January - June 2019

Volume 21 (1-2)

DESERT ENVIRONMENT NEWSLETTER

ENVIS Centre on Combating Desertification

ICAR-CAZRI

In this issue :

Hosted by
ICAR- Central Arid Zone Research Institute
Jodhpur

Supported by
Ministry of Environment, Forests and Climate Change
Government of India

Published by
ENVIS CENTRE
on Combating Desertification

From the desk of chairman

Dear Readers,

Irrigation has contributed significantly to increase agricultural production, improve livelihood security and stimulate broader economic development, particularly in arid and semi-arid regions. Introduction of canal and expansion of rural electrification along with modern drilling technologies (which led to expansion of groundwater irrigation) resulted in a significant expansion of irrigated lands in arid regions of Rajasthan. Groundwater is major source and accounts for ~60% irrigated areas in this region. Irrigation brought many significant changes that include enhanced land area under cultivation, crop yields, usages of improved agri-inputs, profitability, employment and decreased the uncertainty of rainfall dependent agricultural production, inter and intra year variations, migration etc. Despite all these benefits associated with irrigation, there have been many environmental externalities (irrigation induced water logging and soil salinization, over-drafting of groundwater) associated with faulty usages of irrigation. Agriculture faces the tremendous challenge of feeding the ever growing population while conserving freshwater resources and minimizing environmental consequences. With growing water scarcity and projections that indicate the need to increase agricultural production and, concurrently, agricultural water use, is increasingly advocated to focus efforts on enhancing the water productivity and minimizing negative environmental effects of irrigation. Many interventions for efficient utilization of irrigated water and for preventing and reversing irrigation induced problems have been identified. There is a need to adopt them by the active involvement of all stakeholders to consider the use of irrigated water sustainably.

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Know Your Desert

Irrigation in Hot Arid Regions of Rajasthan

Since the beginning of crop cultivation, the irrigation has been used for ensuring adequate water supply to crops throughout growing season aiming to reduce crop drought stress by compensating for low rainfall. The last century has witnessed a drastic increase in irrigation activities across the World, and the irrigated land has increased from 50 mha in 1900 to about 300 mha in 2005. Irrigation represents largest global freshwater using activities and accounts for about 60% of total fresh water withdrawals and 80% of total fresh water consumption. Irrigation contributed significantly to the massive growth in agricultural production and economic development, particularly in arid and semi-arid regions of the world. The significance of irrigated agriculture is illustrated by the fact that irrigated land occupies about 20% of total cropland of the world and produces about 40% of the world's food production. Irrigation has enhanced land area under cultivation, crop yields, usages of improved agri-inputs (seeds, fertilizer, plant protection chemicals, machinery), profitability, employment and decreased uncertainty of rainfall dependent agricultural production, inter and intra year variations, migration etc. It is estimated that the crop yields are higher in irrigated agriculture as compared to that in rain fed agriculture, which is about 2-fold. Despite all these benefit associated with irrigation, there have been many environmental, social and economic externalities associated with creation and expansion of irrigation. Here, we discuss the effects and major problems of irrigation in the arid regions of Rajasthan.

Introduction of canal [Gang, Bhakra, Indira Gandhi Nahar Pariyojana (IGNP) and Narmada] and expansion of rural electrification along with modern drilling technologies (which boosted groundwater irrigation) resulted in significant expansion in irrigated areas in north-western hot arid Rajasthan. As per estimates during 2013 -14 the net irrigated area and gross irrigated area covers about 3316295 ha and 5202067 ha, respectively in arid Rajasthan (Table 1).

Table 1. Cropped and irrigated lands in hot arid regions of Rajasthan

Particulars	Value
Net area sown	11865734 ha
Total cropped area	15701992 ha
Area sown more than once	3836258 ha
Gross irrigated area	5202067 ha
Net irrigated area	3316295 ha
Cropping intensity	132%

Groundwater is major source of irrigation in this region and accounts for about 60% of net irrigated area (Fig. 1). Well and tube wells account for >90% of net irrigated area of Sikar, Jhunjhunu, Nagaur, Jodhpur, Barmer, Pali and Churu districts of the region. The canal is important source of irrigation in Sriganganagar, Hanumangarh, Bikaner and Jaisalmer districts and accounts for 99, 98, 45 and 44%, respectively of net irrigated area of these districts.

Irrigation: benefits and problems

The irrigation had profound influence on agrarian economy of hot arid region, which is manifested by significance change in type of crops grown in the region, cropping patterns, crop yields and returns, shifting from traditional mixed farming to specialized agriculture, use of improved cultivars, fertilizer and plant protection chemicals, and mechanization of agricultural operations. Traditionally mixed farming systems, comprising of crop, tree and livestock, are predominant in hot arid region. With the development of irrigation facilities along with increased agricultural mechanization, the agricultural production system in this region became more and more specialized and there are decline in interest in traditional mixed farming. Pearl millet, moth bean, mung bean, sesame, cluster bean and sorghum

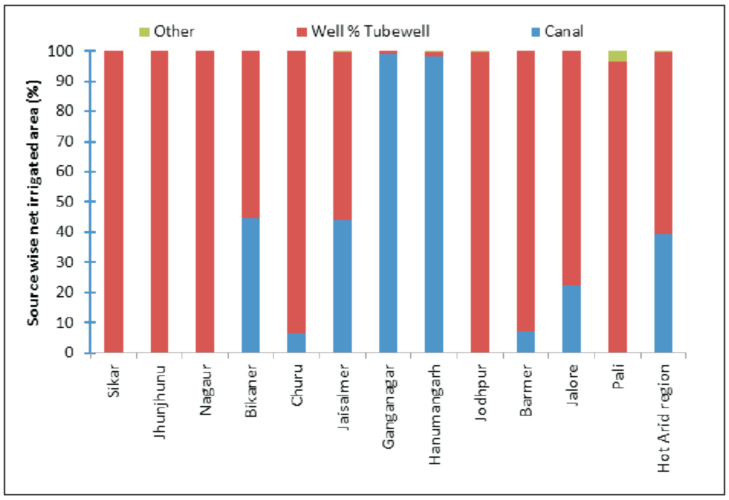

Fig. 1. Source of irrigation in different districts of hot arid regions of Rajasthan

have been major crops of rainfed regions which were grown as either sole or mixed crops in various proportions. Keeping the land fallow in alternate year was also common, which resulted into cropping intensity <100%. With the creation of irrigation facilities, cultivation of groundnut, cotton, wheat, Indian mustard, and cumin have been started in the region and cropped area sown more than once in a year increased substantially in the region. The current cropping intensity amongst 12 districts of hot arid Rajasthan varied from 120 to 158% with an average of 132%. Groundwater irrigation facilities provided opportunity for supplemental irrigation to rainfed crops which had remarkable impact of stabilizing rainfed crop yields. The irrigation facility has provided drought mitigating options to region's agriculture to some extent. The irrigation induced enhancement of crop yield and cropping intensity enhanced land productivity in the region. The creation of irrigation supported diversification to high value crops such as horticultural (fruit: ber, kinnow, pomegranate, aonla, datepalm; vegetable: cucurbitaceous, okra, brinjal, onion, pea, radish, tomato), spice (cumin, fenugreek) and medicinal (isabgol, aloe) crops in the region. The better yields and increased in cropping intensity due to irrigation improved farm profitability, farm wage and year-round demand of farm labor in the region. Irrigation led to increased uses of purchased agri-inputs like quality seeds of HYV of crops, fertilizers and plant protection chemicals. The benefits of canal irrigation is largely confined to command area of IGNP, Gang and Bhakra canals in Sriganganagar, Hanumangarh and parts of Bikaner and Jaisalmer districts. The expansion of irrigated lands using groundwater provides access of irrigation to an overwhelming majority in a large area. Overall, the creation and expansion of irrigation transforms subsistence type of agriculture to commercial agriculture enhanced yields, profits, employment of farming and improved socio-economic conditions of the farming communities in arid region. The irrigation improved the micro climate, soil and moisture conditions and associated fertility and biological properties of soils. In addition, the irrigation promoted human settlement and development of infrastructure facilities (road, markets, and electricity) and agro-based industries in the region. Hence, irrigation contributed substantially to the overall development of hot arid region.

It is well established that irrigation represents an alternation of conditions of natural landscape through extracting water from a source, artificially adding water to the field, and introducing structure and features to extract, transfer and dispose of water. Therefore, the construction and operation of irrigation projects and irrigated agricultural management practices have environmental impacts. The environmental impacts of irrigation systems depend on nature of water source, quality of water and mode of water delivery to land. For instance, withdrawing groundwater may cause aquifer to become saline or lead to other types of ground-water pollution.

Irrigation has an important role in enhancing agricultural productivity and assuring the economic vitality of hot arid region of Rajasthan. However, there are few problems associated with irrigation in this region. In the absence of good management practices in some of the regions the irrigation severely degrades the soil and water quality through waterlogging and salinization, and quantity through ground water depletion. The irrigation induced water logging and salinity build up has emerged in some pockets of IGNP command areas. Lack of proper drainage, excess irrigation, seepage from the canals and distributaries and poor drainage planning have resulted in a rise in water table, followed by salinity build-up in these areas. The average rise of water table in IGNP, Bhakra and Gang canal command areas is 0.88, 0.66 and 0.53 m per year, respectively. About 0.208 million ha land is affected by waterlogging and associated salinity in IGNP command area. The use of pumped groundwater of poor and marginal quality induced soil salinity due to absence of downward soil water flux in adequate quantity to leach salts from the root zone of crops. Most of the groundwater resources in arid regions of Rajasthan have high salinity and water low in salinity contains high RSC. Continuous irrigation with such water developed soil sodicity and resulted in marked decrease in infiltration, permeability and workability of the land. Groundwater resources for irrigation are depleting at an alarming rate due to excessive irrigation without sufficient recharge, and are posing a serious threat for sustainable crop production in the region. These forms of land and water degradation could have severe consequences for increasing crop yields with further concerns for income and employment in the long run. In addition to problems of salinization and waterlogging, downstream degradation of water quality by toxic leachates, agrochemicals and salts is also an important problems associated with irrigation.

Another important concerns linked with irrigation is poor efficiency with which water resources have been used for irrigation. A substantial amount of water diverted for irrigation is wasted from source to that used by crops. This is particular relevant due to the growth of alternative demands for water such as urban and industrial needs. Irrigation in the future will undoubtedly face the problem of maximizing efficiency. Despite significant enhancement in land productivity, most irrigated areas in the hot arid regions produce half or less of their potential crop yield which could be attained with the best management of water and other inputs.

Irrigation induced change in hydrology and landscape affects biodiversity of the irrigated areas. Irrigation-induced perceptible change in plant and animal diversity has been noticed in hot arid regions of Rajasthan. In addition to change in hydrology and landscape the irrigation –driven changes in agricultural practices resulted in change in agro-biodiversity. For instance, replacement of animal power drawn tillage equipment by tractor-drawn tillage resulted in decline in number and diversity of natural vegetation (*Lasiurus sindicus*, *Calligonum polygonoides*, *Ziziphus nummularia*, *Capparis decidua*) in cropped lands of arid regions of Rajasthan.

Many interventions for preventing, mitigating and reversing irrigation induced problems are possible which are applicable at regional, system or farm levels. Due consideration of environmental impact in the design, construction and operations of new irrigation projects, prevention of seepage from main canal and water distribution systems, proper maintenance of irrigation networks, construction and maintenance of drainage and proper use of drain water are some important engineering interventions. Ensuring greater farmer's involvement and use of management information systems in the operation and management of irrigation and drainage system is crucial system management intervention. Minimizing water losses (conveyance, seepage, percolation and surface run-off) in on-farm distribution system, use of proper design considerations (length, width, slope in accordance to soil, topography, and flow rate) for surface methods of irrigation, adoption of efficient methods (furrow, sprinkler and drip) considering soil, crop and socio-economic conditions, applying irrigation according to reliable crop water and leaching requirements are important on-farm irrigation management interventions (Fig. 2).

Fig. 2. Flood and sprinkler methods of irrigation

Adoption of HYV of suitable crops, water-use efficient cropping systems, and need based uses of soil amendments along with good crop management practices (tillage, plant nutrient management, integrated pest management) are important agronomic interventions for enhancing irrigation water productivity. Introducing rational water pricing which represent the market value of water and setting limit for allowable groundwater recharge and comprehensive environmental impact of existing irrigation projects along with assuring incentives for better irrigation management are required policy interventions.

Conclusion

Irrigation plays an important role in the development of hot arid regions of Rajasthan. However, there are negative environmental impacts like water logging, soil salinization, overexploitation of ground water resources, and decrease in agro-biodiversity. So, while irrigation has the potential to developments in these regions, these developments may be eclipsed by degradation of resources. In addition, there is need to evaluate critically the low efficiency with water is used for irrigation compared with other competitive sectors. It is worth-mentioning that the potential to increase the irrigated area in the hot arid region of Rajasthan is limited. Any addition from new generated capacity is expected to offset by loss of irrigated area in which water withdrawal exceed recharge immensely, salinization and water logging. This calls for maximizing efficient use of existing supplies rather than harnessing of new supplies, and minimizing negative environmental impacts of irrigation. The improved water use efficiency and environmental stewardship are complementary goals and both are important for long-term sustainability of irrigated agriculture.

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Technological Options

Protected Cultivation for Boosting Arid Zone Economy

Protected cultivation using greenhouse technology is modification of microclimate enabling the cultivation of crops in adverse climatic, caring least for the outside environment. The overall objective of protected cultivation is to modify the natural environment by practices or structures to achieve optimal productivity of crops by enhancing yields, improving quality, extending the effective harvest period and expanding production areas. It is often used for growing off-season flowers, vegetables, fruits, and other plants. The closed environment of a greenhouse has its own unique requirements, compared with outdoor production. Pests and diseases, extremes of heat and humidity are controlled and assured irrigation is necessary. Major concern is of energy. In hot climate immense energy is required for cooling. Greenhouses protect crops from too much heat or cold, shield plants from dust storms and help to keep out pests. In India with its vast and diverse agro-climatic conditions, protected cultivation technology in the last three decades has made good progress and proved as a boon for production of high value, low-volume crops with better productivity and quality.

Protected cultivation: a promise for vegetable production for enhanced income

The current statistics shows that vegetables productivity of arid part of Rajasthan is merely 1.8 t ha^{-1} which is far below the productivity of the whole Rajasthan (10.6 t ha^{-1}) and India (17.5 t ha^{-1}). In fact, open field cultivation of vegetables in arid regions are challenged due to erratic weather which results less productivity. The demand of vegetables is increasing but supply from local produce is limited, resulting a high price in local market, especially of perishable vegetables. Protected cultivation is an inevitable option that not only provides protection to the crops from aberrant weather but also provides favorable micro-climate for optimal plant growth and production and ensures supply of high quality vegetables even in off-seasons.

Avenues in protected cultivation

Looking to its promise in such a fragile ecosystem, where open field vegetables cultivation is risky, area under protected cultivation is increasing at faster pace. Government, though various schemes, is providing subsidies to promote this venture in the region. The common protected structures in these areas are naturally ventilated polyhouse, shade-net house, insect proof net house and low tunnel or row cover. The commercial polyhouse and shade net house are made in roughly 1000 m^2, 2000 m^2 and 4000 m^2 area.

Protected cultivation is being techno-intensive venture, attracting youths to take up this venture as entrepreneurship. Additionally, it generates good amount of employments to the local people with engaging them right from labour to greenhouse supervisor, agronomist/consultant, inputs suppliers (for seed, fertilizers, pesticides), technicians in development and repair of greenhouse and drip irrigation system. It involves a huge establishment costs but seeing its multifarious benefit and promise in arid environment, its adoption is taking place.

Greenhouse cultivation in arid and semi-arid areas is even possible during off-season in winter and summer with some critical interventions e.g., intermittent operation of sprinkler on rooftop and side curtain along with fogger and shade cover inside naturally ventilated polyhouse of suitable plastic cover with using suitable cultivars make possible its cultivation even during late summer to early monsoon, when prevailing market price of vegetables (e.g., cucumber and tomato) are very high. The added advantage of protected cultivation is the maximization of efficiency of nutrient use, along with essentially employing ferti-drip system in covered structure the water use, which is utmost require in this water scarce region.

Facts of protected cultivation in arid regions

- Ensures year round supply of selected vegetables (in naturally ventilated polyhouse).
- Multifold yield increase per unit area and per unit time, along with superior quality produce.
- High water and nutrient use efficiency.
- More income: a well-managed polyhouse can provide a regular income of Rs. 0.75 to 1.0 lakh per month.
- In general, per acre recurring cost of cucumber and tomato in naturally ventilated polyhouse in arid region ranges from 1.5 to 2.0 lakhs, which can provide gross returns of Rs. 5.0 to 8.0 lakhs depending on season and market price.
- The average yield of cucumber varies from 20 (in summer) to 40 t $acre^{-1}$ (in normal season).
- Probably, it is one of the agri-ventures that helps in attracting and retaining youth in agriculture.

Cultural aspects of protected cultivation

Cucumber is a predominantly grown vegetable in protected conditions in arid region, which is followed by tomato, while capsicum preferred least among these. Greenhouse cucumber cultivation is very remunerative owing to increasing demands for high quality seedless (parthenocarpic) fruits that fetch higher price than open field cucumber, especially during off-season (winter and late summer and early kharif). Likewise, tomato also fetches high price in normal and particularly off-season seasons.

Good management practice followed in greenhouse cultivation:

- Right choice of cultivars is very crucial in greenhouse cultivation. Terminator and Rica in cucumber and Myla, NS (TR) 4266, NS (TR) 4343, IA 07 in tomato were found most suitable for arid greenhouses cultivation.
- Planting on raised beds are preferred over flat beds and seedling transplanting over direct seeding is advised in winter season cucumber.

- Transplanting of both tomato and cucumber is preferred over direct seeding, which is practiced in cucumber. This is to be avoided in winter season crop due to required longer period in seed germination and seedling growth.
- Planting at raised bed (90 cm width) accommodates paired rows of cucumber and tomato with keeping 50 cm between the two rows. Plants are spaced at 45 cm apart in zig-zag fashion in both the rows.
- Incidence of soil borne diseases and nematodes under intensive cultivation in succession is emerging issues in protected cultivation. To manage these, integrated management approach is to be followed. Soil treatment involving deep summer ploughing followed by soil solarization by plastic covering (air tight) of saturated soil, followed by soil fumigation with suitable fumigant (e.g., formaldehyde, metam sodium) or chemical sterilant (e.g., silver-peroxide). Soilless cultivation, though its bit techno-intensive and costly is also a direct and potential solution.
- Based on season, scheduling of water and nutrient supply so as best possible balanced vegetative and reproductive growth are attained.

- Regular pruning of auxiliary shoots is essential operation to train plants to single or double leader system which allow balanced plant growth and fruiting. Removal of lower leaves after attainment of proper fruit size is essentially done in tomatoes, while in cucumber it is required for adequate reaching of sunlight and air movement, especially during winter, this is done only after lower fruits are harvested. In cluster bearing cucumber hybrids, maximum 2-3 fruits per node are retained.
- Double stem training in tomato is found promising to enhance tomato fruit yield by up to 42 percent, besides reducing requirement of 40 percent less seeds, which compensated the extra expenditure on training one extra stem in double stem training. In this, fruit yield increased without compromising the fruit size and quality and yield increase was due to increased fruit numbers.
- The effect of low temperatures that prevail under low-cost protected structure can be alleviated by grafting. Grafting commercial cucumber onto cold hardy fig-leaf gourd (*Cucurbita ficifolia*) rootstock has been found to improve cucumber yield by 30% as compared to non-grafted cucumber.
- To manage high temperatures, some improvement in structures design such as increase in vent size and adequate shading, intermittent operation of sprinkler on top and side wall and mid-day operation of fogger beneath the shade net inside polyhouse. Besides, if possible use of fan-pad evaporative cooling, air circulating fan operated by electricity or solar power would be better. Research on improving heat stress tolerance through grafting by using resistant rootstocks is underway.




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Prospects of Sustainable Production of Pomegranate in Rajasthan, India

Pomegranate performs best in climate of hot dry summer and cold winter at ripening. High humidity during maturity and ripening adversely affect the quality and proliferates diseases. Therefore, arid climate with mild winters and hot summers in away is ideal for its growth. While cool and dry climate during fruit development improves its fruit quality. Pomegranate is fairly drought tolerant and can tolerate soil salinity up to 6.0 dSm^{-1} and sodicity up to 6.8 ESP and can also be grown on marginal and sub marginal lands.

Current status of pomegranate in Rajasthan

Since, pomegranate can be cultivated successfully on saline or sodic lands of marginal and sub marginal dry lands, a large tract of slightly degraded land available in Rajasthan for its cultivation. Moreover, the recent buyer driven introduction of Bhagwa variety under ferti-drip system and further research support has revolutionized the pomegranate cultivation in the region. The growth of pomegranate cultivation in Rajasthan can be easily visualized from the acreage expansion from 793 ha during 2010-11 to greater than 10000 ha during 2016-17 (Fig. 3).

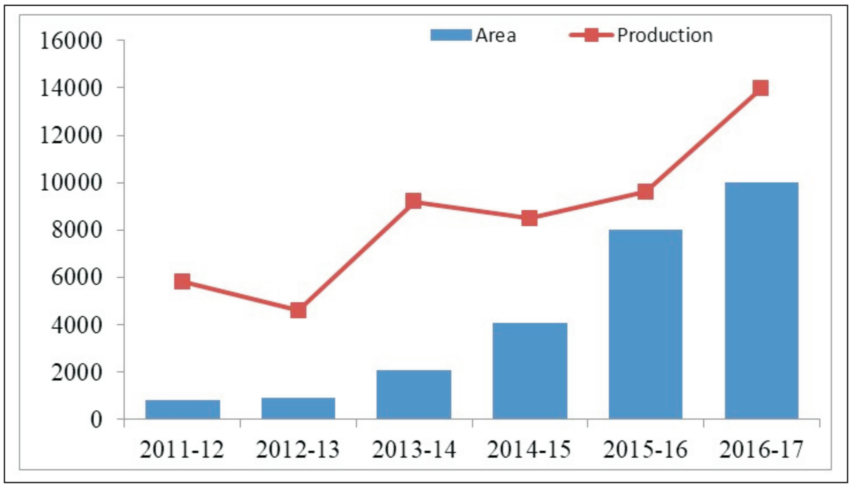

Fig. 3. Area and production of pomegranate in Rajasthan
(Source: Dept. of Hort. Govt. of Rajasthan)

In the state, it is mainly cultivated in Barmer, Jalore, Bhilwara, Sriganganagar, Chittorgarh, Jodhpur etc. Barmer district is the leading district in the cultivation of pomegranate contributing 44.0% to the state production. Jalore has the second largest acreage under pomegranate followed by Bhilwara, Sriganganagar, Chittorgarh and Jodhpur. Majority of the orchards developed with Bhagwa variety under ferti-drip system.

Production practices adopted in Rajasthan

Pomegranate is sensitive to soil moisture fluctuation causing fruit cracking which is a serious problem of this crop. Air-layering and stem cutting are most easy and common vegetative methods of pomegranate propagation. Under arid region, stem cutting is most popular and successful. However tissue cultured plants are find place in commercial plantation. Rectangular planting system at spacing of 4m x 3.5m accommodating 715 plants in one hectare is optimum. Multi stem training with 3-4 main stem is more advantageous over single stem. Plant response well to pruning and has direct influence on yield and quality of fruits. Pomegranate has tendency to bear flower and fruits throughout the year. Mrig bahar season crop bears best quality fruits in arid region. Crop regulated for Mrig bahar by withholding water in June followed by spraying of ethephon (2.0ml/L) in July. Fertigation with water soluble macro and micro nutrient is economical and saves 30-40% of water and fertilizer, reduce fruit cracking and increase production of marketable fruits. Foliar feeding of multi micronutrient solution (2ml/L) containing boron, zinc, iron and calcium is needed to improve the quality of fruit. Water quality also plays a major role on fruit production. High salinity in soils and saline irrigation water affects normal fruit production. On an average fruit yield of 12-15 t ha^{-1} is being obtained from a well maintained five years old orchard. The quality of the fruit produced in the region matches with the export specifications e.g. dark rose pink colour of the fruit and aril, fruit shape of round and globose along with soft seeds and low acid content.

Major Bottlenecks

Undoubtly the region has shown substantial growth both in area and production but productivity with export quality fruits is major concern which is quite low and varies amongst districts. Over exploitation of natural resources especially scarce and poor quality water at alternate days under degraded saline/sodic land of arid climatic conditions aggravating in secondary soil salinity buildup. Over utilization of chemical fertilizers and irrigation water leads to unwanted excessive vegetative growth on expanse of poor canopy architecture. Because of high canopy growth there are too much of flowers set fruit but produces sub grade fruit <350g, uneven size, shape and colour.

Heavy infestation of nematode

Infestation of Bacterial blight

Fruit cracking

Sun Scald

Cracking of pomegranate fruit is a general problem throughout its growing areas and among all varieties and it may varied from 18% to 62%. Sun scald is another factor responsible for low productivity and poor quality fruits of pomegranate in arid region. Heavy infestation of nematode is general problem throughout its growing areas and is directly or indirectly associated to frequent irrigation as it proliferates under excessive soil moisture and humidity conditions in sandy soil. Secondly, the soil media of planting material imported from other region if already infected with nematode multiply at faster rate upon favorable conditions. Same is the case with bacterial blight disease infestation as it is reported from couple of orchards in Barmer district and these conditions are more vulnerable. All these problems are directly related to non-availability of quality planting materials in bulk at local level. Growers of the region following 30-35 sprays of various insecticides-pesticides and other chemicals which is not only redundant but also increase cost of cultivation and may be impediment to become export commodity from the region due to high residual load in fruits. Apart from these major problem for sustainable production of pomegranate in the region is instability in price due to unorganized marketing. There is serious lack of market support and value chain from production to consumers, predominantly marketing is under control of middle man. There is technological gap in utilization of low grade fruits in to some value added products to get better return from the produce.

Opportunities

Even under scarce and poor quality water, degraded saline/sodic land of arid climatic conditions, pomegranate cultivation showed its potential. To maintain and sustain the competitive edge and share, it is necessary to increase productivity by increasing input use efficiency, reducing cost of cultivation and systematic area expansion. Refinement of production practices and its demonstrations increased net profit up to 4.0 - 4.5 lakhs ha^{-1} compared to around Rs. 20,000 from traditional farming and have been demonstrated by most of the growers from this region and thus alleviating poverty levels in the growing belts. It is an ideal crop for the sustainability of poor and relatively degraded soil and agro-climate of arid and semi-arid regions has high potentials to develop wastelands widely available in the region and an ideal crop for diversification. About 153 different phytochemicals viz. ascorbic acid, anthocyanin, polyphenols, β-carotene, total antioxidants activity, minerals content etc. associated with crop made as an important medicinal fruit crop too and preferred crop for health conscious people worldwide. Secondly this crop having extended shelf-life provides buffer time during shipping and transportation globally. Demand in the international market has widened the scope for earning higher dividends from this crop by producing export quality fruits. World trade is around 1.2-1.5 million ton annually but our share is only 5-10% though we are highest producer in the world. This part of country is able to produce finest quality of pomegranate having soft seeds, very less acids and very attractive colour of the fruits and grains.

Desirable fruit characters of fresh Pomegranate for export purpose

- Dark rose pink colour of the fruit.
- Fruit weight around 500 g
- Round and globose shape of the fruit.
- Uniform size and shape of the fruit in a pack or box.
- Dark rose pink arils.
- Softness of the seeds.
- Higher sugar content near about 16-17 Brix.
- Free from scars, rossetting, disease spots, insect injury, scratches, etc.
- Smooth cutting at the stem end.
- Pleasant flavour and aroma.
- Bracts/calyx without any damage and having free.

Bhagwa variety which is a major variety has high acceptance in international market including European market. Harvesting season and quality of produce matches export specification, and hence marketing is not a constraint even under higher production. With adoption of "bahars", pomegranate can be supplied from January to April when there are maximum demands from European market (Fig. 4). Presently, India exports pomegranate mainly to U.A.E., Saudi Arabia, Bangladesh, Bahrain, Kuwait, Oman, Netherlands however, there is great demand of Indian pomegranate in European and the U.S. market. India is the only country able to produce and deliver pomegranates round the year because of diverse climatic condition and by adopting the crop regulation accordingly. Hence, India can become a big player in exports to Europe, the Middle East and the U.S. This region can contribute immensely in Indian export basket by supplying fruits during December to April when there is lean period at major pomegranate producing states like Maharashtra, Karnataka and Tamil Nadu.

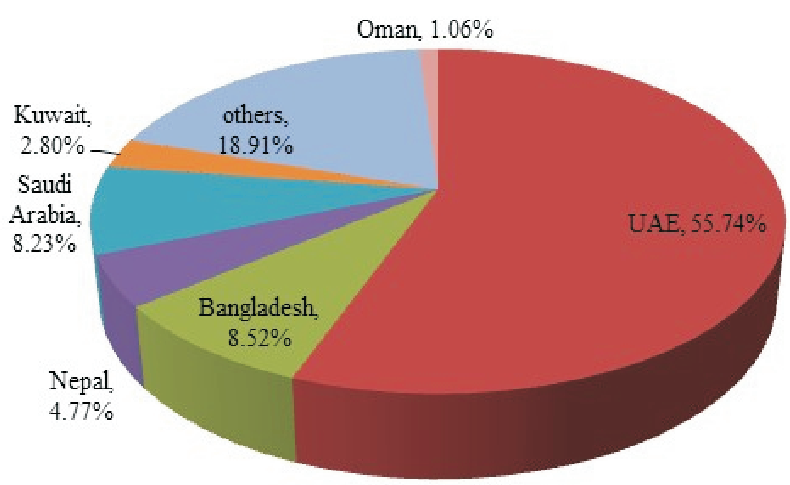

Fig. 4. Share (%) of major importing countries of India's pomegranate

This crop has good commercial potential and the area under this crop is increased significantly in the state. Hence, government support is also sought in developing infrastructure facilities like scientific pack house and storage facilities, processing units, transportation facilities and forward linkage in the region to safeguard the interest of pomegranate growers.

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Know Your Desert Plant

Goondi (*Cordia gharaf*): A multipurpose shrub of Arid Western Rajasthan

Goondi (*Cordia gharaf* Forsk.) belongs to the family Boraginaceae, is an under-utilized multipurpose woody perennial species, and primarily occurs in arid tracts of western Rajasthan and Gujarat and also in some parts of Delhi, Uttar Pradesh and Kerala. It is found grown in wild conditions in dry deciduous forest tracts, particularly well along rocks and in dry gravely soils and commonly planted along the boundary of cultivated fields. It is well adapted to soil moisture stress, desiccated winds and high ambient temperature due to its morphological and physiological characteristics. Under natural habitat, this species is usually found associated with several perennial grasses such Sewan (*Lasiurus sindicus*), Dhaman (*Cenchrus ciliaris*) and Gramna (*Panicum antidotale*) and with important arid shrub and tree species such as Kair (*Capparis decidua*), Gangeran (*Grewia tenax*), Bordi (*Ziziphus nummularia*), Pilu (*Salvadora oleoides*) and Khejri (*Prosopis cineraria*). The variability observed during collections of *C. gharaf* covering different habitats in Jaisalmer district. It was found in existence of two forms viz., tree form in arable area/plantation and shrub form in rangelands. In rangeland condition, it exhibited wide lateral canopy spread, which has great potential in soil conservation. Under domesticated condition, the species generally flowers during March-April and fruiting occurs in May-June. However, flowering and fruiting observed in July and August under rangeland. Ripe fruits showed round to ovoid shape and orange to reddish brown colour.

It is often propagated through seeds. Ripe fruits are crushed on a mesh along with sand to remove the mucilaginous pulp and seeds are extracted. Seeds are sown within 10-20 days after extraction as they lose their viability with time. Prior to sowing, seeds are soaked in water and kept for 24 hours. Germination starts in 5-6 days and continues up to 15-20 days. 50-60% germination can be obtained if shown well in time with proper depth. Nymphal stages of some pest such as Leaf minors are the problem in nursery, which suck the plant sap and if left uncontrolled can devitalize the seedlings, which are controlled by applying systemic insecticide viz., Monocrotophos (0.1%). Seedlings are ready to be planted in field after 3-4 months when they grow up to 60-70 cm in height. Planting density could vary between 100–278 trees per ha based on the purpose of planting and the system followed.

The species is mainly cultivated for its edible fruits. During summer season (May- June), the tree is bestowed with numerous orange colored ripe fruits which are sweet and delicious and provides attractive appearance (Fig. 5). Ripe fruits are sold in local market. Fresh ripe fruits are eaten and also dried for future consumption. It is highly browsed by livestock and wild animals. The species provide excellent fuel wood, the calorific value of which is comparable to wood of *Prosopis cineraria*. It has great medicinal and pharmacological value. Its bark has astringent properties, the decoction of which is used as a gargle and to treat dyspepsia, fever and also shows cardiotonic activity. Fruits have astringent, demulcent, diuretic, purgative, anti-ulcer and hepatoprotective properties beside useful in constipation, stomach worms, piles and toothache. Leaves extract shows significant increase in the wound-healing activity in the animals. Mucilage obtained from its fruit possesses comparable binding properties. The species is hardy and often used as root stock for its commercial counterpart *Cordia myxa*.

Fig. 5. Full bearing stage and harvested ripe fruits of *Cordia gharaf* at farmer's field

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Knowledge Corner

Can solar-based atmospheric water harvesting be a potential method for collecting water in Thar Desert of Rajasthan?

Atmospheric Water Harvesting

In arid regions, abrupt changes (or shifts) and gradual changes (or trends) causing the rainfall variability over the temporal and spatial scales have profound influence on the dynamic linkages between ecosystems and water cycle mainly due to the limiting water resources, which is constrained not only for scarce quantities but also for its intermittency and unpredictable nature. Studies on analyzing rainfall variability are of high importance for the arid regions. However, such studies are mostly carried out in humid and semi-arid regions, and the studies for arid regions are rare. The issues of water-shortages and water scarcity can be easily tackled by rainwater harvesting techniques, which is being practiced from the historical times all over the world. However, under the extreme aridity conditions and failure of monsoon rains, such methods have limitations of dependence on occurrence of rainfall (Fig.6).

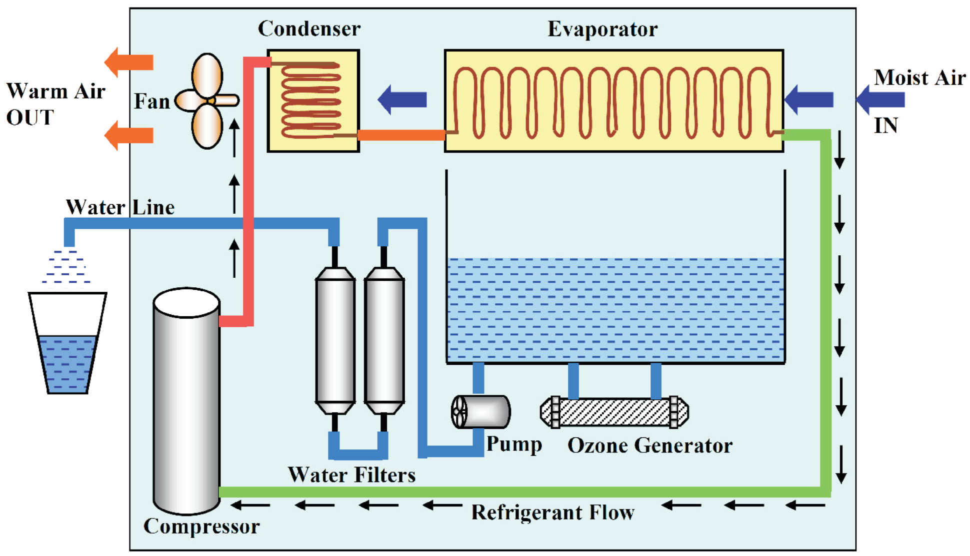

Fig. 6. Schematic of Conventional Atmospheric Water Harvesting System

Atmospheric water harvesting (AWH) is relatively a new concept where moisture available in the atmospheric air is extracted by condensation process and is converted to water. The AWH is one of the promising alternative methods for getting pure water in dry regions especially where relative humidity remains in high amounts in the atmospheric air such as coastal arid lands and similar regions. It is estimated that a plenty of water (12,900 billion tons) is available in the atmosphere even in very dry desert regions, and the atmospheric water, consisting of water vapour and water droplets, is a resource equivalent to about 10% of all freshwater in lakes and is 6 times all water in rivers on Earth. Therefore, atmospheric water is currently captured in remote villages of more than 25 countries worldwide, for example, Chile, China, Egypt, India, Israel, Republic of Korea, Saudi Arabia, Spain, among others.

Water from air can be collected through several ways, for example, fog harvesting, dew harvesting through active/passive refrigeration, and sorption in conjunction with easily accessible low-grade energy. Fog harvesting is considered as the ancient method, where water droplets floating in the air are directly collected. However, this method needs a constantly high ambient relative humidity (~100%), and thus, it is feasible only in very limited areas. In refrigeration method, an engineered cold surface is used to cool adjacent air mass below the dew point to produce water droplet through condensation. In general, it is observed that refrigeration is not feasible in regions experiencing either consistently low relative humidity (<40%) or lack of electricity. The sorption-based method is also a method that employs water sorbent to absorb water vapor from air, followed by heating up the saturated sorbent to release and subsequently condense the water. A major advantage of the sorption-based method over the other methods is its capability of producing water from dry air with humidity even lower than 20% in the absence of electricity.

Principle of Extracting Moisture from Atmosphere

A large amount of water always remains available in the atmosphere in the form of water vapour, moisture, etc. and it is estimated that 30% of that water is usually wasted. Many different type of air water generators have been designed and fabricated to extract that amount of water from air. The water extracted by the AWH technique can be directly used even for drinking purpose as it is pure. The AWH method uses the principle of latent heat to convert water vapour molecules into water droplets. The concept of AWH is relatively new although rapid developments are being made in the field of AWH using many different materials for extracting water from the atmosphere. Initially, it was felt that AWH may be successful only in the areas where adequate relativity humidity exists in the atmospheric air. However, later on, advances in AWH technique made it possible to extract the air even in the regions having low relative humidity. Presently, technique is available to harvest water from the air of desert regions having very low relative humidity. In many countries like India, there are regions of extreme aridity such as Thar Desert where resources of water are limited. At those places, the AWH method is looked as the prospective solution of water scarcity. Previously, many researchers worldwide used the concept of air condensation as well as generation of water with the help of Peltier devices, such as harvesting water for trees using Peltier plates that are powered by solar energy, etc (Fig. 7).

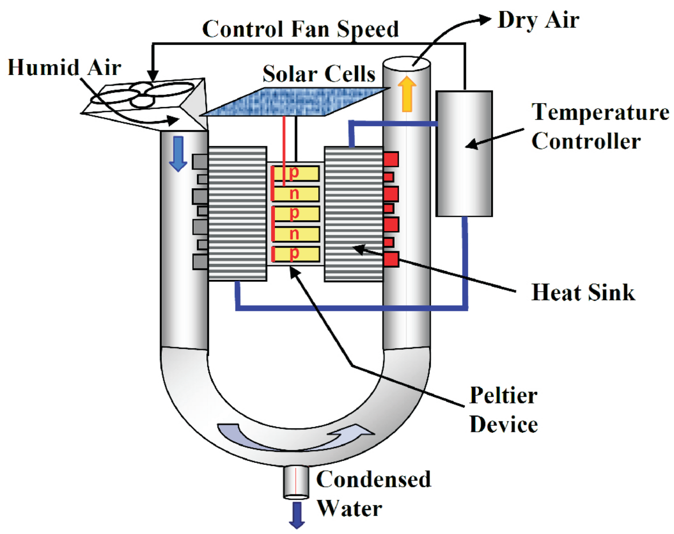

Fig. 7. Schematic of Atmospheric Water Harvesting System with Peltier Effect Powered by Solar Energy

Water is condensed at dew point temperature, which is practically achieved with the help of some electronic devices such as a thermoelectric Peltier couple. The thermoelectric Peltier couple is used to create the environment of water condensing temperature or dew point. A conventional compressor and evaporator system may also be used to condense water by simply exchanging the latent heat of coolant inside the evaporator. Recently, AWH method is combined with solar-thermal process along with effective water vapor sorbent. This type of AWH system is fully solar energy-driven, and thus, is also cost-effective in a long run.

Low Relative Humidity and High Energy Requirements

Since the water potential in atmosphere is about -100 to -500 bar, the AWH system need to be designed in such a way that water potential in the AWH system remains less than -500 bar to enable water moving from high to low water potential side. In nature, water flows either through soil to plant and then to atmosphere or directly from soil/free water body to atmosphere. This is because water potential remains about -0.3 bar in soil at field capacity, -1 to -3 bar in stem and -15 to -20 bar at leaf of the plant. Thus, water flows from high (soil) to low (plant leaf) water potential. Similarly, decreasing relative humidity in atmosphere increases the atmospheric water demand or in other terms decreases water potential in atmosphere. In arid region of western Rajasthan, relative humidity usually remains very low, which may pose difficulty in extracting moisture from the atmosphere as water needs to be flowed in opposite direction of natural flow in the proposed AWH system. Therefore, a large amount of energy may be required to follow the pathway against the natural flow direction of the water. Future studies evaluating feasibility and economics of the AWH system in arid regions of Western Rajasthan may further enlighten scope of solar energy in operating the AWH system.

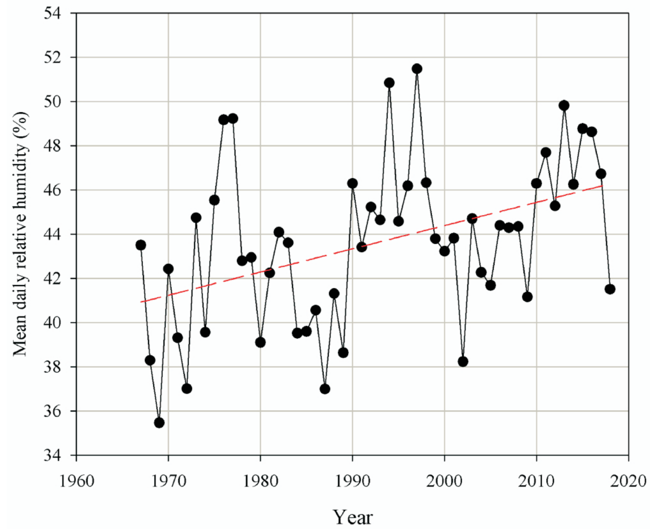

Fig. 8. Mean Daily Relative Humidity at Jodhpur over 52-Year (1967-2018) Period

Analysis of 52-year (1967-2018) relative humidity data collected from Meteorological Observatory of ICAR-Central Arid Zone Research Institute, Jodhpur revealed an increasing linear trend in the mean daily values of relative humidity (Fig. 8). Subsequently, lesser energy would be needed in extracting moisture from the atmospheric air experiencing increasing relative humidity. Thus, there exists a fair scope for utilizing the solar energy under the extreme climatic conditions of the Thar Desert in western Rajasthan for extracting the water from atmosphere.

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Events by ENVIS CAZRI

RE-ENVIS 2019

Seminar on Climate Change and Desertification: Renewable Energy Solutions for Enhancing Mitigation potential in Rajasthan

ICAR- CAZRI, ENVIS Centre on Combating Desertification, Jodhpur and The Energy and Resources Institute (TERI), New Delhi jointly organized seminar on "Climate Change and Desertification: Renewable Energy Solutions for Enhancing Mitigation Potential in Rajasthan" on 10th January, 2019 at Jaisalmer. Dr. Anandi Subramanian, Principal Advisor, Ministry of Environment, Forest & Climate Change, GOI in her inaugural address as chief guest stressed about various facts and facets of desertification and its control including effective strategies. Dr. Devi Dayal, Head, CAZRI-Regional Research Station, Bhuj, Gujarat in his presidential address talked about maladies of climate change and application potential of renewable energy in its mitigation.

Dr. Amit Kumar, Senior Director, TERI in his key note address discussed about various types of renewable energy, its application and assured utilization in future. Dr. J.P. Singh, Coordinator, ENVIS centre of CAZRI, Dr. P.K. Bhattacharya, Coordinator and Ms. Pallavi Shukla, Programme Officer of ENVIS centre of TERI highlighted the activities of their respective centers. Mr. Virendra and Mr. Bhupendra being the participants of already conducted Green Skill Development Programme (GSDP) by CAZRI ENVIS centre shared their experiences.

During technical sessions, Dr. P.C. Moharana, Principal Scientist of CAZRI, Jodhpur opened up the fundamental linkages between geomorphology and geology with desertification. Dr. Pia Sethi, Senior Fellow and Area Convenor, TERI talked about the economic implications associated with desertification. Dr. P. Santra, Principal Scientist of CAZRI, Jodhpur discussed about agri-voltaic system based energy generation in ensuring water and food security in desert landscape. Plenary sessions were also conducted on renewable energy alternatives: mitigation and adaptation to desertification in Rajasthan and also on policy perspectives: the national action programme to combat desertification wherein Dr. Anandi Subramanian, MoEF&CC, GOI, Dr. Amit Kumar, Dr. Pia Sethi, TERI, New Delhi, Dr. Devi Dayal, Dr. Dilip Jain, Dr. P. Santra, Dr. R.K.Kaul and Dr. P.C. Maharana, ICAR-CAZRI, Jodhpur and Dr. G. Singh, AFRI, Jodhpur interacted and expressed their views and concern.

In this seminar representative from Indian Council of Agricultural Research, National Remote Sensing Centre of ISRO and Arid Forest Research Institute of Jodhpur; Department of Forest, Agriculture, Animal Husbandry, Ground Water, Government of Rajasthan, Non-Governmental Organizations, Educational Institutions, experts and farmers actively participated.

National Science Day

Celebrated National Science Day on 28th February, 2019 on the Theme "*Science for the People and People for Science*" at Krishi Vigyan Kendra, Gudamalani, Barmer. On this occasion Dr. J.P. Singh P.S. & Coordinator ENVIS RP, briefed the contribution of science for the people specially its importance in agricultural sector. Dr. Pradeep Pagaria, Head KVK-Gudamalani highlighted impact of science and technology in transforming the agriculture scenario in Barmer district. The programme was attended by teachers, students and local farmers.

International Day of Biodiversity

Organized the International Day of Biodiversity on 22nd May, 2019 in association with M/S Cairn Oil & Gas Vedanta Ltd., Barmer. Shri Vikram Kesar Pradhan, IFS, Deputy Conservator of Forest, Barmer was the chief guest. He emphasized the



contribution of biodiversity in every food item and also cited the role of State bird Godawan in biodiversity. Dr. J.P. Singh, Coordinator, ENVIS, highlighted the overall biodiversity of arid region. Dr. R. S. Tripathi, Principal Scientist shared the ongoing activities of ENVIS and CAZRI, Shri Bhanu Pratap Singh, Manager, CRC, Cairn Oil & Gas Vedanta Limited, Barmer highlighted the activities and working of the company. On this occasion 45 students of CEC actively participated.

World Environment Day

Celebrated the World Environment Day on 5th June, 2019 at village Ghevra, Tinwari, Jodhpur. Chief Guest Shri Chandra Singh, progressive farmer said that every person has to be attentive to the environment in view to reduce the air pollution. Dr. J.P. Singh stressed upon conservation and promotion of plants in our daily life to preserve the desert environment. On this occasion plants of Khejri, Rohida, Gonda etc were distributed and also planted. The seeds of medicinal plants like Tulsi, Ashwagandha, Sarguda, Ghavbel, Sonamukhi were also distributed. Quiz competition for students was also arranged during this programme.




World Day to Combat Desertification

Organized "World Day to Combat Desertification" on 17th June, 2019. On this occasion Dr. P.C. Moharana, Principal Scientist, ICAR-CAZRI delivered lecture on "Understanding sand and dust storms (SDS) through satellite images for desertification studies". He emphasized that evaluation of sand as constituent of soil in arid part of Rajasthan depends upon proper assessment of landforms which are polygenic as evidenced by geomorphic processes of aeolian, fluvial, lacustrine and tectonic types. Chief Guest of the function, Dr. O.P. Yadav, Director, ICAR-CAZRI, Jodhpur said that this institute maintains its identity at the international level for the prevention of desertification. Dr. J.P. Singh, Coordinator, ENVIS elaborated the significance of World Day to Combat Desertification.






News


नई तकनीक की दी जानकारी...
मरुस्थलीकरण रोकने के लिए उठाने होंगे कदम


कृषि क्षेत्र में विज्ञान का उपयोग कर राष्ट्र के विकास में महत्वपूर्ण योगदान दें : डॉ. जेपी सिंह


विज्ञान ने बदली तकदीर व तस्वीर
राष्ट्रीय विज्ञान दिवस पर कार्यक्रम


जैव विविधता के विविध पहलुओं से रू-ब-रू कराया
सीईसी में विश्व जैव विविधता दिवस पर कार्यक्रम


अंतर्राष्ट्रीय जैव विविधता दिवस मनाया
काजरी की कार्यप्रणाली एवं पेड़-पौधों और फल बेर, आंवला, अनार, खजूर की उत्तम किस्म के बारे में विस्तार पूर्वक दी जानकारी


वैज्ञानिक संगोष्ठी आज
जलवायु परिवर्तन एवं मरुस्थलीकरण की रोकथाम विषयक वैज्ञानिक संगोष्ठी संपन्न


विश्व मरुस्थलीकरण रोकथाम दिवस
151 देश आंधी व रेत से परेशान

Conferences

DATE	TOPIC	PLACE
	National	
18-19th January, 2019	National Conference on Recent Trends in Environmental Sciences	Satyaniketan's Adv. Manoharrao Nanasaheb Deshmukh, College, Ahmednagar in association with International Journal of Scientific Research in Science and Technology, Ahmednagar, Maharashtra
31-2nd February, 2019	National Environmental Conference	The Centre for Environmental Science and Engineering (CESE), IIT Bombay
5th April, 2019	National Conference on Biodiversity, Ecosystem & Climate Change (NCBECC 2019)	CSI College of Engineering, Ooty in & Hillgrove Research Pvt. Ltd., Coimbatore, Ooty, Tamil Nadu, India
26th May, 2019	National Conference on Advanced research on Science, Engineering and Technology (NCARSET)	Asian Society for Academic Research (ASAR), Solapur, India
	International	
9th February, 2019	The Golden Jubilee International Salinity Conference (GJISC - 2019)	ICAR-Central Soil Salinity Research Institute, Karnal, Haryana
11-14th February,2019	The13th International Conference on Dry land Development, "Converting Dryland Areas from Grey into Green"	International Dryland Development Commission (IDDC) and Arid Zone Research Association of India (AZRAI) and hosted by the ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur
27 - 28th-April-2019	The International Conference on Environment and Life Science (ICENLISC-19)	National Institute For Engineering And Research (NIER), Bhilai, India
28th April 2019	International Conference on Forestry Food and Sustainable Agriculture (ICFFSA)	World Research forum for Engineers and Researchers (WRFER), Jaipur, Rajasthan