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ICAR-National Institute of Abiotic Stress Management
(Deemed to be University)
Malegaon, Baramati- 413 115, Pune, Maharashtra, India

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भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान
ICAR-National Institute of Abiotic Stress Management
(समतुल्य विश्वविद्यालय / Deemed to be University)

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सचिव एवं महानिदेशक
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FOREWORD

Indian agriculture is confronting with the dichotomous challenges of food security and sustainability within finite land and water resources and impending climate changes. Thus, providing vistas from science of land-water-environment continuum suiting to the societal needs for food security remains a plausible option. Keeping this in view, ICAR established National Institute of Abiotic Stress Management (NIASM) at Malegaon, Baramati on 21st February, 2009. The mission of the institute is to develop an insight into background, hypotheses to mitigate, strategies to incorporate with the foresight and continuously acceptable policy issues with practice of climatically adapted farming system to build sustainable and profitable livelihood in abiotically stressed environment. ICAR-NIASM is completing its 10 years and celebrating the 11th Foundation Day on 21st February 2019. In last ten years, most of the infrastructural facilities have been developed. The significant facilities developed are construction of administrative building, two school buildings, guest house, hostels with dinning block, phenomix facility, well established labs, green houses, livestock and fishery farms and residential quarters at campus as well as at MIDC, Baramati. The most important achievements are the development of model research farm, innovative planting methods for establishment of orchards in shallow basaltic terrain.

The 'Technology bulletin" of ICAR-National Institute of Abiotic Stress Management is very much useful for stakeholders and policymakers to addresses the atmospheric, drought and edaphically stressed environment issues for growth and development of agriculture, horticulture and livestock sector in future.

(T. MOHAPATRA)

Dated the 13th February, 2019
New Delhi

भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्था
ICAR-National Institute of Abiotic Stress Management
(समतुल्य विश्वविद्यालय / Deemed to be University)

Narendra Pratap Singh
Director,
ICAR-NIASM

Preface

Indian agriculture is confronting with the dichotomous challenges of food security and sustainability within finite land and water resources and impending climate changes. Thus, providing vistas from science of land-water-environment continuumsuiting to thesocietal needs for food security remains a plausible option. Keeping this in view, ICA Restablished National Institute of Abiotic Stress Management (NIASM) for undertaking research related to impacts of abiotic stresses on crop production, livestock and fisheries and exploring long-lasting options for their adaptation and mitigation strategies at Malegaon, Baramati, Pune. For addressing the issues of water scarcity, drought and edaphic stress in orchards, pollution due to burning of trash, the institute has demonstrated the innovative planting techniques for establishment of orchard, SORF machine on farrmer's sugarcane field and high value dragon fruit crop orchards forvisiting farmers.

This institute technology bulletin covers various demonstrated technologies at institute and farmers field. I am sure that this information will help the farmers in improving the package of practice of crops including horticulture crops in semi-arid region. ICARNIASM will be guiding the farmers on these issues.

(Narendra Pratap Singh)

CONTENTS

1 Transforming Barren Rocky Basaltic Terrain into Cultivation of Arable Crops

Introduction

Indian agriculture is confronting with the dichotomous challenges of food security and sustainability within finite land and water resources and impending climate changes. Thus, providing vistas from science of land-water-environment continuum suiting to the societal needs for food security remains a plausible option. About 42% (6 m ha) of degraded land in India mainly suffers with hard pan and having shallow soil depth. The soil formation is through the weathering of basaltic igneous rock. The scanty rainfall, recurring droughts, ill drained soil and improper technology for agriculture, ground water recession in addition to high temperature are the major driving forces for the poorly developed soil formation in these areas. The site at ICAR-NIASM was covered with shallow 0.1–0.3 m murrum soil made with parental basaltic rock shield exposed due to slow physical, chemical and biological weathering process. An attempt was made to convert this type of barren rocky land into cultivation depending upon the investment power, risk taking ability and availability of irrigation water. We are having sound techniques for bringing uncultivable rocky barren lands under cultivation for arable crops and horticulture crops.

Details of transformation of rocky barren land

The ICAR-NIASM has developed viable technology for transforming uncultivable rocky basaltic terrain into productive land within a short period of three years. Steps involved in bringing the shallow basaltic rocky land to productive land are:

Step 1: Ripping and chaining by heavy machineries

In mechanical process, parental rock blocks were targeted to be disintegrated into smaller sized boulder/garvels/granular forms either by blasting or ripping. First the land was subdivided into terraces and subplots based on the topography across the slopes. The top 0.1 - 0.3 m *murrum* soil was scrapped and separately collected by front dozer before levelling terrace/plots with the aim of reusing this soil for top filling of terrace/subplot. For performing ripping operations heavy machines (Dozzers, 200 HP) were used. The ripping of the area was carried out using Dozer with ripper (Model No. D355)for breaking the weathered and non-weathered rock/*murrum* fragments down to the 0.9 mdepth through its tines. Finer grades of the primary and secondary zeolite materials were further induced through chaining with the same dozers. The processes of ripping, chaining and pushing were repeated 2 - 3 times till the terrace/plots got uniformly levelled. Though after each ripping operation, big hardy stones got crushed by chaining with the dozers. The hard stones remaining even after chaining were collected physically and transported for their utilization in filling the base of the roads.

Step 2: Blasting

After scrapping/removing the shallow top murrum soil, the exposed hard rocky portions left in patches after chaining and ripping by the heavy dozers were shattered by blasting. For this purpose series of holes of approximately 50 mm size were drilled using semi-automated tractor operated drill machine at spacing 0.5-1 m and 0.6-0.9 m depth depending upon the hardness of the rock along a line defining where the rock should split. Blasting releases energy in the form of fragmentation and displacement of rock, vibration of ground and air blast. The heavy stones during the blasting were collected and used for road filling. The remaining material thus generated was again chained, ripped and pushed for levelling.

Step 1 : Ripping/chaining of rocky surface

Step 2 :Blasting

Step 3: Removal and collection of the heavy boulder for road filling

Step 3: Application of Spent wash

The sugarcane is the major crop of this region and distillery spent wash, a by-product from sugar industries is available in large quantities. Since the raw spent wash is acidic and having pH 4.0, it was used for reaction with parental rocky materials/ *murrum* and thus augmenting the process of soil development by chemical disintegration. Moreover, being a rich source of organic matter (OC 43.8 g/l) in addition to macro-and micro-nutrients, it helps the microbes to flourish and induces the reactions of their by-products e.g. organic acids with zeolites and other materials and subsequently resulting in their dissolution. The raw spent wash (acidic nature) from Malegaon Corporative sugar factory was applied two times with an interval of 6-12 months in all the farm terraces/fields in furrows or on beds with effluent pipes from tankers. The impacts of acids in spent wash and those generated with decomposition of organic matter could be visualised in terms of resultant smaller sized stones/*murrum* so generated. The rocky basaltic/ zeolitic boulders/stones also got so softened and vulnerable after treatment with spent wash that these further disintegrated into smaller pieces of sand and gravels of different sizes when the fields were ploughed. Some plots at ICAR-NIASM were filled with black soil transported from outside up to 2 ft depth.

Step 4: Green manuring for enrichment with organic carbon and application of SMS

Once the field plots in the south-side were ready after ripping/blasting, chaining, spent wash application, removal of boulders and levelling, uniformity test was conducted for each field by growing *Dhaincha*) and also using it for green manuring. It helped to add the organic matter, nutrients etc. in the soil

The analysis of surface soils in plot with native murrum soil showed that these were still gravelly (70-90 % gravels of various sizes and rest 10-30 % less than 2mm) and low in fertility (organic carbon ~ 0.04% and available N and P ~ 14 and 1.4 kg/ha, respectively). Thus further attempts were made to enrich the soil fertility status through addition of organic manures. It was decided to add 20-25 Mg of FYM per hectare. But due to unavailability of FYM in large amount, the alternate sources of organic i.e. spent mushroom substrate based upon the cheaper supplies considering its organic carbon and nutrient content (C:N 30:1, N, P, K 2.35, 0.32, 0.17 %), were used.

Step 5: Levelling of fields

Land levelling is a precursor to good agronomic, soil, and crop management practices. Uneven soil surface has a major impact on the germination, stand, and yield of crops due to non-uniform water distribution and soil moisture. Effective land levelling optimizes water-use, improves crop establishment, reduces the irrigation time and the effort required to manage the crop. The field plots were fine levelled using tractor operated front dozer (75 hp) and land leveller. Recommended safe limit of the slope 0.1 -0.4% based on soil condition in the direction of irrigation was maintained while levelling each field plot.

Step 4: Application of spent wash to field

Step 5: Application of spent mushroom substrate (sms)

Step 6: Levelling of field plots

Step 7: Growing of dhaincha crop

Initial condition of land

Condition of land after 4 years

Cost of technology

For developing 1 ha rocky basaltic terrain into productive land, the cost will vary from Rs 55,000-70,000 depending upon the nature of slope and extent of hardiness. Farmers can generate income of Rs 60,000 from the second year only and this income will gradually increase with the time as a result of increase in yield due to increasing soil content.

Impact and beneficiaries

Nearby farmers adopted the technology mostly spent wash for disintegrating the murrum to soil and theirafter filling their field plots with black soil and used degraded rocky shallow basaltic land under cultivation. Thus, the cultivable area of the country can be increased. Substantial area out of 26.5 million hectare of similar basaltic uncultivable area (8 % of our geographical area) can be brought into cultivation.

Team Members

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2 Innovative orchard establishment methods for obviating drought and edaphic stresses of orchards grown in shallow basaltic soils of semi-arid region

Introduction

The on-site soil and water conservation technologies like trenching, contour/strip planting, graded farrows/ridges are being advocated to overcome the edaphic constraints and to enhance crop/tree growth while the off-site techniques include storage of run-off, transport of canal/drain water through multi-stage-pumping, water tankers and switching to micro irrigation. But the fruit trees suffer the most due to constraint for root proliferation with insufficient soil volume and supply of water and nutrients in required amounts in such shallow soils underlain with hard murrum pans/stones. Therefore, it is generally argued that successful cultivation of fruit trees requires a major shift in planting techniques, site preparation for planting, post-planting management as the initial establishment and growth of fruit tree saplings is the most critical phase for orchards. Thus, the aim should be to create favourable niches in the ambient where their roots are located.

Details of Innovative methods developed

Step 1: Ripping and chaining by heavy machineries

In mechanical process, parental rock blocks were targeted to be disintegrated into smaller sized boulder/garvels/granular forms either by blasting or ripping. First the land was subdivided into terraces and subplots based on the topography across the slopes. The top 0.1 - 0.3 m murrum soil was scrapped and separately collected by front dozer before levelling terrace/plots with the aim of reusing this soil for top filling of terrace/subplot. For performing ripping operations heavy machines (Dozzers, 200 HP) were used. The ripping of the area was carried out using Dozer with ripper (Model No. D355) for breaking the weathered and non-weathered rock/murrum fragments down to the 0.9 m depth through its tines. Finer grades of the primary and secondary zeolite materials were further induced through chaining with the same dozers. The processes of ripping, chaining and pushing were repeated 2 - 3 times till the terrace/plots got uniformly levelled. Though after each ripping operation, big hardy stones got crushed by chaining with the dozers. The hard stones remaining even after chaining were collected physically and transported for their utilization in filling the base of the roads.

Step 2: Blasting

After scrapping/removing the shallow top murrum soil, the exposed hard rocky portions left in patches after chaining and ripping by the heavy dozers were shattered by blasting. For this purpose series of holes of approximately 50 mm size were drilled using semi-automated tractor operated drill machine at spacing 0.5-1 m and 0.6-0.9 m depth depending upon the hardness of the rock along a line defining where the rock should split. Blasting releases energy in the form of fragmentation and displacement of rock, vibration of ground and air blast. The heavy stones during the blasting were collected and used for road filling. The remaining material thus generated was again chained, ripped and pushed for levelling.

Step 1 : Ripping/chaining of rocky surface

Step 2 :Blasting

Step 3 : Sub-surface water harvesting (SSWH) along with larger pits/trenches and microblasting

To increase the accessible water storage capacity from these shallow basaltic soils and for better root proliferation, it is advised to take up larger pits or trenches. This kind of planting is mainly suitable for shallow rooted fruit tree like pomegranate. In grapes, as the spacing is very closer, digging of longer trenches is desirable. However, the underlying murrum/rock often hinders the growth for deep rooted plants like sapota, ber and guava even when planted with larger pits/trenches. Moreover, being the tap root system, the main root has the tendency to align vertically when it penetrates to deeper layers. Therefore, to provide for greater and deeper soil volumes for root growth, about 1.0 m^3murrum below the 1 m depth of the planting site/pit was shattered and fragmented by site specific controlled micro-blasting. Blasting releases energy to crush the rock in the form of smaller fragments and also displaces it. Since these soils are highly porous, the rainwater infiltrates rapidly and penetrates into blasted site from where it is unable to percolate further due to impervious surrounding of murrum/rock. Thus, the crushed sites could further facilitate the deeper root penetration and provide sufficient access to water storage and thereby allow the trees root to carry over during critical summer period/drought.

Making pits

Making trenches

Microblastig in pits

Pits after blasting below plantng sites

Step 4 : Raised bed planting/mounding with stone pitching

Another alternative for enlargement of the rooting volume on shallow soils is to create raised bed by scrapping the surface soil. Normally raised beds of about 0.5 m height are recommended for planting fruit trees. But under arid, basaltic conditions, the broad raised beds of 1.5 m width with the minimum height of 0.8-1.0 m seem better to provide sufficient loose and friable soil for root growth. To increase the soil volume for creating ridges, scrapping may be preceded by ripping. The wide furrows formed in between the two raised beds can be used for in situ conservation of run-off rain water. This structure is highly suitable for fruit trees like mandarin and lime which are surface feeder and their active roots reside in surface about 1.0m soil depth.

Such beds have an advantage over cumbersome trench/ deeper pits that require heavy machinery to pierce into underlain murrum/basaltic rock and its fragmentation. Nevertheless, the disadvantage may be the higher exposed surfaces which are prone to high water losses in terms of evaporation/run-off. To overcome this, the ridges were covered with black plastic weed mulch which will help to reduce both the evaporation and weeds. Sometime the pitching of the ridges were done with available gravels and covering with thin black polythene sheet helps in reducing the soil erosion also.

Nagpur mandarin established on raised beds

Performance of sapota orchard

Performance of Pomegarate orchard

Guava

Sweet Orange

Cost of technology

The cost involved per hectare in various planting methods are 2 – 2.5 lakhs in general and will again vary as per the crop type, nature of slope, extent of hardiness. Farmers can generate income of Rs 2-3 lakhs per hectare from the third year only and this income will gradually increase with the time as a result of increase in yield due to better soil formation and crop development at planting site.

Impact and beneficiaries

There is potential to spread in unutilized area of degraded lands of Deccan region. It improves the socio-economic status of farmers through establishing and improving the fruit productivity of horticulture crops by using the improved planting techniques for shallow basaltic soil. Substantial area out of 26.5 million hectare of similar basaltic uncultivable area (8 % of our geographical area) can be brought into cultivation.

Team Members

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3 Dragon Fruit: Wonder crop for rocky barren lands and water scarce areas

Introduction

The impact of climate and human interference on land use pattern and land degradation has drawn worldwide attention. The proportions of productive lands are gradually declining with anthropogenic interventions. The Deccan region of India contributes a large portion to these types of landforms where rain, high temperature and edaphic constraints exist. Generally, from crop adaptation and production management point, these harsh landforms are more suited for horticultural crops as compared to field crops. Hence, there is an urgent need to identify crops, species and genotypes that can grow in these harsh agro-ecologies. Moreover, the urban consumers are now nutritionally aware and are willing to try natural products for their ever increasing ailments, of course diabetes, cardio-vascular and other stress related diseases being the most common. While choosing the crop and species for introduction, facts related to its adaptation, shelf-life, consumer acceptability must be on priority so as to contribute in the economic development of the debt ridden farming community of drought prone and degraded land areas.

Details of improved cultivation practice

Dragon fruit (*Hylocerus undatus*) has been introduced as a new crop to adopt in low rainfall zone for rocky barren land and gaining rapid popularity amongst farmers. Botanically, dragon fruit is available in three variants viz., Red skin with white pulp (*Hylocereus undatus*), Red skin with red pulp (*Hylocereus polyrhizus*) and Yellow skin with white pulp (*Hylocereus megalanthus*). It is very well grown in shallow basaltic soil in arid and semi-arid region.

The cultural practices were standardized from initial planting of cropfor rocky barren land in semi-arid regions of Maharashtra. The initially cement pole of 6 feet were fixed, the 400 poles per acre are required. The four cuttings per pole were used while planting. The drip irrigation system is provided on upper side which will help in irrigating and fertigating the plant directly through aerial roots which are attached to pole during growing.

The dragon fruit is a climbing cacti so immature stem must be tied to that column for aerial roots to develop and bound to the column. Lateral shoots are restricted and only 2-3 main stems allowed to grow. The concrete circular or rectangular frame or trye is fixed on the top of pole which will take load of drooping the stems after reaching the top of pole.

Proper shading arrangements should be done along the row as shown in figure at high sunlight intensity areas to reduce the intensity of the sunlight by 30-35 % during hot sunny days.

Nutrient management : Dragon fruit requires judicious application of manure and fertilizer for higher yield. In initial stage, more nitrogen should be applied for good vegetative growth and in the later stages, more amounts of phosphorus and potash should be applied. Application of Calcium and other micronutrient are beneficial for this crop. Organic Matter plays key role in dragon fruit development and growth. Each plant should be applied with 10 to 15 kg of organic

No shade net required in normal areas

In high sunlight intensity areas shade should be provided with the help of shade net of 30-35 % during summer period

compost/organic fertilizers. As these types of lands are having very poor soil fertility therefore initially 10-15 kg FYM and 100 g SSP/ plant are required at the time of planting. Application of chemical fertilizers should be practiced 2 to 3 months after planting a dragon fruit when plant starts gaining growth. Depending upon the type of soil the chemical fertilisers should be given. We have developed fertiliser schedule for rocky barren land which act as light soil with very poor soil fertility status. Therefore during the first two years, 500 g urea and 500 g P and 300 g K should be applied to each pole per year in four splits at three month interval.After it has been in the ground for a year or more, the dragon fruit's roots have become established and are demanding more nutrients from the soil. Plants grow faster and need more nutrition. After two years each pole having for plants should be fertilised with 800 g N, 900 g P and 550 g K per pole per year which should be well distributed in six splits as mentioned in table. Nutrients should be supplied both through basal as well as through aerial drips installed at top of the pole to feed aerial roots.

No.	Time of application	Type of fertilizer	Application rate per pole
1	Immediately after final harvest	N P_2O_5 Manure	200g 250g 25kg
2	Two months later	N P_2O_5 K_2O	200g 200g 150g
3	Just before flowering	N P_2O_5 K_2O	150g 200g 100g
4	One month after 3rd application	N P_2O_5 K_2O	100g 100g 75g
5	One month after 3rd application	N P_2O_5 K_2O	100g 100g 75g
6	One month after 3rd application	N P_2O_5 K_2O	100g 100g 75g

The Dragon fruit can also be grown organically without applying chemical fertilizers and pesticide. The farm yard manure and poultry manure may be used for supplementing nutrients. These organic fruits have more demands in the market.

Water management : The best part of this crop is that it required no/extremely less amount of water during most critical water availability period i.e. March to June. From June onward flowering starts in this crop and continues till October. Irrigation is applied whenever there is a long dry spell. However, in general, the crop is subjected to dry period in the pre-bloom period to produce more flowers. Drip irrigation system is used to maintain soil moisture. The irrigation requirement is 1500-2000 litre/plant./year. While in heavy soils planting should be done on ridges with the furrow of 50 cm depth to avoid waterlogging.

Dragon fruit starts fruiting from second year onwards, while the potential average yield of 18-20 t/ha can be expected from third year onwards with the recommended package and practices.

It was observed from the initial storage studies done at ICAR-NIASM that the that the keeping quality and shelf life of this fruit is good. It can be stored up to 5-7 days at ambient room temperature, 10-12 days and 20-21 days in cold storage at temperature of 18 °C and 8 °C, respectively.

Planting pattern

Trellies

Flowering

Raw Fruit and Ripened Fruit

Drooping

Bagging

Fruit

Fruit cut view

Cost of technology

Dragon fruit as a money-spinning business with an initial investment of Rs 6.0-7.5 lakhs per ha. As the crop doesn't require intensive management/ intercultural operations and also fetching retail price of Rs.150-250 in the nearby city markets farmers generating income of Rs 3-4 lakhs per year per ha during second and third year and Rs. 6-7 lakhs from 4th year onwards. This will not only bring large unutilized area of degraded lands of Deccan region under use but also improve the socio-economic status of farmers.

Impact and beneficiaries

Farmers and SAU's and ICAR institutes in different parts of our country namely Punjab, Rajasthan, New Delhi, Odisha, Bihar, Gujrat, Jharkhand and Maharashtra at farmers field and research organisations has introduced the crop in their region.There is need to shift from the traditional orchards and diversify the fruit basket which meet the therapist demand of consumers, and also suited to drought prone & degraded lands. It has good potential to spread in unutilized area of degraded lands of Deccan region to improve the socio-economic status of farmers.

Team Members

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4 SORF : A multi-purpose machine for ratoon sugarcane

Introduction

Sugarcane is one of the important cash crop in Indian economy. In India, it is cultivated over an area of 5.0 million hectare with average productivity of about 70 tonnes per hectare and provides livelihood to 7.5 million cane growers.Its ratoon crop that is cultivated on half of the total sugarcane area, yields 20−30% less than the crop mainly due to lack of machinery for proper placement of fertilisers, and poor acquisition and utilisation of nutrients by the older roots and higher mortality of tillers. Therefore, practices should aim at inducing fresh finer roots and healthier tillers, in addition to retention of trash to act as mulch for better hydro−thermal regime and placement of fertilisers closer to newer roots. However, farmers usually burn the trash because of constraints in fertiliser placement and other intercultural operations, results in loss of organic carbon, plant nutrients, soil biota besides the environmental pollution and health hazards due to release of soot particles, smoke and green−house gases. *In-situ* retention of sugarcane trash can play an important role in replenishing soil quality and reducing environmental pollution, but there is a lack of suitable machine for placement of fertilisers. To address these issues, a machine developed by ICAR−IISR, Lucknow, has been upgraded with the inclusion of robust power transmission system, larger capacity fertiliser box and root pruning mechanisms to perform multiple operations like stubble shaving, off-baring, root pruning and placement of basal dose of fertilisers in one go while retaining the trash at the soil surface. The machine is nicknamed as "SORF".

On farm trash burning after sugarcane harvest- a common practice

Salient features of SORF machine

The SORF machine is suitable to perform four major operations in a single run which are as follows

1. Placement of fertilisers: A fertiliser drill attachment is utilised for band placement of fertiliser near the root zone of ratoon sugarcane while retaining the trash at the surface.
2. Stubble shaving: Un-even stubbles which are left in the field after manual harvesting of sugarcane are cut very sharply at a uniform height close to soil surface with a stubble shaver.
3. Off-baring: Adjustable vertical inclined off-baring discs cut the raised bed partially from outer sides and spread the cut soil over the chopped trash to accelerate its decomposition.

4. Root pruning: The side older roots of ratoon sugarcane are pruned to stimulate in fresh root growth. The slush of newly developed roots promotes the uptake of water and nutrients for boosting initial growth of ratoon sugarcane.

Ratoon management operation by SORF

Performance results

With the use of SORF machine, ratoon cane yield improved by 10−38%. In the era of water scarcity and higher input costs, 6−21% irrigation water and 20−25% fertilisers could be saved with the use of SORF machine. This machine can perform the ratoon management operations under surface trash retained field conditions, thus trash burning which creates environmental pollution could be avoided. *In situ* retention of trash in the field sequestered the carbon and improved the soil health in long run. Band placement of fertiliser−N not only improved the NUE (13%) but also reduced the ammonia volatilization losses and N_2O emission 15−20%, later is 310 times more potent green-house gas than the CO_2. Considering the benefits of the SORF machine, it was imperative to reach the technology, many on-farm experiments, demonstrations and programs were conducted.

The main benefits of SORF machine are as given below.

1. Timely completion of important ratoon management operations.
2. Band placement of fertilisers is possible even under surface retention of trash conditions
3. Healthier and more numbers of millable canes and least tiller mortality rate.

Ratoon cane performance under SORF machine over conventional practices

Cost of technology

The maximum cost of SORF machine is Rs. 1, 00, 000 with all accessories. Net profit increased up to Rs. 50, 000 per hectare. Keeping in mind around 2.5 million ha area under ratoon crop, it is estimated that approximately Rs. 6.75–12.50 thousand crore/annum could be earned as an additional net profit by the farmers

Impact and beneficiaries

The stubble shaver, off-bar, root pruner cum fertiliser drill (SORF) machine, is one of the revolutionary development for ratoon sugarcane which enhanced the input-use efficiency, crop productivity and profitability of the sugarcane growers, in addition to reducing the environmental pollution by avoiding the trash burning and reduced emissions of GHGs. Further, with improved soil health and carbon sequestration through residue retention, it has potential to address the adverse effects of climate change in long run. The technology not only benefited the sugarcane growers but also the machinery manufacturers and sugar industries.

Team members

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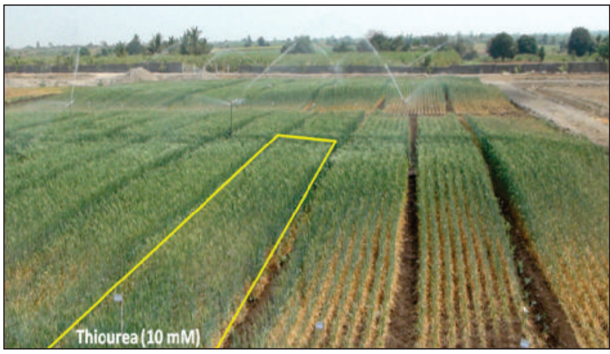
5 Plant bio-regulators for enhancing productivity and quality of major crops under water scarce regions

Introduction

Water deficit is most common abiotic stress in almost 68% cultivated area of India. To provide immediate solution to farmers' in semi-arid regions, the concept of Low External Input and Sustainable Agriculture (LEISA) is gaining significant interest. LEISA based agriculture system is based upon the options which are ecologically sound, economically feasible and culturally acceptable. This is generally achieved through the exogenous application of low concentration of chemicals termed as "Plant Bio-Regulators (PBRs)". PBRs are powerful tools for maximizing yield and quality and increasing net income to farmers.

Details of foliar application of PBR in major crops

Details of recommended doses of exogenous application of PBRs to the specific crop grown under water-scarce conditions are given below.



Wheat (*cv.* HD 2189)

Testing period : 2012–2015
Recommended PBR : Thiourea (10 mM)
Application rate : 10 mM/litre
Growing stages for application:

1. Crown root initiation (CRI, 20 Days after sowing)
2. Flag leaf (42–45 Days after sowing)
3. Seed milking stages (65 Days after sowing)

Sorghum (*cv.*PhuleSuchitra)

Testing period : 2015–2017
Recommended PBR : Sodium benzoate
Application rate : 100 mg/litre
Growing stages for application:

1. Seedling elongation (20–25 Days after sowing),
2. Reproductive (50 Days after sowing)
3. panicle formation (75 Days after sowing)

Soyabean (*cv.*JS-335)

Testing period : 2013–2014
Recommended PBR : Salicylic acid
Application rate : 100 µm/litre
Growing stages for application:

1. Flag leaf (35 Days after sowing),
2. Grain formation (55 Days after sowing)

Onion (*cv.* Bhima Kiran)

Testing period : 2015–2017
Recommended PBR : Potassium Nitrate
Application rate : 10 mg/ litre
Growing stages for application:

1. Vegetative (40 Days after transplanting)
2. Bulb formation (60 Days after transplanting)
3. Bulb development (80 Days after transplanting)
4. Post developement (100 Days after transplanting)

Eggplant (*cv.* Panchganga)

Testing period : 2016–2018
Recommended PBR : Salicylic acid
Application rate : 10 µM/litre
Growing stages for application:

1. 40 Days After Transplanting (Days after transplanting)
2. 65 Days after transplanting
3. 95 Days after transplanting

Performance results

The performance of bio-regulators (PBRs) is highly specific environment conditions and varies with crop to crop. In all tested crops, application of PBRs enhanced grain yield, total biomass and water productivity as compared to the control (Table 1). PBRs also reduced yield declination rate with the deficit irrigation as well as the reduced irrigation water use i.e. 19–56, 25–49, 17–34, 25–60 and 24–54% to achieve water productivity (WP) equivalent to the maximum without PBRs for wheat (1.18 kg/ m^3), sorghum (1.03 kg/ m^3), soybean (0.98 kg/ m^3), onion (8.4 kg/ m^3), egg plant (4.9kg/ m^3) respectively. Higher WP was recorded with PBRs under water deficits. Integrating use of bio–regulators with deficit irrigation can enhance substantial productivity vis-à-vis profitability from these crops under water–scarce conditions.

Table 1. Enhancement in grain/fruit yield, biomass and water productivity with PBRs

Crop	Improvement in grain/fruit yield (%)	Improvement in biomass yield (%)	Water productivity, WP, (kg m^{-3})
Wheat (*cv* HD-2189)	5.9-20.6	4.8-15.3	1.20-1.35
Sorghum (*cv* Phule Suchitra)	6.8-18.5	5.7-14.7	1.16-1.41
Soyabean (*cv* JS-335)	4.2-14.2	3.7-11	1.02-1.12
Onion (*cv* Bhima Kiran)	10.1-25	6.1-14.2	7.8-9.6
Eggplant (*cv* Panchganga)	6.2-20.9	-	3.1-6.1

Cost of technology

Cost of exogenous application of PBRs is nominal and variable depending upon their availability in the local market and crop.

Impact and beneficiaries

The PBRs like thio-urea (10 mM), sodium benzoate (100 mg L^{-1}), potassium nitrate (KNO_3) and salicylic acid (10 µM) helped to alleviatethe water stress in wheat, sorghum, onion, soybean and eggplant, respectively. PBRs also enhanced nutritional quality of vegetable crops under water deficits. Overall use of PBRs can help to boost the productions of major crops grown in water scarcity regions and profitability of farmers.

Team Members

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6 Nanostructured material for stress alleviation in aquaculture

Introduction

Abiotic stress such as ammonia and biotic stress such as pathogenic bacteria constitute major obstacle to further increases in aquaculture production. Due to the magnitude of these problems and the lack of a reasonable solution, a rapid, cost-effective, ecologically responsible method of remediation is greatly needed. Nanomaterials have increasingly been used in water treatment because of economical and environmental viability and wider availability.

Zeolites are abundantly available in quarries of Maharashtra. Zeolites are three-dimensional, microporous and crystalline solids, which have increasingly been used in water treatment because of their ion exchange properties and thermal stability. Zeolites have cation exchange capacity for various applications in industries, agriculture and aquaculture because of its cage-like structure consisting of SiO_4 and AlO_4tetrahedra joined by shared oxygen atoms. The negative charges of the AlO_4 units are balanced by the presence of exchangeable cations - Ca, Mg, Na, K and Fe. Modifications of the surface and pores of zeolites make them attractive candidates for various applications. Zeolite trapped with silver nanoparticles and fish feed formulated with silver nanoparticles have been developed as stress alleviator, which may have potential application in aquaculture.

Salient Features

A process for the synthesis of silver nanoparticles using fishery wastes has been developed and characterized spectrophotometrically and microscopically(Single step synthesis process of bactericidal silver nanoparticles from tissue extracts of *Labeo rohita*. Patent Application No. 3255/MUM/2012, Patent Journal Publication No. 30/2014, Date: 25/07/2014). A patent has been filed.Nanosilver zeolite has been synthesized by trapping silver nano particles in a zeolite and characterized using various analytical techniques. Silvernano particles trapped in zeolite, its trapping mechanism and also the presence of micronutrients and other metallic elements in zeolite have also been ascertained.

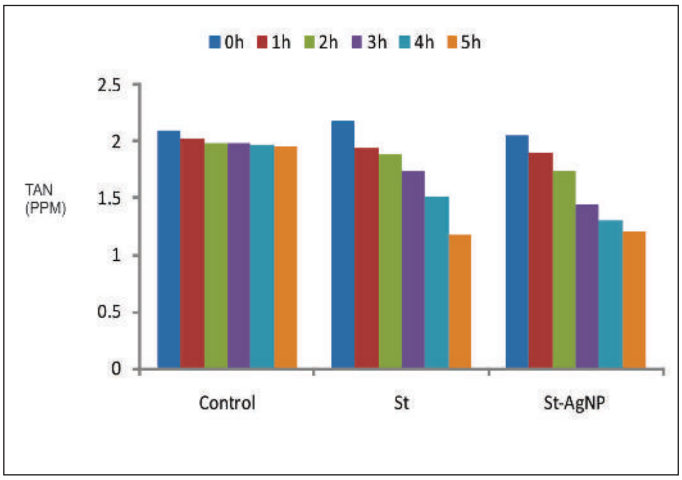
Trapping of synthesized silver nano particles in zeolite has been scaled up for mitigation of ammonia in small fish ponds. Zeolite trapped with silver nano particles have been found to be effective in ammonia removal.

Bactericidal activity of synthesized silver nanoparticles and zeolite trapped with silver nanoparticles have been determined against *Aeromonas hydrophila* (infectional rot), *Vibrio harveyi* and *Pseudomonas*s pusing agar well diffusion method.

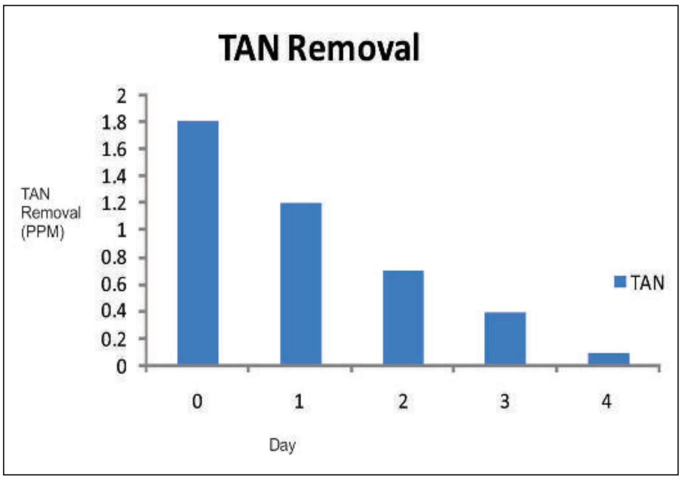
Preparation of fish feed formulated with nanoparticles has also been standardized for its potential application for stress mitigation in fish. The biochemical enzymes such as anti-oxidative enzymes, protein metabolic enzymes, carbohydrate metabolic enzymes and acetylcholine esterase were evaluated.

Performance results

Zeolite and zeolite trapped with silver NPs have beene valuated under laboratory condition for ammonia removal and bactericidal activity. 46% ammonia removal was achieved. The product has been scaled up and applied in two farm/fish ponds depending on the ammonia toxicity. Zeolite trapped with silver nano particles has been found to be effective in ammonia removal in fish/farm ponds. Ammonia level of 1.8 ppm was reduced to 0.1 ppm using zeolite trapped with silver nanoparticles in a farm/fish pond. Ammonia level of 0.328 ppm was reduced to 0.07 ppm using zeolite based product in another farm/fish pond. Application dose @ 12-20 kg zeolite trapped with Ag NPs per hectare is recommended based on the ammonia toxicity in farm/fish ponds. Based on the yard experiment conducted in the aquaria / wet lab, supplementation of nanoparticles @ 0.5 mg as important nano-delivery component is recommended per one kilogram fish feed formulation.

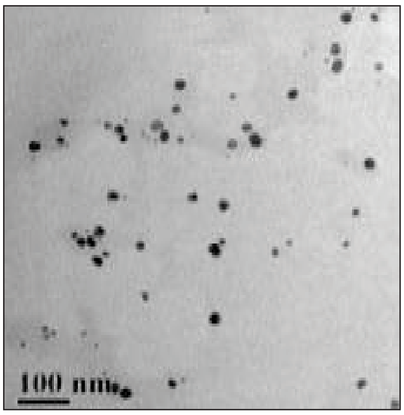


Ammonia removal using zeolite and zeolite trapped Ag NPs under laboratory condition

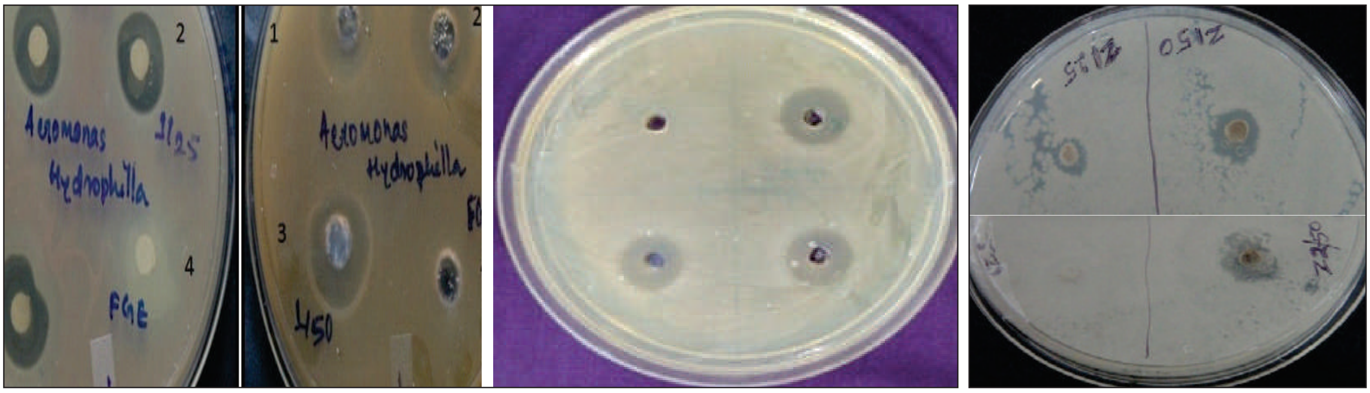


Ammonia removal in farm/fish pond

Zeolite



Ag NPs



Bactericidal activity

Cost of technology

Cost economics of trapping of silver nanoparticles in zeolite has been evaluated.Cost economic has been worked out as Rs. 150-250 for the development of every one kilogram zeolite based product.

Impact and beneficiaries

The present work on value addition of naturally and abundantly available zeolite, and fish feed using nanotechnological interventions, conducted under laboratory and yard conditions may have the future potential application in alleviation of multiple stresses in aquaculture systems. Pilot scale synthesis of silver nanoparticles, and zeolite based product and large scale preparation of fish feed formulated with nanoparticles requires further industrial collaboration with the Research incubator/Venture capitalist/Entrepreneur/Industrialist.

Team Members

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7 Development of a microbially derived polymeric product for gel formation, microbial colonization and metals binding

Introduction

Exopolysaccharides are carbohydrate-rich polymeric material synthesized by the microorganisms mainly under limiting nitrogen conditions. These molecules constitute an important class of biological polymers having multifaceted utilization potential in variety of industries. Extensively cross-linked sugar moieties in an exopolysaccharide makes a highly branched, carbonaceous structure, with multiple surface ligands capable to react readily with different types of chemicals and elements. Highly branched structure enables these polymers holding high amount of water and other solvents, as well as capability to interact with different elements, and many other industrially important properties.

Water deficit is major concern currently to agricultural productivity worldwide. Currently available strategies in this regard predominantly include development of tolerant varieties, improved management practices, and fertigation techniques. Major limitations among the existing strategies include lack of a system to ensure sustained supply of moisture in rhizosphere region. Moisture being the key factor for plant growth, as well as for microbial colonization and optimal activity, its availability can be ensured through amendment of water holding agents in the rhizosphere. Water holding polymers have been shown best fit for this purpose, where they could gain moisture during surplus availability, and release the slowly during deficient conditions. Variety of polymers having synthetic / semi synthetic origin have been proposed for similar function, however demand of completely green, biologically originating material is frequent. Therefore microbial exopolysaccharide-polymers being completely green, carbonatious materials, have gained rapid importance for agricultural utility. The polymers are important in agriculture particularly due to high water holding capacity and improvement of soil health and quality; these molecules also serve as attachment factors for microbes, thus able to induce colonization of microbes through development of biofilms. Additionally role of exopolysaccharides in promoting soil aggregation and improving microbial colonization in rhizosphere is well known. Therefore present biopolymer based technology was developed to alleviate abiotic stresses in crop plants.

Technology details/salient features

Aforesaid biopolymer was developed by using *Rhizobium* strain originating from wild habitat. Detailed characterization of the biopolymer was performed which revealed presence of multiple functional ligands that could react with different chemical moieties. The product also exhibited high water holding capacity, and potential to induce microbial colonization. Thus applicability of the said biopolymer to facilitate microbial colonization, mitigation of drought stress was analyzed and validated under *in situ* conditions. The technology has applicability for alleviation of drought stress. Similarly it has wide applicability for enhancement of microbial colonization as well as soil microbial activity. Moreover biological origin of synthesis, and ability to facilitate the colonization by plant growth promoting microorganisms including phosphate solubilizers and nitrogen fixers further extend applicability of the technology to promote sustainable farming, with reduced dependence on chemical fertilizers.

Some of the most prominent salient features of the biopolymer-based technology include :

- Excellent gelability
- High water holding capacity
- Eco-friendly product
- Enhance soil microbial activity, and soil health
- Interact with multiple elements including micronutrients
- Induce microbial colonization
- Can be utilized in crude form
- Economic production
- Easy-to-use
- Suitable for multiple crops
- Retain activity in diverse soil types

Biopolymers developed using *Rhizobium* strain

Performance results

The biopolymer was initially utilized for alleviation of drought stress in onion crop under field conditions. Foliar application of the product was performed and response was evaluated under a gradient of water deficit stress, generated using line source sprinkler system.

Evaluation of biopolymer for mitigation of drought stress in onion under field conditions.

Similarly the product was also evaluated in brinjal crop for mitigation was water deficit stress. In onion as well as brinjal crops, the product yielded promising outcomes under moderate water deficit conditions (IW: CPE 0.55).

Microbial colonization and nutritional-enhancement ability of the product under nutrient-limiting conditions was evaluated in turmeric crop. Various formulations including diluted crude form of the product, and beads imposed significant positive influence in turmeric crop. Colonization of the rhizosphere, rhizoplane, and roots by phosphate solubilizers, nitrogen fixers and exopolysaccharide producers was significantly enhanced under the influence of biopolymer.

Cost of technology

Medium designed for production of the biopolymer involves use of simple carbon and nitrogen sources having low cost. Moreover, utilization in crude form further reduces downstream costs. Thus estimated cost of the biopolymer remains around INR/- 30 L^{-1}.

Impact and beneficiaries

Technology and the package-of-practice developed using aforesaid biopolymer for mitigation of drought stress, as well as for improved microbial colonization has been rigorously analysed in different crop plants. The technology is currently under incubation; however massive impact is expected on arid, and semi-arid regions of the country, particularly to promote sustainable farming under water limiting conditions. Similarly significant impact is also expected on several cropping systems where improvements of microbe-plant interactions are required. Beneficiaries are estimated to save significant cost particularly with respect to water budgeting, and chemical fertilizers application. Direct ecological impact of the technology is estimated in terms of improved soil health, and microbial activity, which is directly linked to crop productivity.

Team Members

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8 Deficit irrigation as on-farm strategy for improving water productivity of horticulture crop grown limited water in shallow basaltic terrain

Introduction

In semiarid drought prone areas, horticultural fruit crops grown in shallow basaltic soils faces frequent water stress due to poor soil depth and low rainfall which adversely affect the growth, yield and quality of fruit crops. It is becoming very difficult for farmers to maintain orchards in theses basaltic poor soil depth areas with limited irrigation facility, insufficient water availability under changing climatic conditions with the increase in drought probabilities. Proper soil mixtures/depth with different irrigation approaches i.e. deficit irrigation and partial root zone irrigation at different crop growth stages may help in reduction of seasonal irrigation volume withjudicious use of available water, optimises life span without compromising fruit yield and quality due to good orchard health, which ultimately improves water use efficiency.

Technology details/salient features

In tomato crop grown in shallow murrum soil under drip irrigation, the recommended deficit irrigation scheduled is 0.6 ET at vegetative stage followed by full irrigation at 1.0 ET at other growth stages for getting better yield and quality fruits. The average water saving will be 10 % with average increase in yield of 5 %.The tomato crop will tolerate interruptions of irrigation up to 15 days at growth stages and will help in minimizing yield losses by3-7%.

The papaya crop grown in shallow murrum soil will be irrigated with the partial root zone drying strategy with 0.75 ET with an interval of 15 days for obtaining maximum yield under limited water condition.

In pomegranate crop grown in shallow murrum soil, the partial root zone drying strategy with 0.6 ET with an interval of 15 days along with mulch and foliar application of salicylic acid should be followed for obtaining maximum productivity under limited water condition.

Performance results

In tomato, the regulated deficit irrigation (RDI0.8 i.e 0.8xET) did not affect the marketable fruit yield (MFY) as compared with the full irrigation (FI; 78.0 Mg/ha). The water productivity of 19.2 kg/m^3 was the maximum under RDI0.8. The MFY was improved by 4% with deficit irrigation (DI0.6) at vegetative stage whileDI0.6 at flowering stage showed little effect and a decline of 7% was monitored with DI0.6 at fruiting stage. The DI0.6 applied at either of two stages vegetative & flowering, flowering & fruiting and vegetative & fruiting resulted in 14-18% decline in yeild.


Tomato

The percent increase in yield and irrigation water use efficiency (IWUE) under partial root zone drying with deficit irrigation is 8 % and 8.5 %, respectively for Papaya grown under shallow murrum soil. The yield and IWUE was found better under PRD irrigation and cultivated over native murrum soil as compared to mixed soil. The activities of enzymatic antioxidant such as catalase and ascorbate peroxidase were found higher under PRD compared to RDI treatment. Total phenolic content, total sugar, reducing sugar was observed higher under PRD compared to DI treatment.


Papaya Crop

In Pomegranate, average increase in yield with PRD60 with mulch over the regulated deficit irrigation (RDI80) was 7.6 % with water saving of 25 %. Under mulched condition, foliar spray of Salicylic acid (SA) helped in increasing yield of 3.7 % in PRD60 over DI60. The higher enzymatic activity like SOD, peroxidase, catalase regulated by water deficit under PRD ascompared to RDI.

Cost of technology

The deficit irrigation strategies will help in minimizing the yield loss 5-8 % and increase in water productivity 10-15 % under limited water condition. Also, it will help in reducing the energy cost on drip irrigation by 10-12% for horticulture crops.

Pomegranate crop

Impact and beneficiaries

Under water scarcity condition, the regulated deficit irrigation in tomato and partial root zone drying irrigation strategy with drip irrigation in Papaya and Pomegranate will help the farmers to improve cultivation practice,cropand waterproductivity of the horticulture crops grown in shallow basaltic terrain under semi-arid region.

Team Members

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