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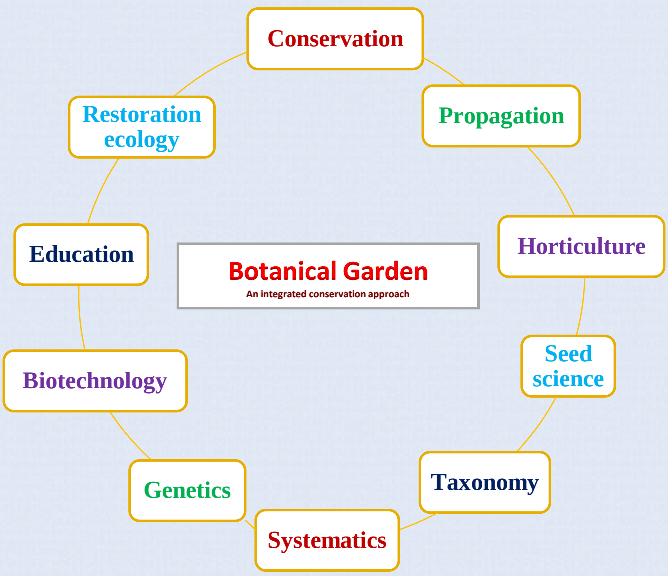

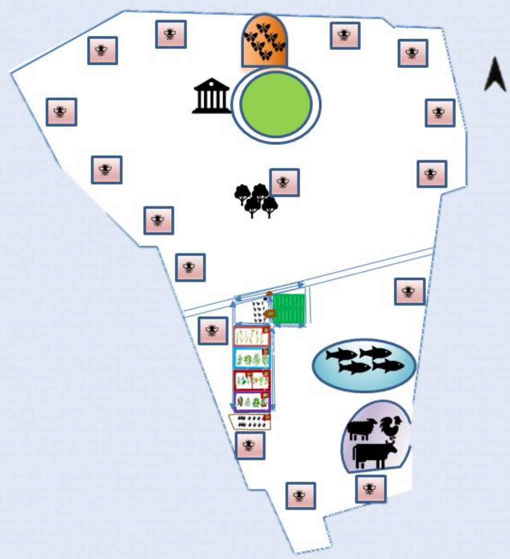

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Preface

In agriculture, occurrence of abiotic stress such as drought, salinity, waterlogging, heat and cold stress etc. can cause huge loss to agricultural productivity and economic returns. Development and adaptation of climate resilient crop varieties, livestock and fish breeds is best one of the strategy in combating the impact of abiotic stresses in agriculture to sustain food and nutritional security. Hence, conservation and utilization of diverse genetic resources such as landraces, local or framers crop varieties, wild relatives of crops, crop germplasm, breeding lines, local and indigenous livestock breeds and fish species is very crucial. *Ex-situ* conservation through different approaches such as zoos, captive breeding, aquarium, botanical gardens including genetic garden and gene banks is ideal for scientific and educational purpose.

Realizing the importance of genetic gardens, different kinds of genetic gardens are being established at nation and international level. Similarly, an initiative has been taken at ICAR-NIASM, Baramati to establish genetic garden for abiotic stress tolerance under an umbrella project on "Genetic garden and gene bank for abiotic stress tolerant plants, animals and fisheries for food security and sustainability. Understanding the concept, selecting and prioritizing the components, planning, designing and setting goals and activities are very essential for establishing a model genetic garden for abiotic stress tolerance. In this context, all these aspects are covered in this publication. We hope this publication will serve as a guide or blue print to establish a model genetic garden for our project team of above mentioned project and also other stake holders associated with biodiversity conservation to replicate the same.

Our sincere thanks to the Director, ICAR-NIASM, Baramati and collaborating institutes such as ICAR-NBPGR, New Delhi, ICAR-CSSRI, Karnal, ICAR-IISS, Mau and ICRISAT for need felt help and support to conceptualize and develop the genetic garden for abiotic stress tolerant crop plants, animal and fishes at ICAR-NIASM, Baramati.

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1. Introduction

Biodiversity plays a crucial role in food and nutrition security, sustainable livelihoods, and ecosystem resilience. Conservation and sustainably managing biodiversity is necessary for mitigating and adapting to climate change effects on agriculture, particularly in the abiotic-stressed regions. Maintaining the full range of genetic variation within a particular species is the fundamental objective of biodiversity conservation. Genetic resources in the forms of crop, livestock, fish, microbes and tree germplasms can be conserved both *in-situ* and *ex-situ*. However, *ex-situ* conservation through different conservation strategies such as zoos, captive breeding, aquarium, botanical gardens including genetic garden and gene banks holds good for scientific and educational purpose. This bulletin describes the roadmap including the concept, planning and activities of establishing a genetic garden displaying abiotic stress tolerance as a model at the ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra.

2. Concept

Genetic garden is an integrated approach for conservation and utilization of plant genetic resources (Boraiah and Basavaraj 2020). Understanding the concept is essential to establish a model genetic garden. Since genetic garden is a type of botanical garden, it is felt necessary to provide the general information on botanical garden and its activities.

Botanical garden is a tract of land devoting for the cultivation of a diversity of plant species. It is like an institution holding documented collections of living plants for the purpose of scientific research, conservation, display and education. There are about 2500 botanical gardens in the world (Golding et al. 2010) together holding more than 6 million accessions of living plants, representing around 80,000 taxa i.e., about one-quarter of the estimated number of vascular plant species in the world (O'Donnell and Sharrock, 2017). Different activities conducted by botanical gardens are conservation, propagation, horticulture, seed science, taxonomy, systematics, genetics, biotechnology, education, restoration ecology and public education (Fig. 1). They include herbarium, lecture rooms, laboratories, libraries, museum, gene & seed banks and experimental or research plantings to conduct those activities.

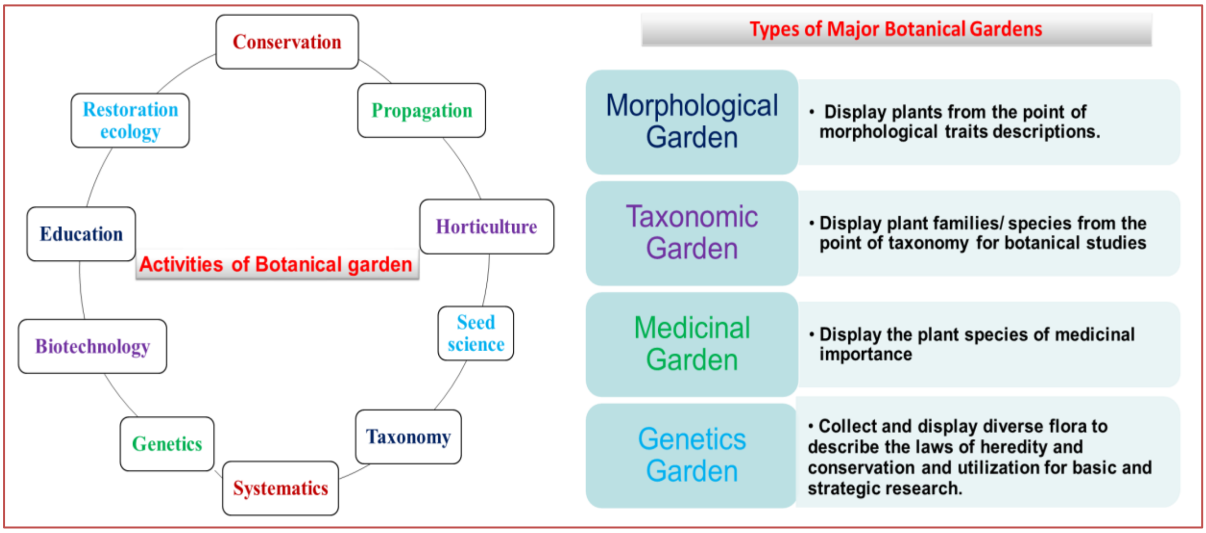

Fig. 1. Activities and major types of botanical gardens.

The genetic variation within species, which is an area of major of concern of conservation genetics is totally underrepresented in botanical gardens (Hurka 1994). This gap can be substantially bridged by the genetic gardens with focused to explore and collect diverse plant genetic resources (PGR) and making provisions for further utilization of such diverse genetic resources for basic and strategic research to understand the genetic cause and mechanisms responsible for variations in adaptability to abiotic stress environments.

Brief information on important genetic gardens established around the world including India is presented in Table 1 for better understanding the concept of genetic garden.

Table 1. List of some of genetic garden at national and international level.

S.No.	Location, founder/collaborators, components and purpose of genetic gardens
A. International level	
1.	**Genetic Garden at Oxford University, United Kingdom** • **Founder:** Cyril Dean Darlington a geneticist and eugenicist • **Components:** It comprises herbaceous plants, bulbs, trees and shrubs remain from the first plantings in 1964, some of which were part Darlington's collection. • **Purpose:** To display mechanisms important in evolution and exploited by plant breeders.
2.	**Genetic Garden at School at Botanical Garden of Dundee University, United Kingdom** • **Establisher:** School Life Sciences, University of Dundee, Scotland • **Component:** Genetics Garden divided into three plots 1. Model plant species (primroses, maize and carnations) used in genetics (history of genetics). 2. Varieties of barley, oat and wheat displayed to show how height has altered through selection (cereal diversity). **3.** Third plot was designed like the shape of the barley chromosome 2 and each row marks the position of a specific gene. Barley plants in the row represent a mutation in that gene which causes a change in plant development. • **Purpose:** As a hub for science engagement activities and to highlight the importance of plants in understanding of genetics and important milestones of plant breeding.
B. National level:	
1.	**Genetic garden of bio-fortified plants:** • **Founder:** M S Swaminathan Research Foundation (MSSRF) & DBT-BIRAC • **Location:** KVK, Kanpur Dehat (UP), Palghar (MH), Thirur (TN) & Odisha • **Components:** Nutri-rich plants (Ex: Vitamin A& C and iron-rich plant species) • **Purpose:** To implement the diversification of the 'diet' and 'bio-fortification' in the farming system and developing nutrition responsive agriculture among small and marginal farmers by providing quality planting materials.
2.	**Genetic garden of halophytes:** • **Founder:** MSSRF and Society for Integrated Coastal Management • **Location:** Siruthalaikadu,Vedaranyam Nagapattinam (Dist.), TN • **Components:** More than 1,600 species belonging to 550 genera and 117 families of Halophytes • **Purpose:** To conduct basic research and explore collected genetic resources for food, nutritional and fodder purpose.

S.No.	Location, founder/collaborators, components and purpose of genetic gardens
3.	**Genetic garden of native fruit crops:** • **Founder:** Bengaluru Centre of Bioversity International • **Components:** More than 150 varieties of 95 species have been planted in *ex-situ* gene bank. Compiled information on origin, flowering and fruiting season, nutrient composition and use. • **Purpose:** To explore, collect, characterize and conserve underutilized rare fruit species.

An overview on established genetic gardens around globe, provide ample scope to define genetic garden as "a kind of botanical garden which collects, conserve and displays genetically diverse flora/fauna to depict the diversity in the natural phenomena or mechanisms of biological system that can be explored through study of genes/traits, genetic variation, and heredity". Presumably, a model genetic garden in the context of abiotic stress tolerance should fulfill the following objectives:

- Collection and exploration of natural and induced diversity in survival and performance of crop species and their wild relatives.
- Conservation, maintenance and propagation (including developing propagation and multiplication protocols) of rare and endemic species or genetic stocks.
- Sharing and utilization of genetic resources with stakeholders for research and cultivation.
- Public education or awareness on importance and conservation of genetic diversity.

Though the objectives may vary according to purpose of the genetic garden, the Genetic Garden should have a mandate to provide an access to existing genetic diversity in the genetic cause and mechanisms of particular trait/s or phenomena by exploring the variations in diverse flora and fauna and displaying them at a particular location.

3. A Road Map to Establish Genetic Garden at ICAR-NIASM, Baramati

Realizing the multidimensional roles of genetic gardens spread across collection, conservation and sustainable management of genetic resources for food and agriculture (GRFA) an initiative has been taken at ICAR-NIASM, Baramati to establish genetic garden for abiotic stress tolerance. Therefore, an umbrella project on "Genetic garden and gene bank for abiotic stress tolerant plants, animals and fisheries for food security and sustainability" has been proposed. The project aims to accomplish important tasks by collecting, conserving and maintaining GRFA and by facilitating basic research for better insights into trait diversity and mechanisms underlying tolerance to abiotic stresses through in-house and collaborative research projects with other institutes.

3.1. Planning

A good plan is the first step in establishing a model genetic garden. Planning includes deciding the objective of garden, selecting the site for establishment; deciding the size/area of the garden; conceptualizing the landscape for display of diversity; prioritizing and selecting the crop plants, livestock and fisheries (components of garden); planning commodity calendar and planting in the garden; Improving aesthetics and enhancing visibility of garden and preparing garden design.

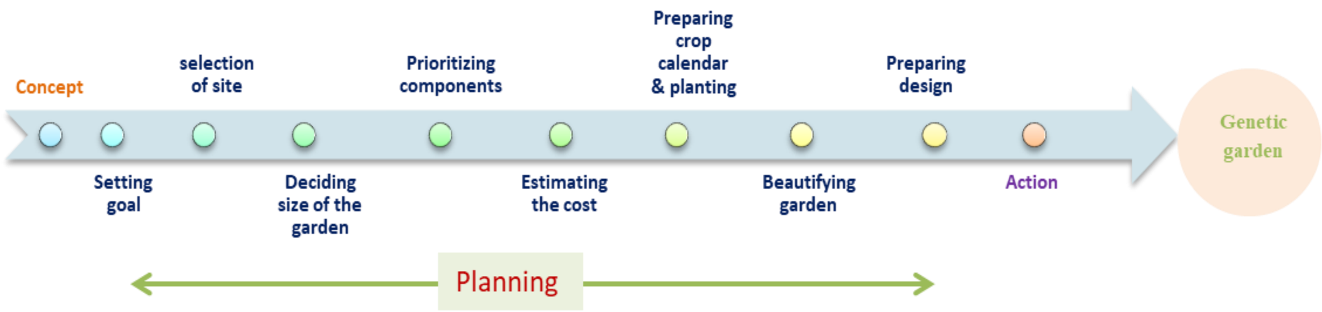

Fig. 2. A road map to establish genetic garden.

3.1.1. Objectives of the genetic garden

Collecting, conserving and displaying diverse genetic resources to facilitate investigations on trait diversity and mechanisms underlying tolerance to abiotic stresses, to enhance public awareness about importance of genetic diversity and to strengthen capacity building in abiotic stress management.

3.1.2. Site selection

This aspect should take into consideration two key dimensions of genetic garden *viz*., display and conservation. While the site for display should be necessarily featured by natural or induced abiotic stresses, the site for conservation and propagation should be free from stresses to avoid loss of material. The site for display of known as well as rare species for display should be well connected to main roads and can be easily accessible for visitors. The site selected for conservation and multiplication should have fertile soil, levelled, and well-drained. Low and undulated/sloppy area prone to water logging or run off should be avoided. It is very essential to have an access to regular water supply and also a water tank for life saving irrigation during summer or water shortage. Further, greenhouse/shade net is also very necessary for maintenance of plants (specific crops/plants) during summer. By considering all these points, an area (E block) in front of farm office building identified and selected for establishment of genetic garden, which is well connected to road and irrigation pipe line. All the plots of selected site (E block) situated within 400 m distance from metrological station which is very important from the practical point of view for accessing real time and accurate weather parameters (rainfall, temperature, RH and sunshine hours etc.) which can be useful during evaluation/screening of germplasm for different abiotic stresses. The selected site represents the semi-arid regions of the south India. The climatic data (based on weather parameters since 2012) of the site is presented as Annexure-I. This block also comprises already established cactus garden which is also a component of genetic garden. However, the soil fertility of the site is poor and needs to be improved. The nutrient status of the soil is provided in Annexure-II. The animal and fishery genetic resources will be maintained at Livestock and IFS unit and fishes at museum and fishery unit. While genetic diversity block for the prioritized crop is the core of conceptualized genetic garden, the existing diversity in the fauna and flora spread across the institute campus will be integrated in the extended concept of genetic garden particularly to enhance awareness and interest of the visitors in biodiversity and agro-eco tourism.

3.1.3. Area/size of the garden

The size or area of genetic garden is depending on the type and purpose of genetic garden. If genetic diversity or evolution aspects of single crop or particular species has to be displayed, about half an acre is sufficient to accommodate diverse genetic resources/germplasm of that crop/species. Again, it also depends on size of samples with diverse genetic resources of species. Since the focus of proposed genetic garden is on diversity in abiotic stress tolerance, approximately 1.25 ha area allotted for genetic garden at present is sufficient for the prioritized crops. It can be expanded if more number of crops or varieties/germplasm included (i.e., fruit, agroforestry, etc.).

3.1.4. Landscape plan

The view of garden can be made more attractive by dividing entire area into blocks and subblocks, planting seasonal flowering plants, trees/hedge plants etc. The allotted area divided into different blocks (E2, E3, E4, E5 and E6) based on existing plot size and different group of crops planted in these blocks. Further, these blocks has to be divided into subblocks (E2-A/ E2-B/ E2-C etc) depending on sub categorization of crop groups. The different crops are to be planted block wise. Further, to display popular varieties of crops, one plot (preferably road side plot) to be identified as crop cafeteria block. Seasonal and attractive hardy flowering plants (Niger, sunflower, sunhemp, mesta, etc.), trees species or shrubs will be planted at borders of each block which can provide a garden look and can also demarcate the blocks. Further, the plan should get extended to display the overall biodiversity existing in the campus in the form of orchards, medicinal gardens, livestock and fishes etc.

3.1.5. Prioritizing and selecting the components

It is very essential to decide number and size of each component in the garden for better management and to achieve the objective of the garden. Major components comprise the plants including crops varieties/genotypes, local cultivars, breeding lines, genetic stocks germplasm, and wild relatives of crops (WRC) tolerant to different abiotic stresses currently prevailing at the site in the first phase and those which can be created in the next phase. Similarly, abiotic stress tolerant animal including local/indigenous breeds of livestock (cattle, sheep, goats and other small ruminant animals) and fowls will be maintained at IFS unit/livestock unit. Further, rare, endemic and abiotic stress tolerant fish species also maintained/preserved and displayed at fisheries unit/ in fish museum. Butterfly garden is being established near main building to collect and display diverse butterflies. Honey bee hives will be installed at different places (along borders of orchard/compound) depending on availability of forage/pollen source. Further, it is very crucial to identify, document, conserve natural flora and fauna of local/existing within campus. Therefore, fencing the land located westside of farm office (NIASM original site) is very important. If possible, hardy and local plants/trees which are being used in research related to abiotic stresses can be planted. The details and location of the components of genetic garden presented in Table 2 and Fig. 3.

3.1.6. Cost estimation

After deciding the components it is very essential to calculate the cost of each component to be included in the garden. Since already we have some basic facilities like land, water for irrigation and machines etc the cost to establish the genetic garden will not be too high. The major cost includes the man power in the form of labour charges for field preparation, planting and crop management and for other skilled/technical works (Young professional/ skilled labour) related monitoring, data recording and documentation. Details of tentative cost to establish the genetic garden is given in the Table 2.

Table 2. Estimated cost for establishing a model genetic garden for abiotic stress tolerance (for five years).

S.No.	Components	Cost (Rs. Lakh)

Recurring/Establishment / maintenance cost		
1.	Purchase of planting materials, animals, and fish	3.00
2.	Museum (Racks, seed storage bins, display & herbarium items	5.00
3.	Seed bank	2.00
4.	Animal cages/ fish units	2.00
5.	Shade net house	2.00
6.	Butterfly garden	3.00
7.	Apiary	1.00
8.	Mango diversity block (Maintenance)	2.50
9.	Dragon fruit diversity orchard (Establishment)	2.50
10.	Travels (collections/exploration)	2.00
11.	Consumables/farm inputs (chemicals/ fertilizers/FYM, boards, etc.)	5.00
12.	Installation of irrigation system and maintenance	3.00
13.	Miscellaneous	3.00
Total		36.00
Man power/labour		
14.	Field operations for crop management (Man-days/costs)	10.00
15.	YP/Skilled labour	24.00
Total		34.00
Grand total		**70.00**

3.1.7. Planning crop calendar and planting

The crops will be planted in different blocks based on types of crops and seasons. For instance, the wheat, chickpea, lentil, quinoa, chia etc will be sown during rabi seasons. Similarly, crops such as finger millets, foxtail millet, sorghum, maize, pigeon pea, groundnut, cowpea, will be sown/planted during kharif seasons. Accordingly, every season crop calendar will be prepared for timely sowing/planting, and standard agronomic practices will be followed for better management of crop. Field crops including cereals/millets, pulses, oilseeds and spices crops will be planted in E3, E4 and E5 blocks; vegetable crops including wild species in E6 and diverse dragon fruit plants will be maintained in E7. If necessary, within blocks sub block can be made by planting border crops/seasonal annual flowering plants to differentiate individual crops. The mango diversity located besides Manas pond will be maintained under genetic garden project. Besides these crop plants, model plants which were used in research related to drought, waterlogging/flood, heat & cold/chilling, salinity will be collected, maintained and displayed in genetic garden or green house. For instance, resurrection plants, gene silenced plants will be collected and maintained in green house. These kinds of model plants can be demonstrated to school and college students during special events.

3.1.8. Beautifying the garden

Making garden more attractive and visible is very important. Thus, garden components (particularly plants) should be placed/planted in systematic way (labelling with brief descripting of displayed materials) so that even general public/school students can understand the purpose of genetic garden. Further, wherever possible the name plates/boards (with brief description about components including QR scan) can be installed to make more informative and self-explanatory. Therefore, at entrance of genetic garden main board will be installed to display the general information on the umbrella project on genetic garden for abiotic stress tolerance. At corner of each block a field board will be erected to display the information related crops/varieties planted in that block. Further, to beautify the garden aesthetic enhancement elements like arches, metal/wooden arts, etc. will be erected in the garden wherever possible. The existing tree at the entrance of genetic garden (near cactus plot) will be made focal point by constructing a small platform around tree.

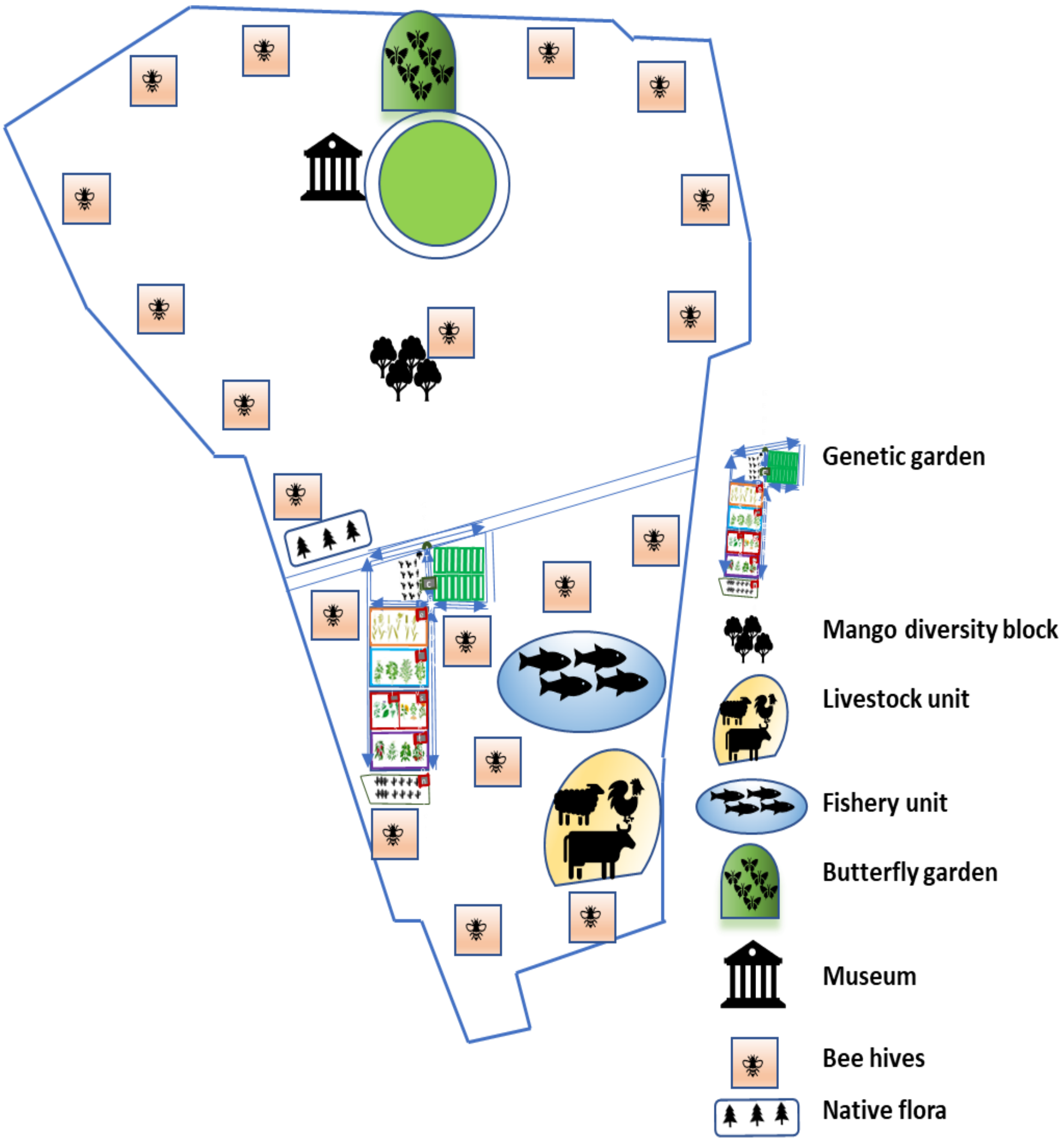

Fig. 3. Location of genetic garden components in NIASM campus.

Table 3. Components of genetic garden project.

S.No.	Genetic resources components	Source	Remarks

1.	Plants/crops (Genetic Garden)		
a.	• Abiotic stress tolerant varieties, breeding lines, mapping populations, mutant lines, model plants • Promising genotypes/germplasm, genetic stocks • Wild relative of crops, registered farmers varieties	• ICAR-NBPGR, New Delhi • ICAR-Institutes/ SAUs • Bioversity International, Rome • World Vegetable Centre, Taiwan	Seed or planting material of different crops will be procured from concerned institutes through proper channel
b.	• Land races • Local cultivars, farmers varieties • Wild relative of crops	• Seed banks/ associations /NGO/SHGs • Farmers' fields • Forest and tribal areas etc.	Seed material will be collected from farmers' fields / gardens, seed banks of SHGs/NGOs etc.
c.	• Native plant/ trees species	• From local area/ within	Identifying and documenting species
d.	• Mango diversity block	• Collecting and planting exotic and indigenous varieties	Evaluate the performance under semi-arid and shallow soils
2.	**Animals/Livestock**		
	• Local breeds of cattle and buffalo	Khillar, Pandharpuri buffalo	Based on survey/ information the local breeds will be procured.
	• Goats	Osmanabadi, Sangamneri	
	• Sheep	Madgyal, Lonad, Kolhapuri, Solapuri, Sangamneri	
	• Fowls	Native/Ornamental poultry / birds	
3.	**Fisheries**		
	• Endemic fish species	Rivers, reservoirs	Sampling of fish species along the reservoirs and rivers will be carried out.
	• Fresh water crabs	Rivers, reservoirs	
4.	**Tentative list of butterfly species to be collected (Butterfly Garden)**		
	Papilio demoleus, Graphium dosum, Danaus spp, *Limenitis* spp, *Pieris brassicae, Catopsilia Pomona, Delias eucharis, Strymon melinus, Hyplolimnas misippus*	The species exist locally during different seasons will be attracted / collected in the garden by growing preferred flora.	Captive breeding and display in green house
5.	**Honey bee species to be collected (Apiary)**		
	Apis mellifera	Local SAUs/ KVK	Bee hives will be maintained in campus.
6.	**Museum**		
	• Rare, historical specimens and plants, animals, fishes relevant abiotic stress research; digital display of abiotic stress tolerant genetic stocks recorded in crop science institute.	Procure from research organizations and collection from wild/forest/fields	Display as live or preserved as specimens, as a herbarium (plants)

3.1.9. Preparing garden design

A successful and model garden begins with a good design. Therefore, by keeping all the above points in mind, a design for genetic garden is prepared (Fig. 4). This design will be served as blue print for establishing proposed genetic garden.

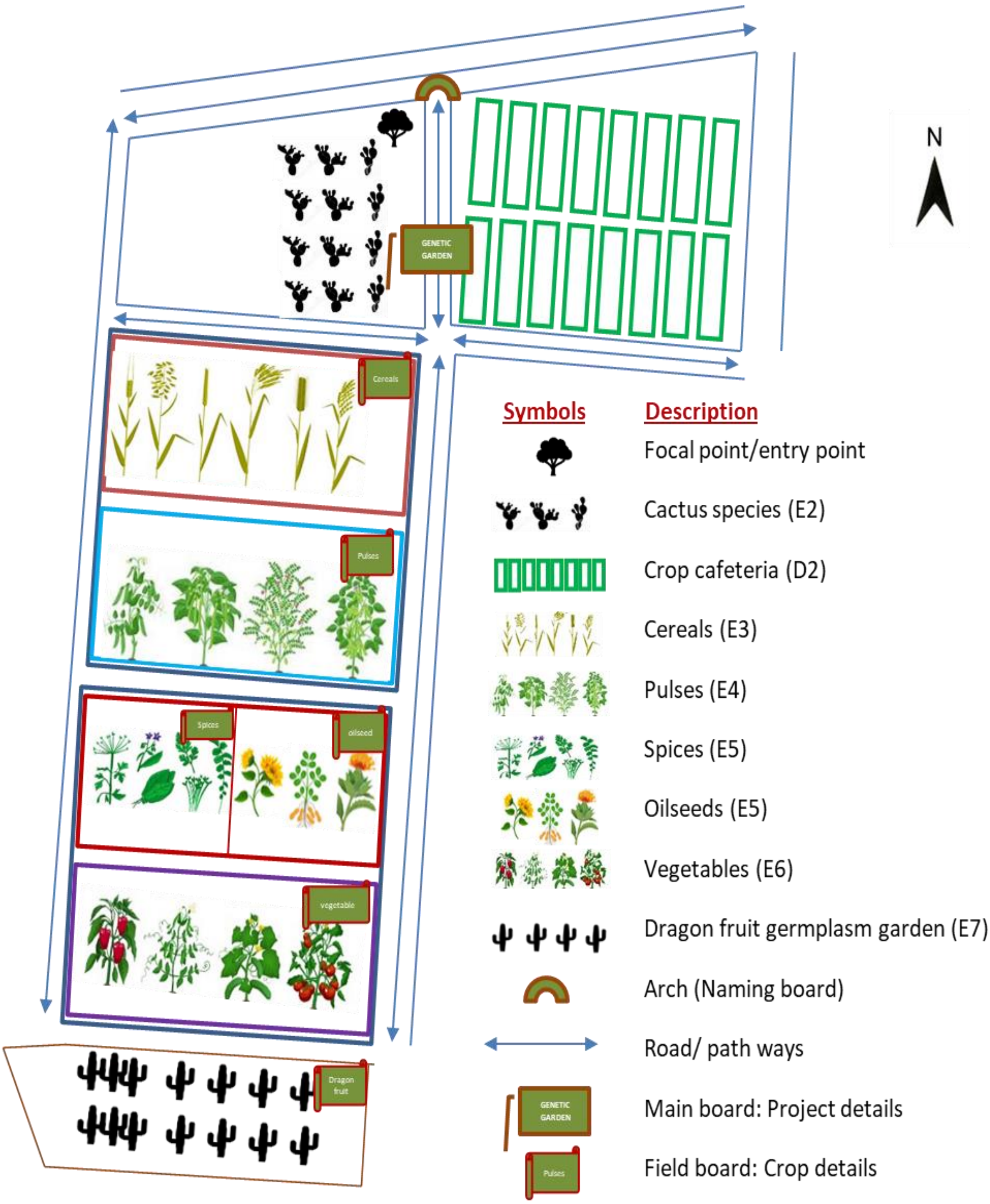

Fig. 4. Design of the genetic garden.

4. Activities

The above planning provides a roadmap to establish genetic garden. But actual implementation of the plan depends on right and precise action with well-defined activities. Therefore, the activities to establish genetic garden are described briefly in the following section.

4.1. Collection, display, conservation and maintenance of abiotic stress tolerant plants, animals and fisheries genetic resources

The entire project implementation and its success depend on the collection and maintenance of different genetic resources of plants, animals and fisheries and also other components of biodiversity (native flora and fauna including local plants representing arid and semi-arid vegetation; insects, butterflies, honey bees). The diverse plant, animal and fisheries genetic resources (abiotic stress tolerant varieties/breeds, genetic stocks, breeding lines, mutants including model plants) will be collected from different institutes (listed as Table 2).

4.1.1. Plant components

i. Collection and planting

The local cultivars, land races and wild relatives of crops will be collected from farmer's fields, seed banks of SHGs, NGOs, seed organizations etc. For this purpose, information on abiotic stress tolerant plants, animals and fish will be gathered and explored the possibility of collecting such genetic resources (seed/planting materials) and information through communication/collaboration. In this context, compiled the information on abiotic stress tolerant crop varieties, livestock breeds and fish species and published as Technical Bulletin (Boraiah et al., 2021). This comprehensive information will be helpful in collecting genetic resources tolerant to drought, water logging, high temperature, cold, chilling and salinity. The collected seed or planting material will be stored in cold storage chamber as seed bank. Subsequently, collected seed/planting material of different crops will be planted during different growing seasons (kharif/ rabi) in different blocks of genetic garden or in pots/ greenhouses for displaying. The crop management practices including inter-cultivation/ earthing up, weeding, nutrient/ irrigation management, pest and disease management will be followed according to standard package of practices. However, some of these practices may be regulated in case of demonstration/experimentation plots as per treatments. The transgenic/ gene silenced and model plants will be grown in confinement greenhouses.

ii. Displaying (exhibition/demonstration)

All the plants or crops grown in genetic garden, in pots, greenhouses, native plants (at original site) and varieties in mango diversity block will be labelled properly with brief description of plants or varieties features and their uses along with location of collection or sources. If in case plants not able to maintain due environmental factors and other reasons, such plants/ specimens/seeds will be stored or preserved in bottles or as a herbarium in the museum. The transgenic/ gene silenced and model plants will be displayed in confined growth chambers or greenhouses with proper arrangements for visitors and following bio-safety guidelines. The photos/ videos of model plants, animals and fishes used in experiments/research related to abiotic stress tolerance will be collected and displayed in museum galley.

The popular and abiotic stress tolerant crop varieties will be planted during rabi and kharif seasons in crop cafeteria plots for demonstration purpose. Similarly, the different dragon fruit varieties/types will be collected and planted to display the diversity (Dragon fruit diversity orchard).

iii. Multiplication, maintenance, and conservation (seed bank)

The collected genetic resources of different crop plants will be maintained properly with adopting all agronomic practices and pest disease management. Further, based on the mode of pollination, the genetic purity of crops will be maintained. The special care will be taken in case of cross-pollinated crops; selfing will be done by bagging before anthesis and harvest separately. Sometimes in typical cross-pollinated crops (like maize) sib mating will be followed to avoid inbreeding depression. Further, if any mixtures observed in the genotypes, purification of such genotypes will be carried out by following standard breeding methods/ procedure. After ensuring the trueness or purity of genotypes, the seed or planting materials will be stored properly in cold chamber with proper labelling and documentation so that there should not be any duplication and misplacing. The vegetative planting materials will be maintained with proper labelling and documentation in neat and clean garden area or green houses to prevent pest and disease attack particularly virus infection. If necessary, the seed/ planting materials will be multiplied at every alternate year to ensure sufficient seeds and particularly in case of crop seeds with poor storability (poor seed longevity). For long term storage and self-sufficiency of seeds, the small seed bank will be established with upscaling existing seed storage facilities. Further, provision will be made to store farmers seeds of landraces/ local cultivars by extending facilities for farmers/ other local stakeholders involved in conservation of climate resilient genetic resources.

4.1.2. Animal component

i. Repository of information on animal genetic resources

India being one of the world's twelve mega biodiversity countries, diverse animal genetic resources were adapted and spread across diverse agro-climatic regions of the country. There are 50 cattle breeds, 17 buffalo breeds, 34 goat breeds, 44 sheep breeds, 7 horse and pony breeds, 9 camels, 3 dog breeds, 19 chicken breeds, 10 pig breeds, 3 donkey breeds, 1 yak breed, 2 duck breeds, and 1 goose breed registered in India. The information on these animal genetic resources will be collected and displayed in poster format.

ii. Collection and conservation of local breeds of livestock

Local or indigenous livestock breeds inherently tolerance to biotic and abiotic stresses mainly heat stress tolerance and indigenous cows well known for quality (A2) milk. Crossbreeding with exotic breeds, loss of utility (draught) and large-scale mechanization of agricultural activities are contributing to the extinction of native cow breeds. The majorities of indigenous animals are beneficial for low-input production systems throughout the country. Therefore, as a component of Genetic garden and gene bank for abiotic stress tolerance such native and climate resilient breeds will be collected/ purchased, preserved as future genetic insurance, scientific study, cultural and ethical purpose.

Suitable strategy will be developed for the conservation and utilization of indigenous livestock breeds such as Deoni, (Latur), Dangi (Nasik, Ahmednagar Distt.), Marathwada (Marathwada region), Nagpuri (Vidhharbha region), Khillar (Sangli and Satara), Phandharpuri (Kohlapur, Sangli, Solapur), Gaolao (Nagpur), and Solapur (Solapur), Red Kandhari (Nanded), Osmanadadi goat (Osmanabad, Latur), Deccani sheep, Lonad sheep, Sangamneri sheep, Madgyal sheep, Kolhapuri sheep, Satpuda Desi fowl, Dog breeds and others. Pure breeding with high-producing animals will be carried out for the conservation and propagation of elite animals. Some of the animals will be procured from local farmers/markets and will be reared following standard management practices.

iii. Characterization and registration of native germplasm

A review of the literature and a survey of the local area will be used to gather information about locally adapted indigenous livestock breeds in the semi-arid region. Animals will be procured which have distinct characteristics, and their qualities will be investigated. During local survey, the livestock breeds having distinct abiotic stress tolerance will be characterized and will be registered as a potential breed with distinct characteristics.

4.1.3. Fisheries component

The fishes from local water bodies/ tanks/ rivers will be collected and identify the species and study their responses for different stresses. Further, proper documentation and preservation of collected fish species in museum/ aquarium.

4.1.4. Establishment of Butterfly Garden

Butterfly is one of the most important indicator species (indicates health of our surroundings and it plays vital role in food chain & ecosystem. Species diversity of butterflies is declining because of rapid loss of their habitat due to rapid development in urban areas. Approximately 1500 species of butterflies are found in India. About 230 species have been recorded in Maharashtra of which about 150 species are recorded in Mumbai city. State butterfly of Maharashtra is Blue Mormon. An effort will be made to collect, conserve and multiply different species of butterflies by establishing butterfly garden.

Butterfly garden will be established by setting up of insect mass-rearing facilities/unit and erecting greenhouse structure besides admin building at ICAR-NIASM, Baramati (Fig 3 and 5). The different of species of flowering flora which attract butterflies, provide them nectar, and space for breeding will be identified, collect their seed/planting materials to grow inside greenhouse. After establishing flowering garden, different kinds of butterfly species will be released and subsequently the butterfly garden will be maintained with proper management.
Flowing host and nectar plants identified for attracting and rearing butterflies species:

i. Host Plants

The specific host plants such as Kadipatta (*Murraya koenigii*), Lemon (*Citrus limon*), Bel (*Aegle marmelos*), Panfuti (*Bryophyllum pinnatum*), Mussaenda (*Mussaenda frondosa*, *Mussaenda erythrophylla*), Halad kunku (*Asclepias curassavica*) etc can be grown on which specific species of butterflies lay eggs and caterpillar eats leaves of only these specific plant.

ii. Nectar Plants

Flowering plants such as Pentas (*Pentas lanceolate*), Periwinkle (*Vinca rosea*), Jamaican Spike (*Stachytarpheta jamaicensis*), Pink Portweed (*Stachytarpheta mutabilis*), Lantana (*Lantana camara*) etc can be grown from which butterflies suck the nectar. Butterflies not only feed on flower nectar but also on decomposing meat, plant sap, salt from soil etc., depending on butterfly species. Overripe fruits also attract certain butterfly species.

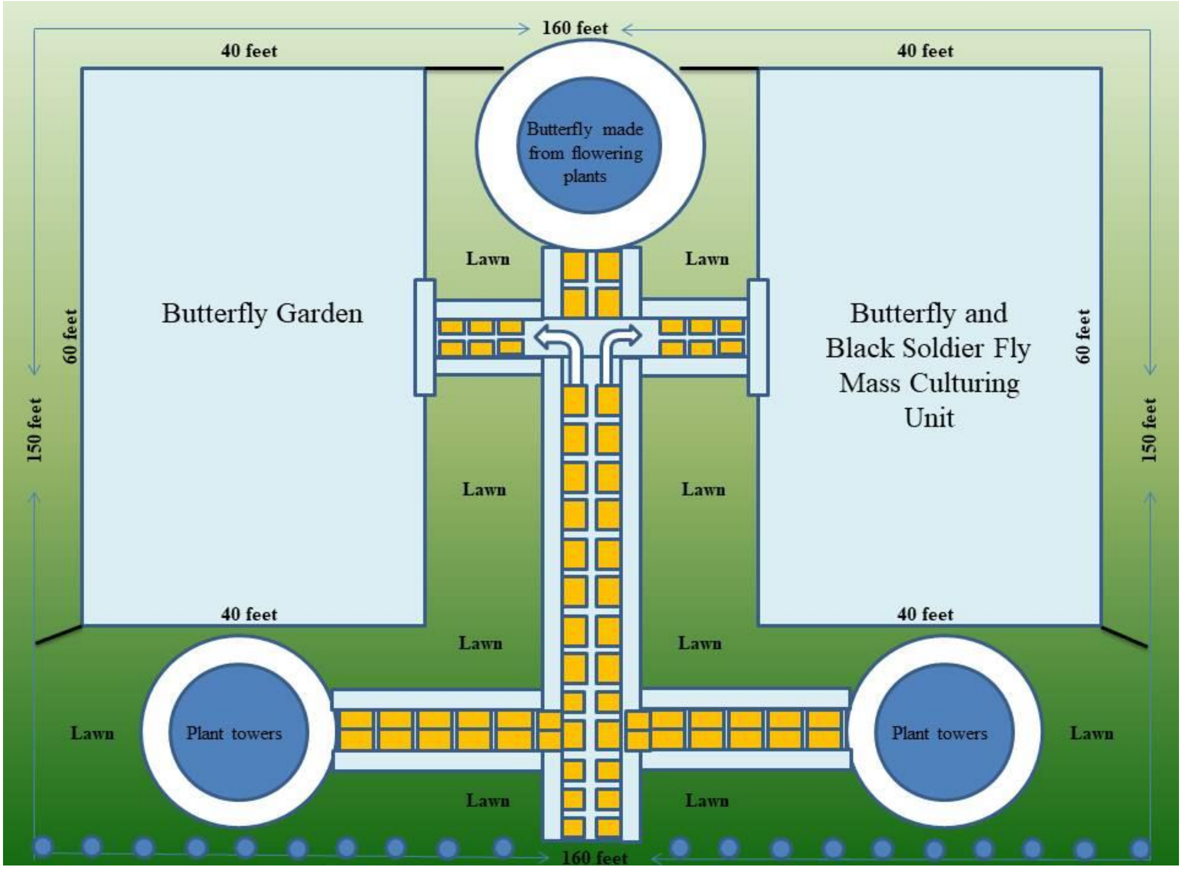

Fig. 4. Design of the butterfly garden (green house) and butterfly mass culturing unit.

4.1.5. Establishment of apiary

The apiary will be established by procuring bee hives and placed them at proper sites within campus to ensure pollen sources and other favorable conditions. Subsequently established apiary will be maintained by frequent monitoring and suitable managements including pest and disease control, supplementary pollen/nectar feeding, etc.

4.1.6. Establishment of museum

The model museum will be established by placing all materials to display the specimens. The live plants or specimens (by preserving in bottles, or as herbarium) of model plants used in model experiments related to abiotic stress tolerance will be displayed with proper labelling or brief description. Further, very rare, historical and relevant plants, animals, fishes etc which are not able to collect or asses will be displayed in photographs or videos. Such collections of photo/videos will be maintained and documented properly and will be displayed during special events of institute and student, farmers and public visits.

4.2. Evaluation and characterization of PGRs for different abiotic stress responses

4.2.1. Screening and evaluation of collected PGRs

The collected genetic stocks, promising genotypes, germplasm lines from institutes will be evaluated in the field or controlled conditions for different abiotic stress tolerance for their confirmation and validation. Similarly, the diverse plant genetic resources (PGR) such as landraces, cultivars, farmer varieties and wild relatives of crop plants will be screened extensively in the field or controlled conditions to identify the promising lines tolerance for different abiotic stresses. Further, these PGR (initially underutilized and few dryland crops) screened for other valuable traits such as nutrient content and other special traits and the promising lines will be shared with other institute or flagship projects and also with other collaborating institutes for further use.

4.2.2. Characterization of collected PGR

All the evaluated and promising PGRs (genetic stocks, promising genotypes, breeding lines, germplasm lines, landraces, cultivars and wild relatives of crop plants) will be characterized to identify the traits responsible for their adaptive mechanisms for different abiotic stresses at physiological, biochemical and molecular level.

i. Morpho-physiological characterization

The physiological basis of abiotic stress responses in promising PGR lines will be unraveled by assessing the physiological traits at various growth stages in filed or controlled environment. The non-destructive and phenomics tools will be used to assess morphological and physiological traits.

ii. Bio-chemical characterization

Deciphering the biochemical basis of drought stress tolerance of elite germplasm/ identified lines by bio-chemical analysis. Further, microbiome associated with stress tolerant lines of crop plants, xerophytes, cactus and halophytes will be studied.

iii. Molecular characterization

The stress tolerance responses in diverse and promising lines will be confirmed and validated through identified molecular markers and gene expression studies. Molecular markers (SSR, SNP etc.) associated with abiotic stress tolerance traits can be identified using the diverse genetic resources and mapping population. The collected genotypes/cultivars will be characterized for abiotic stress tolerance using identified/ developed molecular markers. The ribulose biphosphate carboxylase (*rbcL*) marker-based approach will be adopted for molecular identification and also phylogeny study of identified promising lines. The specific and novel abiotic stress tolerant genetic resources of plants, livestock and fish will be registered.

4.3. Identification and validation of genes/traits/mechanisms associated with abiotic stress tolerance in genetic stocks or identified promising lines

The genes responsible for different abiotic stress tolerance viz., water stress, salinity and heat stress tolerance will be identified and unravelled bio-physio-chemical pathways involved in complex mechanism of stress tolerance. The different methods, techniques, bio-informatics, comparative transcriptomic analysis using contrasting lines or mutants & wild plants, gene expression in model plants, and other different gene silencing approaches will be employed to identify genes controlling stress tolerance and also to validate their function.

4.4. Sharing genetic resources and capacity building for abiotic stress tolerance

The promising lines/genotypes, genetic stocks identified will be shared with other organizations/ institutes for research and crop improvement programmes with suitable MoA/MTA. Further, various extension/training programmes will be organized for research scholars, college students, and farmers to strengthen capacity building and also facilitate agro-eco tourism, exposure visits to school children, students, farmers and public.

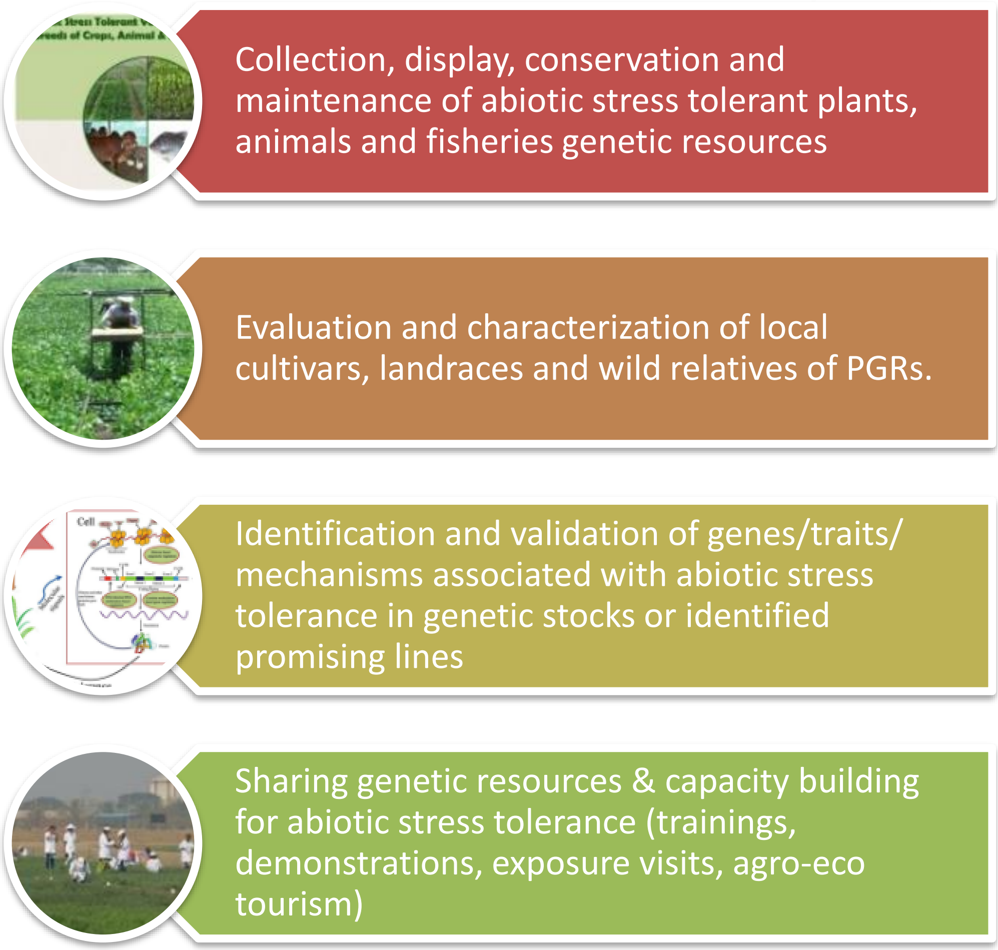

Fig. 5. Activities to establish the genetic garden.

Annexure-I

Table 1. Monthly average temperature (T), relative humidity (RH) and rainfall at ICAR-NIASM.

Month	Temperature			Relative humidity			Rainfall (mm)
	Min T	Max T	Mean T	Min RH	Max RH	Mean RH	
Jan	29.62	12.72	21.17	80	31	55	0.01
Feb	32.35	14.73	23.54	71	26	48	0.09
March	35.48	17.76	26.62	63	21	42	15.59
April	38.32	20.83	29.58	62	18	40	11.86
May	38.81	22.76	30.78	67	23	45	27.84
June	33.19	22.71	27.95	84	51	67	98.34
July	30.09	22.11	26.10	87	63	75	74.99
August	30.26	21.30	25.78	88	61	75	58.03
Sept	30.94	21.08	26.01	90	56	73	166.81
Oct	31.78	20.21	26.00	87	45	66	115.51
Nov	30.65	16.45	23.55	80	38	59	11.13
Dec	29.50	13.81	21.66	82	36	59	1.16

Table 2. Monthly rainfall (mm) during 2012-2020 at ICAR-NIASM.

Year	Months											
	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
2012	0.0	0.0	0	2	7.6	8.7	32.6	33.8	61.9	65.9	8.5	0
2013	0.0	0	0	0	0	100.4	92.2	25.4	253.2	31	1.4	1.4
2014	0.0	0.6	80.4	54.4	107.6	84.6	89.4	191.7	73.7	26.1	44	7.6
2015	0.1	0	22.4	16.2	80	49.7	26.1	4.6	120.7	62.8	4.6	0
2016	0.0	0.2	0.6	3.8	16	121.6	49.2	39.6	211	48.2	0	0.8
2017	0.0	0	0	0	1.8	182.1	49.2	108.5	306	109.4	2.8	0
2018	0.0	0	0	14.8	9	143.6	32.6	20.5	36.4	80.8	13.3	0.2
2019	0.0	0	0	0	0	36.4	162.6	19.6	162.6	332.4	25.6	0.4
2020	0.0	0	36.9	15.5	28.6	158	141	78.6	275.8	283	0	0
Average	0.0	0.1	15.6	11.9	27.8	98.3	75.0	58.0	166.8	115.5	11.1	1.2

Source: Meteorological Station, ICAR-NIASM, Baramati

Note: Data is based on observations recorded from meteorological station (working since 2012) located 50 m away from genetic garden

Annexure-II

Soil health status of the site

A. Physical properties

Plot No.	Depth (cm)	<2 mm (%)	>2mm (%)	Sand (%)	Silt (%)	Clay (%)
E3	0-15	28.97	71.05	81.56	9.96	8.48
	15-30	26.30	73.70	83.00	9.06	7.95
E4	0-15	25.02	75.03	82.81	9.28	7.91
	15-30	23.23	76.78	84.04	8.74	7.23
E5	0-15	26.43	73.58	80.89	10.86	8.25
	15-30	23.78	76.23	82.51	9.79	7.70
E6	0-15	23.07	76.93	84.68	8.81	6.52
	15-30	21.88	78.13	86.05	7.72	6.24
E7	0-15	27.34	72.68	82.88	9.66	7.46
	15-30	23.75	76.25	84.15	8.89	6.96

B. Chemical properties

Plot No.	Depth (cm)	pH	EC (dS m^{-1})	OC (%)	N (kgha^{-1})	P (kgha^{-1})	K (kgha^{-1})	S (mgha^{-1})	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm
E3	0-15	7.48	0.14	0.35	79.99	2.03	77.44	8.20	0.49	2.71	0.38	0.15	0.09
	15-30	7.60	0.16	0.34	77.11	1.95	75.25	7.88	0.35	1.96	0.61	0.17	0.07
E4	0-15	7.44	0.15	0.35	68.08	1.91	78.59	7.70	0.34	1.98	0.30	0.10	0.06
	15-30	7.53	0.17	0.31	65.84	1.83	73.68	7.27	0.00	0.02	0.06	0.02	0.07
E5	0-15	7.56	0.17	0.36	72.10	1.95	78.38	7.77	0.00	0.11	0.07	0.02	0.09
	15-30	7.64	0.18	0.35	69.41	1.81	74.93	7.40	0.00	0.10	0.06	0.02	0.10
E6	0-15	7.40	0.19	0.40	62.03	1.45	71.05	6.39	0.01	0.12	0.06	0.02	0.07
	15-30	7.45	0.20	0.38	59.83	1.36	67.88	6.08	0.01	0.15	0.06	0.02	0.09
E7	0-15	7.23	0.15	0.31	71.87	1.97	77.77	7.43	0.00	0.06	0.08	0.02	0.09
	15-30	7.38	0.18	0.28	69.61	1.90	74.05	6.60	0.00	0.19	0.06	0.02	0.10

Source: Rajagopal et al. (2018)

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