. Ravi
July 14-26, 2014	Refresher Course on Agricultural Research Management at ICAR-NAARM, Hyderabad	N.S. Nathawat
July 15-26, 2014	Management Development Program on Leadership Development (a pre-RMP program) at ICAR-NAARM, Hyderabad	N.D. Yadava
March 2-3, 2015	Workshop on Right to Information Act-2005 for CPIO at ISTM, New Delhi	N.D. Yadava
July 01- September 30, 2015	Foundation Training at ICAR-NAARM, Hyderabad	Sheetal K.R. Renjith P.S.
October 09-November 08, 2015	Orientation Training at ICAR-CAZRI, Jodhpur	Sheetal K.R. Renjith P.S.
November 20-29, 2015	Geo Informatics in Natural Resource Management and Climate Change Mitigation at ICAR-ISSS, Bhopal	Sheetal K R.
November 12, 2015-February 11, 2016	Professional Attachment Training at ICAR-CSSRI, Karnal	Renjith P.S.
November 12, 2015-February 12, 2016	Professional Attachment Training at ICAR-IISS, Bhopal	Sheetal K R.
October 06-26, 2016	CAFT Training on Advances in Experimental Data Analysis at ICAR- IASRI, New Delhi	Renjith P.S.
October 25-November 14, 2017	Winter School on Advances in Water Management Practices for Enhancing Water Productivity in Agriculture at ICAR-IARI, New Delhi	Sheetal, K.R.
November 09-29, 2017	Winter School on Advanced Technologies in Natural Resources Management to Mitigate Climate Change Impacts at ICAR-IISWC, Research Centre, Ooty	Subbulakshmi, V.
December 08-19, 2020	Management Development Program on Leadership Development (a pre-RMP Program) on-line at ICAR-NAARM, Hyderabad	V.S. Rathore

Participation in Conference/Seminar/Symposia/Workshop/Meetings

Date	Name of Seminar and Venue	Name of participant
August 05-06, 2011	Brain Storming Session on Prioritization of Plant Physiology and Biochemistry Research for 12 th Five Year Plan Period at IARI, New Delhi	N.S. Nathawat
November 24-26, 2011	National Seminar on Sustainable Crop Productivity through Physiological Intervention at Ramnarain Ruia College, Matunga, Mumbai	N.S. Nathawat
November 28-30, 2011	Impact Assessment of International Trainings in Frontier Areas of Agricultural Sciences at ICAR, NASC Complex, New Delhi	M.L. Soni

Date	Name of Seminar and Venue	Name of participant
December 20-22, 2011	National Symposium on Resource Utilization through Integrated Farming System and Biodiversity Conservation in Drylands at ICAR-CAZRI, RRS, Kukuma, Bhuj	N.D. Yadava Birbal V.S. Rathore N.S. Nathawat S. Bhardwaj
February 28, 2012	Brain Storming Workshop on Accelerated Fodder Development: Possibilities and Challenges at ARS, SKRAU, Bikaner	N.D. Yadava V.S. Rathore
April 25, 2012	Workshop on Olive Cultivation in Rajasthan organized by Department of Agriculture, Govt. of Rajasthan at Lunkarnsar Bikaner	Birbal
May 26-27, 2012	28 th Annual Workshop on Arid Legume at Kerala Agricultural University, ARS, Patambi	N.D. Yadava
June 18, 2012	Seminar on Pomegranate Cultivation at Directorate of Horticulture and Farm Forestry, Govt. of Madhya Pradesh, Bhopal	Birbal
September 05, 2012	National Brain Storming Workshop on Rehabilitation of Degraded Rangelands for Sustainable Livelihood of Thar Desert at ICAR-CAZRI, RRS, Jaisalmer	N.D. Yadava
November 02-03, 2012	National Symposium on Sustainable Production of Forages from Arable and Non-Arable Land and its Utilization at ICAR-IGFRI, Jhansi	V.S. Rathore
November 26-30, 2012	Third International Agronomy Congress on Agricultural Diversification, Climate Change Management and Livelihoods at ICAR, New Delhi	N.D. Yadava V.S. Rathore
November 27-29, 2012	International Conference on Sustainable Agriculture for Food and Livelihood Security at PAU, Ludhiana	M. L. Soni Birbal
December 01-02, 2012	National Symposium on Managing Stress in Drylands under Climate Change Scenarios at ICAR-CAZRI, Jodhpur	N.D. Yadava M.L. Soni V.S. Rathore Birbal N.S. Nathawat
December 12-14, 2012	National Seminar on Physiological and Molecular Approaches for Development of Climate Resilient Crops at Department of Crop Physiology, Acharya N.G. Ranga Agricultural University, Hyderabad	N.S. Nathawat
January 22, 2013	Biodiversity Workshop Program under CRP 1.1 Dryland System at ICAR-CAZRI, Jodhpur	N.D. Yadava
March 08-09, 2013	National Seminar on Enhancing Water Productivity in Agriculture at Department of Agronomy, SAP-UGC, IAS, BHU, Varanasi	V.S. Rathore
March 13-14, 2013	Rastriya Sangosthi on <i>Krishi eyum Pariyawarn; Awasar eyum Chhunotiyam</i> . ICAR-CSSRI, Karnal	Birbal
March 14-15, 2013	Targeting Climate Resilient Agriculture Technology in Arid Western Rajasthan at ICAR-CAZRI, Jodhpur	N.D. Yadava
August 19, 2013	Brain Storming Session on Water Productivity at ICAR-CAZRI, RRS Bikaner	N.D. Yadava M.L. Soni V.S. Rathore Birbal N.S. Nathawat S. Bhardwaj
October 23-26, 2013	National Seminar on Development in Soil Science-2013 at ICAR-CAZRI, Jodhpur	M.L.Soni

Date	Name of Seminar and Venue	Name of participant
December 05-08, 2013	International Conference on Extension Educational Strategies for Sustainable Agricultural Development-A Global Perspective at UAS, Bangalore	Birbal
December 14-15, 2013	Rastriya Krishi Vigyan Sangosthi on <i>Krishi ki Adhunik Prodhyogiki ki Upalabdhiyan evam Chunotiyay</i> at ICAR-CIFE, Mumbai.	Birbal
January 10, 2014	National Workshop on Science, Technology, Innovation and Intellectual Property Rights (IPR): Envisaging the Interfaces at ICAR-CAZRI, Jodhpur.	R. Ravi
January 23-24, 2014	State Level Workshop on Precision Farming Technologies for Citrus at SKRAU, Bikaner	N.D. Yadava M.L. Soni Birbal V.S. Rathore N.S. Nathawat S. Bhardwaj R. Ravi
February 04, 2014	Workshop on Managing Arid Agriculture in Changing Climate at ICAR-CAZRI, Jodhpur	N.S. Nathawat
February 10-14, 2014	3 rd World Congress on Agroforestry on Trees for Life: Accelerating the Impact of Agroforestry organized by World Agroforestry Center, Nairobi and ICAR at New Delhi	N.D. Yadava M.L. Soni Birbal V.S. Rathore R. Ravi
August 22-23, 2014	Workshop on Improving Crop Water Productivity in IGNP areas at ICAR-CAZRI, RRS Bikaner	N.D. Yadava M.L. Soni V.S. Rathore Birbal N.S. Nathawat S. Bhardwaj
November 18-20, 2014	National Symposium on Agriculture Diversification for Sustainable Livelihood and Environmental Security at PAU, Ludhiana	V.S. Rathore
November 23-25, 2014	National Conference of Plant Physiology-2014 on Frontiers of Plant Physiology Research: Food Security and Environmental Challenges at OUAT, Bhubaneswar	N.S. Nathawat
March 16-17, 2015	Workshop on Action Plan for Better Water Management for Various Water Using Departments in Rajasthan at IGNP, Bikaner	Birbal N.S. Nathawat
March 18-22, 2015	National Workshop on Olive at RAJUVAS, Bikaner	M.L. Soni Birbal Subbulakshmi, V.
March 25, 2015	Workshop on Improving Productivity and Returns to Rainfed Farmers in Barmer organized by Technoserve and CAIRN India at Barmer	Birbal
June 13-14, 2015	National Seminar on Climate Change and Smart Agricultural Technologies at Rajmata Vijayaraje Scindhia Krishi Vishwa Vidyalaya, Gwalior	V.S. Rathore
August 19-22, 2015	National Symposium on Sustaining Agricultural Productivity in Arid Ecosystems: Challenges and Opportunities (SAPECO-2015) at ICAR-CAZRI, RRS, Leh	N.D. Yadava M.L. Soni V.S. Rathore
November 20-24, 2015	XXIII International Grassland Congress (IGC-2015) Organized by RMSI & ICAR-IGFRI at New Delhi	V.S. Rathore

Date	Name of Seminar and Venue	Name of participant
December 11-14, 2015	3 rd International Plant Physiology Congress on Challenges and Strategies in Plant Biology Research organized by ISPP, JNU and NIPGR at JNU, New Delhi	N. S. Nathawat
February 17-19, 2016	25 th National Conference on Natural Resource Management in Arid and Semi-arid Ecosystem for Climate Resilient Agriculture and Rural Development organized by Soil Conservation Society of India at SKRAU, Bikaner	N.D. Yadava M.L. Soni Birbal V.S. Rathore S. Bhardwaj Subbulakshmi, V.
February 26, 2016	Workshop on Climate Change Mitigation and Adaptation in Hot Arid Region at ICAR-CAZRI, RRS, Bikaner	N.D. Yadava M.L.Soni Birbal V.S. Rathore N. S. Nathawat S. Bhardwaj Manesh Dagla Subbulakshmi, V. Sheetal, K.R. Renjith, P.S.
March 02, 2016	Workshop on Improving Water Productivity in IGNP-Expanding Dimensions at ICAR-CAZRI, RRS, Bikaner	N.D. Yadava M.L. Soni Birbal V.S. Rathore N.S. Nathawat S. Bhardwaj Manesh Dagla Subbulakshmi, V. Sheetal, K.R. Renjith, P.S.
March 11-13, 2016	National Seminar on Agriculture Resource Management for Sustainability and Eco-Restoration organized by Society for Agriculture and Arid Ecology Research at ICAR-CIAH, Bikaner	Birbal
June 25-26, 2016	3 rd International Conference on Agriculture, Horticulture and Plant Science organized by IJTA and Serial Publications Pvt. Ltd. at New Delhi	M.L. Soni Birbal
November 22-26, 2016	4 th International Agronomy Congress (IAC) on Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenges at ICAR, New Delhi.	N.D. Yadava V.S. Rathore
January 21-23, 2017	5 th National Seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security at SKRAU, Bikaner	Subbulakshmi, V. Sheetal K. R. Renjith P.S.
March 08-09, 2017	National Seminar on Environmental Management and Technology at Maharaja Ganga Singh University, Bikaner	Sheetal K.R.
April 03-07, 2017	XIX Commonwealth Forestry Conference-Forests for Prosperity and Posterity at FRI, Dehradun	Subbulakshmi, V. Sheetal, K.R.
November 23-25, 2017	National Conference of Plant Physiology on Emerging Role of Plant Physiology for Food Security and Climate Resilient Agriculture at IGKV, Raipur, Chattisgarh.	N.S. Nathawat
December 11-14, 2017	National Seminar on Development in Soil Sciences at Amity University, Kolkata	M.L. Soni

Date	Name of Seminar and Venue	Name of participant
January 09, 2018	Sensitization Workshop Towards Sexual Harassment of Women at Work Place held at ICAR-CAZRI, RRS, Bikaner	N.D. Yadava G.L. Bagdi M.L. Soni Birbal V.S. Rathore N.S. Nathawat S. Bhardwaj Sheetal, K.R. Renjith, P.S.
February 26, 2018	Brainstorming Session on Enhancing Crop Water Productivity in Hot Arid Regions: Challenges and Opportunities at ICAR-CAZRI-RRS, Bikaner	N.D. Yadava G.L. Bagdi M.L. Soni Birbal V.S. Rathore N.S. Nathawat Sheetal, K.R. Renjith, P.S.
June 25-26, 2018	Farmers Scientists Interaction Workshop on “अनार उत्पादन प्रौद्योगिकी एवं उत्पादन में आ रही समस्याएँ” at ICAR-CAZRI, RRS, Bikaner	Subbulakshmi, V. Sheetal, K.R. Renjith, P.S.
October 03-06, 2018	International Conference on Global Water Security for Agriculture and Natural Resources organized by ASABE and ISAE at Hyderabad	N.D. Yadava V.S. Rathore
October 27-29, 2018	National Conference on Arid Horticulture for Enhancing Productivity and Economic Empowerment at ICAR-CIAH, Bikaner	Birbal G.L. Bagdi
November 14, 2018	Workshop on Status and Strategies For Enhancing Crop Water Productivity in IGNP Area Phase-II at ICAR-CAZRI, RRS, Bikaner.	N.D. Yadava G.L. Bagdi M.L. Soni Birbal V.S. Rathore N.S. Nathawat Sheetal, K.R.
December 02-05, 2018	4 th International Plant Physiology Congress, organized by CSIR-NBRI, Lucknow and ISPP, New Delhi	N.S. Nathawat
January 10, 2019	Climate Change and Desertification organized by ENVIS CAZRI Jodhpur and INVIS TERI at ICAR-CAZRI, RRS, Jaisalmer	N.D. Yadava M.L. Soni V.S. Rathore
February 11-14, 2019	13 th ICDD-Converting Dryland Areas from Grey into Green organized by IDDC and AZRAI at ICAR-CAZRI, Jodhpur	N.D. Yadava G.L. Bagdi M.L. Soni Birbal V.S. Rathore N.S. Nathawat
March 12-13, 2019	National Seminar on Entrepreneurship and Innovation in Agriculture for Socio-Economic Empowerment of Farmers at SKRAU, Bikaner	Subbulakshmi, V. Sheetal, K.R.
May 28-31, 2019	International Conference on Innovative Horticulture and Value Chain Management at GBPUA&T, Pantnagar	Birbal Subbulakshmi, V.

Date	Name of Seminar and Venue	Name of participant
November 01-02, 2019	National Dialogue on Land Use for Integrated Livestock Development at Pusa, New Delhi	V.S. Rathore
November 14-16, 2019.	ISEE National Seminar-2019 on Holistic Approach for Enhancing Agricultural Growth in Changing Rural Scenario at SKRAU, Bikaner	G.L. Bagdi
November 15-18, 2019	84 th Annual Convention of Indian Society of Soil Science at BHU, Varanasi	M.L. Soni
March 05-06, 2020	National Agroforestry Symposium on Climate Resilient Agroforestry Systems to Augment Livestock Productivity Ensuring Environmental Biodiversity at Institute of Animal Nutrition, TANUVAS, Chennai	Subbulakshmi, V.
June 13-14, 2020	National Webinar on Post COVID-19 Strategies for Sustainable Agriculture organised by SAAHAS in collaboration with University of Agricultural and Horticultural Sciences,, Shivamogga	Birbal
June 16, 2020	National Webinar on Technological Advances in Crop Production during COVID-19 at SKRAU, Bikaner	N.D. Yadava Subbulakshmi, V. Sheetal, K.R.
June 18, 2020	National Webinar on Harnessing the Potential of Indigenous Ornamentals: Post COVID 19 Pandemic organised by ICAR-Directorate of Floricultural Research, Pune and Horticultural Science Division, ICAR, New Delhi	Subbulakshmi, V.
July 06, 2020	Webinar on Industrial Agroforestry-Trends and Advances organised by Mettupalayam Agro Forestry Business Incubation Forum (MAFBIF), Forest College and Research Institute, TNAU, Mettupalayam	M.L. Soni Subbulakshmi, V.
July 22-24, 2020	International Webinar on Achieving Land Degradation Neutrality organised by Indian Association of Soil and Water Conservationists (IASWC), Dehradun.	Subbulakshmi, V. Sheetal, K.R.
August 16-17, 2020	National Web-conference on Technological Approaches for Resource Conservation and Management for Environmental Sustainability organized by Academy of Natural Resource Conservation and Management (ANRCM), Lucknow	V.S. Rathore
August 25-28, 2020	National Webinar on Advances in Moringa Farming-A way forward to trending entrepreneurship organised by EDII Periyakulam Horticulture Business Incubation Forum, HC & RI, TNAU, Periyakulam	Subbulakshmi, V.
September 26, 2020	Webinar on Farm Bills 2020: Understanding the Implications organized by NAHEP (ICAR)-CAAST, IARI, New Delhi	M.L. Soni
September 30, 2020	National Webinar on Halophytes for Alleviating Salinity Stress in Agriculture: Potential and Problems organised by NIASM, Baramati	M.L. Soni Sheetal, K.R.
October 01, 2020	International Webinar on Soil Spectroscopy organised by ICRAF and ICAR-IISS, Bhopal	M.L. Soni
October 05-07, 2020	International Webinar on Moringa-A Super Food-Boon to Mankind organised by Department of Vegetables and EDII Periyakulam Horticulture Business Incubation Forum, HC & RI, TNAU, Periyakulam	Sheetal, K.R. Subbulakshmi, V.

Participation in Meetings and Programs with State Line Departments

Date	Subject of Meeting/Program	Department/ Stakeholder/Agency	Place	Name of participants
July 18, 2011	Scientific Advisory Committee Meeting	KVK, Bikaner	SKRAU Bikaner	N.D. Yadava
August 23-24, 2011	Zonal Research and Extension Advisory Committee Meeting (Rabi-2011)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava
February 28, 2012	Brain Storming Workshop on Accelerated Fodder Development Possibilities and Challenges under AFDP Programme	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
April 14, 2012	International Group Meet on Possibilities and Strategy of Zozoba Cultivation	Zozoba association, Bikaner	Bikaner	N.D. Yadava
September 12, 2012	Scientific Advisory Committee Meeting	KVK, Bikaner	SKRAU, Bikaner	N.D. Yadava
September 20-21, 2012	Zonal Research and Extension Advisory Committee Meeting (Rabi, 2012)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava
October 03, 2012	Panchayat Samiti Meeting on Rajasthan Ajeevika Mission	Panchayat Samiti, Bikaner	Panchayat Samiti, Bikaner	N.D. Yadava
February 24-28, 2013.	Zonal Monitoring Committee on National Initiative on Climate Resilient Agriculture	KVK Jhunjhunu, Jodhpur and Valsad	KVK, Jodhpur	N.D. Yadava
April 17, 2013	Scientific Advisory Committee Meeting	KVK, Bikaner	SKRAU, Bikaner	N.D. Yadava
August 21, 2013	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
February 24, 2014	Promotion of Pearl millet Technologies in Western India for Improving Productivity, Profitability and Livelihoods of the Poor : A Policy Outreach Workshop	ICRISAT and SKRAU Bikaner	DHRD, SKRAU, Bikaner	V.S. Rathore
March 07-08, 2014	Forage Crops National Group Meet (Kharif-2014)	ICAR and SKRAU, Bikaner	SKRAU, Bikaner	V.S. Rathore
March 08, 2014	Brain Storming Session on Micronutrient Deficiency in Fodder in Western Part of the Country	IGFRI and SKRAU, Bikaner.	SKRAU, Bikaner.	M.L. Soni
March 11-12, 2014	Zonal Research and Extension Advisory Committee Meeting (Rabi, 2012)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	V.S. Rathore

Date	Subject of Meeting/Program	Department/ Stakeholder/Agency	Place	Name of participants
16-17 March, 2015	Workshop on Preparation of Action Plan for Better Water Management for Various Water using Departments in Rajasthan	WAPCOS and IGNP, Bikaner	Bikaner	V.S. Rathore
March 18, 2015	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
November 27, 2015	Meeting of State Level Nodal Agency (SLNA) and Rajasthan River Basin Water Resources Planning Authority Rajasthan	Pant Krishi Bhawan, Jaipur	Pant Krishi Bhawan, Jaipur	N.D. Yadava
February 27, 2016	Crop Evaluation Committee Meeting in Kisan Mela	ATMA and RAJUVAS, Bikaner	RAJUVAS, Bikaner	N.D. Yadava
April 05-06, 2016	Zonal Research and Extension Advisory Committee Meeting (Kharif-2016)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava
July 15, 2016	Academic Council Meeting	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
August 22, 2016	Meeting on GRAM	DoA, Govt. of Rajasthan, Bikaner	Collectorate, Bikaner	N.D. Yadava
October 20, 2016	Academic Council Meeting	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
March 09-10, 2017	Zonal Research and Extension Advisory Committee Meeting (Kharif- 2017)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava V.S. Rathore
March 23, 2017	Scientific Advisory Committee Meeting	KVK Lunkaranser and KVK Bikaner	SKRAU, Bikaner	N.D. Yadava
April 05-06, 2017	Zonal Research and Extension Advisory Committee Meeting (Kharif -2017)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava
May 24, 2017	Academic Council Meeting	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
September 05, 2017	Scientific Advisory Committee Meeting	KVK, Bikaner	SKRAU, Bikaner	N.D. Yadava
September 06, 2017	Scientific Advisory Committee Meeting	KVK, Lunkaranser	SKRAU, Bikaner	N.D. Yadava
September 12-13, 2017	Zonal Research and Extension Advisory Committee Meeting (Rabi-2017)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava V.S. Rathore
November 27, 2017	Academic Council Meeting	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
May 10, 2018	Academic Council Meeting	SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
September 17-18, 2018	Zonal Research and Extension Advisory Committee (Rabi 2017-18)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava V.S. Rathore
October 02, 2018	KRISHIFEST-2018	DOA, Govt. of Rajasthan and various ICAR institutes	CIAH, Bikaner	N.D. Yadava

Date	Subject of Meeting/Program	Department/ Stakeholder/Agency	Place	Name of participants
February 21, 2019	Pradhan Mantri Kisan Samman Nidhi (PMKISAN)	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
March 01-02, 2019	Admission Committee Meeting	IABM College, SKRAU, Bikaner	SKRAU, Bikaner	N.D. Yadava
March 25-26, 2019	Zonal Research and Extension Advisory Committee (Kharif-2019)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	V.S. Rathore Birbal
June 04, 2019	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
September 16-17, 2019	Zonal Research and Extension Advisory Committee (Rabi-2019)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	V.S. Rathore N. S. Nathawat
October 31, 2019	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
January 08, 2020	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
January 09, 2020	Scientific Advisory Committee Meeting	KVK, Bikaner	SKRAU, Bikaner	N.D. Yadava
March 12, 2020	ATMA GB Meeting	DoA, Govt. of Rajasthan	Collectorate, Bikaner	N.D. Yadava
May 19, 2020	Zonal Research and Extension Advisory Committee (Kharif-2020)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	V.S. Rathore
September 18, 2020	Zonal Research and Extension Advisory Committee (Rabi-2020)	ARS, SKRAU and DOA, Govt. of Rajasthan, Bikaner	SKRAU, Bikaner	N.D. Yadava V.S. Rathore

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- Yadava, N.D., Soni, M.L., Birbal and Nathawat, N.S. 2014-15. मरु क्षेत्रों में नींबू आधारित बागवानी पद्धति में फसलों का विविधीकरण. *Maru Bagwani* 9: 37-38.
- Yadava, N.D., Rathore, V.S. and Soni, M.L. 2018. Enhancing farmers' income through crop diversification. *Indian Farming* 68(09): 38-40.
- Yadava, N.D., Soni, M.L., Rathore, V.S. and Nathawat, N. S. 2018. Agri-horti-silvi system for production stability in arid zone. *Indian Farming* 68 (09): 33-37.

Awards and Recognitions

- Dr. Birbal received "Indira Gandhi Excellence Award" for outstanding individual achievements & distinguished service to the nation at a Seminar on Economic Growth and National Integration on 9th February, 2013 by India International Friendship Society, New Delhi.
- Dr. Birbal received Third Prize as co-author for the article entitled "फसलों के लिये पोषक तत्व प्रबंधन" under the scheme "डेयरी विज्ञान में हिन्दी पुस्तक/बुलेटिन/फोल्डर तथा शोध पत्र, आलेख पुरस्कार योजना" organized by NDRI, Karnal on 15th September, 2014.
- Dr. Birbal was awarded "Outstanding Scientist Award-2016" by International Journal of Tropical Agriculture and Serial Publications Pvt Ltd. on the occasion of 3rd International Conference on Agriculture, Horticulture and Plant Science from 25-26 June, 2016.
- Dr. Birbal was awarded "Distinguished Scientist Awards-2016" by All-India Agricultural Student Association (AIASA), New Delhi.
- Dr. Birbal received "Reviewer Excellence Award" for significant and outstanding contribution to the journals -Indian Journal of Agricultural Research and Legume Research- An International Journal) by ARCC, Karnal.
- Dr. M.L. Soni was awarded "Distinguished Scientist Award-2015" by Society for Scientific Development in Agriculture & Technology (SSDAT), Merrut, India.
- Dr. M.L. Soni was awarded "Outstanding Scientist Award-2016" by International Journal of Tropical Agriculture and Serial Publications Pvt Ltd. on the occasion of 3rd International Conference on Agriculture, Horticulture and Plant Science from 25-26 June, 2016.
- Dr. M.L. Soni was awarded "Krishi Vigyan Gourav-2018" by Bhartiya Krishi Anusandhan Samiti and Agricultural Research Communication Center, Karnal.
- Dr. M.L. Soni was awarded "Reviewer Excellence Award -2019" for significant and outstanding contribution to the journal "Legume Research- An International Journal" by Agricultural Research Communication Center, Karnal.
- Dr. M.L. Soni was awarded "Reviewer Excellence Award-2020" for significant and outstanding contribution to the journal "Agricultural Science Digest" by Agricultural Research Communication Center, Karnal.
- Dr. N.D. Yadava was awarded "Distinguished Scientist Awards-2016" by All-India Agricultural Student Association (AIASA), New Delhi.
- Dr. V.S. Rathore was awarded "Award for Research Excellence-2016" by The Indus Foundation Inc., USA.
- Dr. V.S. Rathore was awarded "Distinguished Scientist Awards-2016" by Society for Scientific Development in Agriculture & Technology (SSDAT), Merrut, India.
- Dr. V.S. Rathore was awarded "Distinguished Scientist Awards-2016" by All-India Agricultural Student Association (AIASA), New Delhi.
- Dr. V.S. Rathore was awarded "Reviewer Excellence Award-2016" by Agricultural Research Communication Center, Karnal.

Best Oral Presentation Award

- Dr. Birbal received Best Oral Presentation Award for presenting the paper entitled “सूक्ष्म क्षेत्रों में वर्षा आधारित टिंडा उत्पादन पर पूरक सिंचाई का प्रभाव” by Birbal, Rathore, V.S., Nathawat, N.S., Soni, M.L. and Yadava, N.D. In: Rastriya Krishi Vigyan Sangosthi at CIFE Mumbai by Bhartiya Krishi Anusandhan Samiti, Karnal (Haryana) during 14-15 December, 2013.
- Dr. Birbal received Best Oral Presentation Award for presenting the Paper entitled “Effectiveness of various mulching material in Okra-pea cropping sequence in hot arid ecosystem” by Birbal, Soni, M.L., Rathore, V.S., Nathawat N.S., and Yadava N.D. In: 25th National Conference on Natural Resource Management in Arid and Semi-Arid Ecosystem for Climate Resilient Agriculture and Rural Development Organized by Soil Conservation Society of India, New Delhi; SKRAU, Bikaner and Directorate of Watershed development and Soil Conservation, Govt. of Rajasthan, Jaipur at SKRAU, Bikaner during February 17-19, 2016.
- Dr. M.L. Soni received Best Oral Presentation Award for presenting the paper entitled “Above ground biomass production and carbon storage during restoration of water logged saline soils of IGNP area” by Soni, M.L., Beniwal, R.K., Garg, B.K., Tanwar, S.P.S., Burman U., Yadav, P. and Yadava, N.D. In: International Conference on “Sustainable Agriculture for Food and Livelihood Security” held at PAU, Ludhiana from 27-29 November, 2012.
- Dr. V.S. Rathore was awarded with best Paper Award in National Web-conference on Technological Approaches for Resource Conservation and Management for Environmental Sustainability organised by Academy of Natural Resource Conservation and Management (ANRCM), Lucknow (UP) during 16-17 August, 2020.

Best Poster Presentation Award

- Dr. N.S. Nathawat received Best Poster Presentation award for presenting the paper entitled “Salicylic acid and related compounds induced physiological and biochemical changes in clusterbean (*Cyamopsis tetragonoloba* L.) under water stress” by Nathawat, N.S., Rathore, V.S. and Yadava, N.D. In: *National Conference of Plant Physiology on Frontiers of Plant Physiology Research: Food Security and Environmental Challenges* organized by Department of Plant Physiology & ISPP at OAUT, Bhubaneswar during 23-25 November, 2014.
- Dr. V.S. Rathore received Best Poster Presentation Award for presenting the paper entitled “Improving Crop Water Productivity: Needs and Options.” by Rathore, V.S., Birbal, Nathawat, N.S., Bhardwaj, S., Singh, R. and Yadava, N.D. In: *National Symposium on Resource Utilization through Integrated Farming System and Biodiversity Conservation in Drylands* organized by AZRAI and CAZRI Jodhpur at CAZRI, RRS, Kukma, Bhuj during 20-22 December, 2011.
- Dr. V.S. Rathore received Best Poster Presentation Award for presenting the paper entitled “Deficit Irrigation for Improving Crop Water Productivity in Hot Arid Region” by Rathore, V.S., Nathawat, N.S., Bhardwaj, S., Birbal and Yadava, N.D. In: 25th National Conference on Natural Resource Management in Arid and Semi-Arid Ecosystem for Climate Resilient Agriculture and Rural Development, organized by Soil Conservation Society of India, New Delhi; SKRAU, Bikaner and Directorate of Watershed development and Soil Conservation, Govt. of Rajasthan, Jaipur at SKRAU, Bikaner during February 17-19, 2016.

Institute Foundation Day Award

- Dr. V.S. Rathore received CAZRI Foundation Day Award -2012 for best research paper entitled “*Haloxylon stocksii* (Boiss.) Benth.et Hook.f., a promising halophyte: Distribution, cultivation and utilization” by V.S. Rathore, J.P. Singh and M.M. Roy. In: *Genetic Resources and Crop Evolution* 59: 1213-1221.”
- Dr. M.L. Soni received CAZRI Foundation Day Award-2013 for best oral presentation in International conference on “Sustainable Agriculture for Food and Livelihood Security” held at PAU, Ludhiana from 27-29 November, 2012.
- Dr. Birbal received CAZRI Foundation Day Award-2013 for receiving Indira Gandhi Excellence award for outstanding individual achievements & distinguished service to the nation at a Seminar on Economic growth and National Integration on 9th February, 2013 by India International Friendship Society, New Delhi.
- Dr. N.S. Nathawat received CAZRI Foundation Day Award-2015 for best poster presentation in National Conference of Plant Physiology on Frontiers of Plant Physiology Research: Food Security and Environmental Challenges, Organized by Department of Plant Physiology & ISPP at OAUT, Bhubaneswar during 23-25 November, 2014.
- Dr. V.S. Rathore received CAZRI Foundation Day Award -2017 for best research paper entitled “Yield, water and nitrogen use efficiencies of sprinkler irrigated wheat grown under different irrigation and nitrogen levels in an arid region.” By V.S. Rathore, N.S. Nathawat, S. Bhardwaj, P.S. Renjith, B.M. Yadav, M. Kumar, P. Santra, N.D. Yadava and O.P. Yadav. In: *Agricultural Water Management*. 187: 232-245.

Medals/Awards in Sports

- Subbulakshmi, V. was awarded Best Athlete (Women) and won 6 medals in various individual events at ICAR-Zonal Sports meet (Western zone) from 24-27 Sept, 2016 at Bikaner.



- Subbulakshmi, V and Sheetal K.R. were winners of badminton doubles (women) at ICAR-Zonal Sports meet (Western zone) from 24-27 Sept, 2016 at Bikaner.



- Renjith P.S. was member of winning football team of CAZRI at ICAR-Zonal Sports meet (Western zone) from 24-27 Sept, 2016 at Bikaner.

Distinguished Visitors

- Shri Dushyant Singh Chautala, Member of Parliament and Member ICAR Governing Body on October 4, 2015.
- Dr. N.K. Ramaswami, Ex-BARC/DAE Member of HBNI/BRNS on February 15, 2016.
- Shri Dushyant Singh Chautala, Member of Parliament and Member ICAR Governing Body on April 22, 2016.
- Dr. S.K. Gupta, INAED Prof. CSSRI, Karnal on September 2, 2016.
- Dr. A.K. Bawa, Ex Principal Scientist, ICAR, New Delhi on February 17, 2017.
- Padam Bhushan Dr. R.S. Paroda, Former Secretary DARE & Ex Director General, ICAR, New Delhi on April 24, 2017.
- Shri Narendra Singh Mehra, Assistant Director (Execution), Ministry of Home Affairs, New Delhi on June 15, 2017.
- Shri R.P. Singh, Member, ICAR Governing Body on March 28, 2018.
- Dr. L.N. Harsh, Ex. Vice Chancellor, Agricultural University Jodhpur on September 2, 2018.
- Dr. T. Mohapatra, Secretary DARE and Director General ICAR, New Delhi on October 2, 2018
- Dr. J. Jena, DDG (Fisheries Science) ICAR, New Delhi on October 2, 2018.
- Dr. S. Bhaskar, ADG (AAFCC), NRM Division, ICAR, New Delhi on December 15, 2018.
- Dr. W.S. Dhillon, ADG (Horticulture), ICAR, New Delhi on January 4, 2020.
- Dr. R.P. Singh, Vice Chancellor, SKRAU, Bikaner on February 27, 2020.





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