Abiotic Stress Tolerant Crop Varieties, Livestock Breeds and Fish Species

ICAR- National Institute of Abiotic stress Management
Baramati, Pune-413115, Maharashtra

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Authors

Boraiah KM
Basavaraj PS
Harisha CB
Kochewad SA
Khapte PS
Bhendarkar MP
Kakade VD
Rane J
Kulshreshtha N
Pathak H

राअस्ट्रैप्रसं
NIASM

ICAR-National Institute of Abiotic stress Management
Baramati, Pune, Maharashtra 413115

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Mr. Pravin H More, Senior Technical Assistant

PREFACE

In changing climatic scenario, frequent occurrence of climate aberrations can cause huge loss to agriculture productivity, predominantly under rainfed conditions. Hence, ensuring food and nutritional security to increasing population has emerged as the biggest challenge. With diverse agro-ecologies, Indian agriculture is featured by agro-climatic situations often experiencing drought, frost, hailstorm and heat wave. Therefore, climate resilient crops, livestock and fish can play a crucial role in development of climate adaptation strategies for crop production and efficient management of natural resources. In addition to abiotic stress resilience in these commodities, good management practices can significantly reduce losses due to adverse climate.

Persistent efforts have been made by ICAR institutes; State Agriculture Universities, NGO, etc. have resulted in some climate resilient varieties/ hybrids of crops with high yielding ability under various abiotic stress conditions. Adoption of abiotic stress tolerant plants varieties, animal breeds etc. can enhance agricultural productivity per unit of land and per unit of natural resources spent and hence can significantly contribute to sustainable as well as profitable agriculture that can help in improving the economic status of farmers.

In this publication, an attempt has been to provide updated information about abiotic stress tolerance in crop varieties, animal breeds and fish breeds released under National Agricultural Research and Extension System (NARES). This compilation may serve as ready reference for the students, academicians, scientists, teachers and farmers interested in management of abiotic stress in agriculture. This can also help in orientation of research programs aiming at improvement of abiotic stress tolerance in crops, animals and fish.

Authors

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1. Introduction

Agriculture is a livelihood for a majority of the population in India and its contribution to the national economy can never be underestimated. Although its contribution in the Gross Domestic Product (GDP) has reduced to less than 20% and contribution of other sectors increased at a faster rate, agricultural production has enhanced substantially. With new innovations and adaptation of technologies in agriculture since after independence, India is now self-sufficient in food production and even a net exporter of agriculture and allied products. Total food grain production in the country is estimated to be a record 291.95 million tonnes, according to the second advance estimates for 2019-20. Besides this, India is the top producer of milk, spices, pulses, tea, cashew and jute, and the second-largest producer of rice, wheat, oilseeds, fruits and vegetables, sugarcane and cotton (Sharma, 2021). In spite of this growth in agriculture, an increasing population, increasing average income and globalization effects has led to further increase in the demand for quantity, quality and nutritious food, and a variety of food. The task of meeting the food demand is challenged by global warming and potential weather anomalies associated with climate change and also enhanced responsibilities to preserve nature without living environmental footprints of agricultural production technologies.

Being a tropical country, India is more challenged with a multitude of several abiotic and biotic stresses. Since the past few decades, the country is witnessing the episodic and frequent droughts, floods, degradation of land, extremes of temperature as well as pest and disease outbreaks resulting in losses in agricultural productivity. These problems are likely to aggravate with changing climate that can be a serious threat to food security in the 21st century. Although the impacts of climate change are global, countries like India are more vulnerable in view of the greater proportion of its population depending on agriculture, excessive pressure on natural resources and poor coping capabilities (Vision 2050, ICAR-NIASM).

Biodiversity and genetic resources play a crucial role in supporting human society for ensuring food security, sustainable livelihoods, ecosystem resilience, coping strategies for climate change, adequate nutritional requirements. Conserving and sustainably managing biodiversity including genetic resources for food and agriculture (GRFA) is necessary for mitigating climate disruption and food security. Climate change poses new challenges to the conservation and management of GRFA but it also underlines their importance. GRFA underpins the capacity of crop, livestock, aquatic and forest production systems to withstand and adapt to harsh conditions. Conservation and sustainable utilization of GRFA are key to maintaining our ability to achieve food security under changing climate scenarios (FAO, 2015.)

The diverse GRFA is the main and ultimate source for the genetic improvement of the climate resilience in crops, livestock and fish breeds. Hence, identifying such climate resilient crop genotypes and livestock and fish breeds for different agro-ecologies of the country is essential to sustain and accelerate the productivity to meet the increasing demand of food. Tolerant crop varieties and livestock and fish breeds perform well even under different abiotic stresses, such as drought, floods, heat, cold etc. Further, integrated and proper management strategies are helpful for realizing the genetic potential of abiotic stress tolerant genetic resources of crops, animals and fish (Maheswari *et al.*, 2019).

2. Abiotic Stresses in Agriculture

Agriculture production and productivity are constrained by many entities, which may be classified into living or nonliving factors. The stresses caused by nonliving factors are largely referred to as abiotic stresses. This section briefly explains the abiotic stresses and the possible amplification of these abiotic stresses due to climate change.

2.1.Types of abiotic stresses

Abiotic stresses emerge due to extreme moisture condition (drought and floods), extreme temperatures (heat and cold/chilling/frost), radiation (UV, ionizing radiation), chemicals (nutrient deficiencies, excess of soluble salts, salinity, alkalinity, low pH/acid sulfate conditions, high P and anion retention, calcareous or gypseous conditions, low redox, chemical contaminants-geogenic and xenobiotic), physical (high susceptibility to erosion, steep slopes, shallow soils, surface crusting and sealing, low water-holding capacity, impeded drainage, low structural stability, root-restricting layer, high swell/shrink potential), and biological (low or high organic contents) components (Minhas et al., 2017). Among these, stressors, extreme temperatures (heat and cold), precipitation (drought and floods) are occurring more frequently and are responsible for major reduction in agricultural production in India (Fig. 1). However, metal/mineral toxicity is increasing day by day due to indiscriminate use of chemical fertilizers and also due to use of pollutant/sewage water for irrigation. Furthermore, enhanced frequencies of cyclones have devastated coastal agriculture, besides disturbing the entire population of the regions. Coping with these calamities which invariably leads to the abiotic stresses in agriculture are difficult to manage due to underlying complexity caused by the dynamic nature, uncertainties as well as combined occurrence of stress with varying intensity.

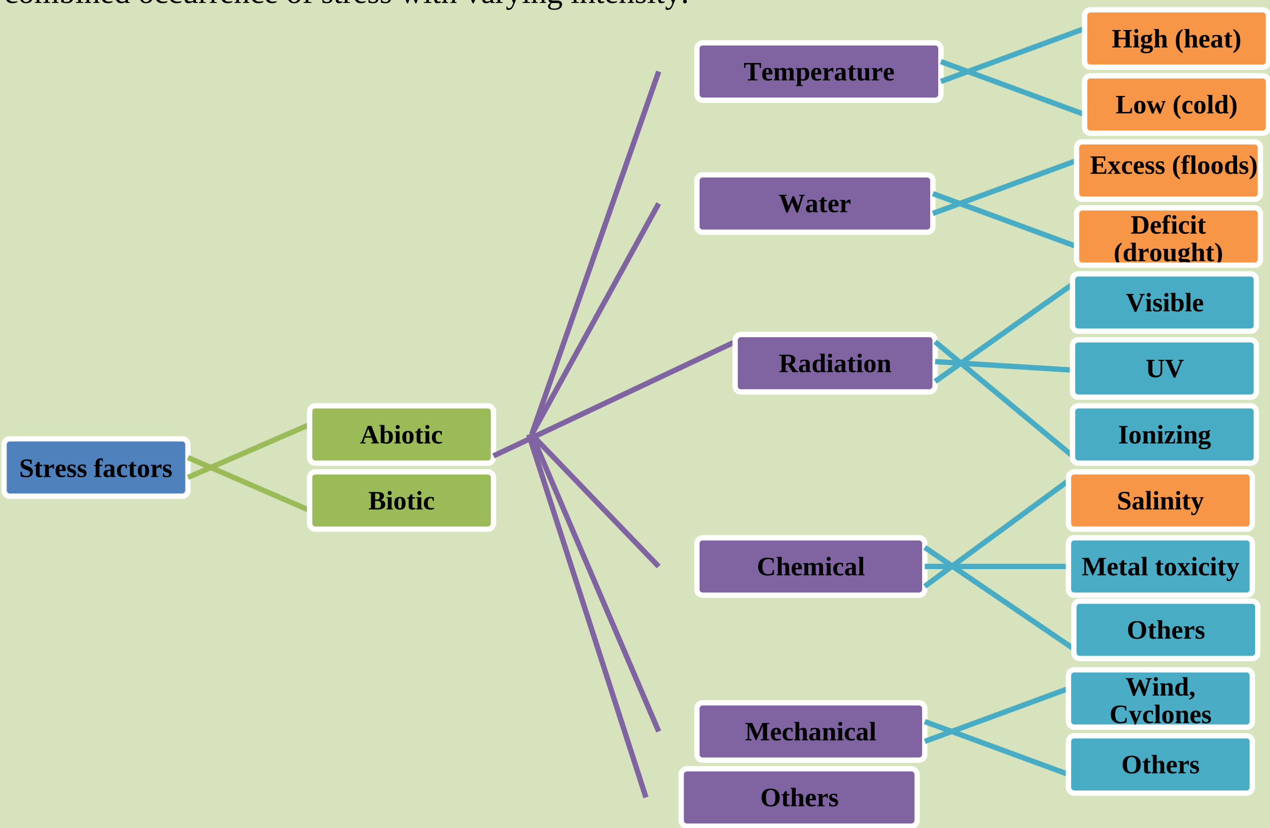


Fig. 1. Abiotic stress factors affecting agriculture. Orange colored fields denoting the stressor often affecting crops, livestock and fish (Modified after Calanca, 2016 and Minhas et al., 2017).

2.2. Climate change impacts on abiotic stresses

Although the impacts of abiotic stresses are being experienced globally, countries like India are more vulnerable in view of the large population depending on agriculture. Small and marginal farmers especially of arid and semi-arid regions are likely to be more vulnerable to the risks associated with abiotic stresses. Since the last two decades, various regions of the country have witnessed an increase in frequency and intensity of abiotic stresses particularly drought, floods and heat & cold waves. The country witnessed a drought in 2002 with 19% deficit rainfall. There was an extreme cold wave in winter 2002-03 leading to frost damage of winter crops. The state of Andhra Pradesh faced three weeks of heat wave during May, 2003. The high temperatures during March 2004, adversely affected crops like wheat, apple and potato across northern India, while there was a drought like situation in July, 2004 with overall deficit rainfall of 13%. The year 2005, witnessed destructive hurricanes/cyclones across the globe with some major floods in India (Venkateswarlu, 2013). The increase in frequency of heavy rainfall events in the last 50 years over Central India indicates a significant changing climate pattern in India (Goswami, 2006). The states of Rajasthan, Andhra Pradesh witnessed floods during 2006, while in North Eastern States it was a drought year. During 2012, widespread drought was reported in the states of Punjab, Haryana, Gujarat and Karnataka while cyclone Neelam hit the east coast of the country that caused severe flood in Andhra Pradesh. The year 2014 was yet another year that witnessed a number of natural calamities including hail storms, early season dry spells; devastating floods in Kashmir and Hudhud cyclone in coastal Andhra Pradesh. Cyclone Amphan was the world's costliest natural disaster, (estimated economic loss of 15 billion USD) occurred during 2020 and it devastated West Bengal and the coastal districts of Odisha. Further, extreme events such as heat waves in Andhra Pradesh and Telangana during 2016; cold waves in Jammu & Kashmir during 2017; and many others (add recent ones) (Kulkarni et al., 2017) have been experienced in recent years. Significant contribution of anthropogenic warming in the rise of the frequency of extreme precipitation in India has been suggested (Mukherjee et al., 2017). Moreover, recent analysis indicates strong trends towards intensified droughts in Northwest India and parts of Peninsular India while in contrast, in Northwest Himalaya, and Central India experienced increased extreme daily rain intensity leading to higher flood vulnerability (Malik et al., 2016). Also a threefold increase in widespread extreme rain events over central India during 1950–2015 have been reported (Roxy et al., 2017). Further, satellite data suggests that there has been an increase of around 1 degree Celsius (°C) in maximum temperatures across India in the last 50 years (between 1951–60 and 2001–10) and forecasts by expert groups suggest more alarming situations in coming years. IPCC predicts that temperatures are likely to rise by 30C–40C by the end of the 21st century (Pathak et al 2012). Increase in the mean temperature and increases in the number of hot days have been documented across the country (IMD 2018). Most of these natural calamities make news due to their devastating impact on human lives and properties. This often masks the impacts on agriculture. The following section briefs about the reports on impact of abiotic stresses on crops and livestock production and fisheries. Impact of abiotic stresses

Losses to the tune of 50% of agricultural production occur due to abiotic stresses depending on their intensity. Even though all stresses are not directly linked to climate factors, the occurrence of abiotic stresses is often triggered by anomalous climatic conditions, such as extreme temperatures, prolonged and intermittent droughts due to extreme precipitation.

2.3. Impact on crop production

Crop growth and yield is mainly determined by climatic factors, edaphic factors, pests and nutrient availability in the soil. Stress refers to any kind adverse environmental condition that hampers proper growth and productivity of a plant. However, in crops abiotic stresses such as drought, floods, elevated temperature, low temperature and salinity are more prevalent (Fig. 1). Abiotic stress conditions such as drought, high and low temperature and salinity also influence the occurrence and spread of pathogens, insects, and weeds. Concurrent occurrence of abiotic stresses such as drought and heat has been shown to be more destructive to crop production than these stresses occurring separately at different crop growth stages. Since different types of stress interactions can have a range of effects on plants depending on the nature, severity, and duration of the stresses, the task of assessing such effects is very difficult mainly due to complexity and multi-dimensionality of abiotic stresses (Pandey et al., 2017).

Further, underlying uncertainties in the assessment of impact, adaptation and mitigation of climate change in agriculture makes it imperative to optimize the methodology (Pathak et al., 2012). Recently, advanced computation and simulation models made it possible to quantify and also predict the impacts of different abiotic stresses on crops with certain levels of confidence. Projections by IPCC and other agencies have revealed that unless we adapt, global warming will lead to 10-40% loss in crop production in India by 2080-2100. An average of 30 per cent reduction in crop yields is anticipated by the mid-21st century in South Asian countries. For instance, in India, an increase in temperature by 1.5°C and a reduction in the precipitation of 2 mm can reduce the rice yield by 3 to 15 per cent (Ahluwalia and Malhotra, 2006). Climate change will reduce the wheat yield in India in the range of 6 to 23% by 2050 and 15 to 25% by 2080. Loss in wheat production in Indo-Gangetic plains would be 4 to 5 million tonnes with 1°C rise in temperature (Aggarwal, 2008 and Kumar et al., 2014)). High temperature causes moisture stress situations, directing sunburn and cracking symptoms in fruit trees like apricot, apples and cherries. The temperature increase at the ripening stage causes fruit burning and cracking in litchi (Kumar and Kumar, 2007). Further, it is also estimated that the yield of vegetable crops will reduce by 5-15 per cent if the ozone concentration reaches more than 50 parts per billion / day (Raj, 2009).

2.4. Impact on livestock production

Climate change is a long-term shift in the statistics of the weather of a particular region and sustainability of livestock production systems is largely affected by climate change (Kebede 2016). The climate, being a function of several elements such as environmental temperature, humidity, precipitation, air movement, solar radiation, atmospheric pressure and ionization, can influence the livestock behavior and productivity significantly. In addition, climate change can affect livestock production indirectly through its effect on the animal's environment and vegetation. In India, the estimated losses of about 1.8 million tonnes of milk of approximate value Rs 2661 crore a year could be attributed to high temperature stress on cattle and buffaloes (Upadhayay, 2010).

Climate change will affect livestock production through competition for natural resources, quantity and quality of feeds, increase in incidence of livestock diseases, heat stress and biodiversity loss. It adds another dimension to the climate change imposed challenges particularly to maintain a balance between livestock productivity, household food security and environmental preservation (Wright et al., 2012). Further, quality of feed crops and forage also are affected by increased temperatures and dry conditions due to variations in concentrations of water-soluble carbohydrates and nitrogen. Fodder availability for livestock will be affected by increases in temperature, CO_2 and rainfall variation. Temperature increases may increase lignin and cell wall components in plants (Polley et al., 2013), which reduce digestibility. An increase of 2^0C will produce negative impacts on pasture and livestock production in arid and semiarid regions and positive impacts in humid temperate regions (Melissa et al., 2017).

2.5. Impact on fisheries

Fish, being poikilothermic vertebrate, are more prone to the impacts of global warming. Aquaculture now provides half of the all fish products for human consumption (FAO, 2016). Capture fisheries landings are reported to have either plateaued around 90 Mt annually (FAO, 2018) or decreased (Pauly & Zeller, 2016) since the mid-1990s. As of 2013, 31.4% of global stocks were overfished, 58.1% were fully fished, and only 10.5% were under fished (FAO, 2016). While some wild fisheries may experience short-term benefits from climate change, overall global landings are predicted to decrease 10% by 2050 (Barange et al., 2014). Given the potential range of biotic and abiotic climate change stressors, impacts to resources, the diversity of biological response mechanisms and the potential for stressor interaction, cost–benefit evaluation of aquaculture adaptation efforts is vital. Research into the multiple dimensions of climate change is increasing exponentially (Gregor et al., 2019).

Climate changes affecting fisheries including aquaculture are reflected mainly by temperature fluctuation in both marine and freshwater, particularly surface temperatures in marine conditions and other alterations in oceanographic conditions, including currents, wind speed and waves. Extreme weather conditions becoming more intense and more frequent are important effects, either as storms causing material damage or flooding of freshwater farms. Fish or shellfish will be subject to different abiotic stresses and physiological effects, affecting growth and survival, which may further increase their susceptibility to diseases and infections. Physical, chemical and perceived stressors can all evoke non-specific responses in fish, which are considered adaptive to enable the fish to cope with the disturbance and maintain its homeostatic state (Fig. 2).

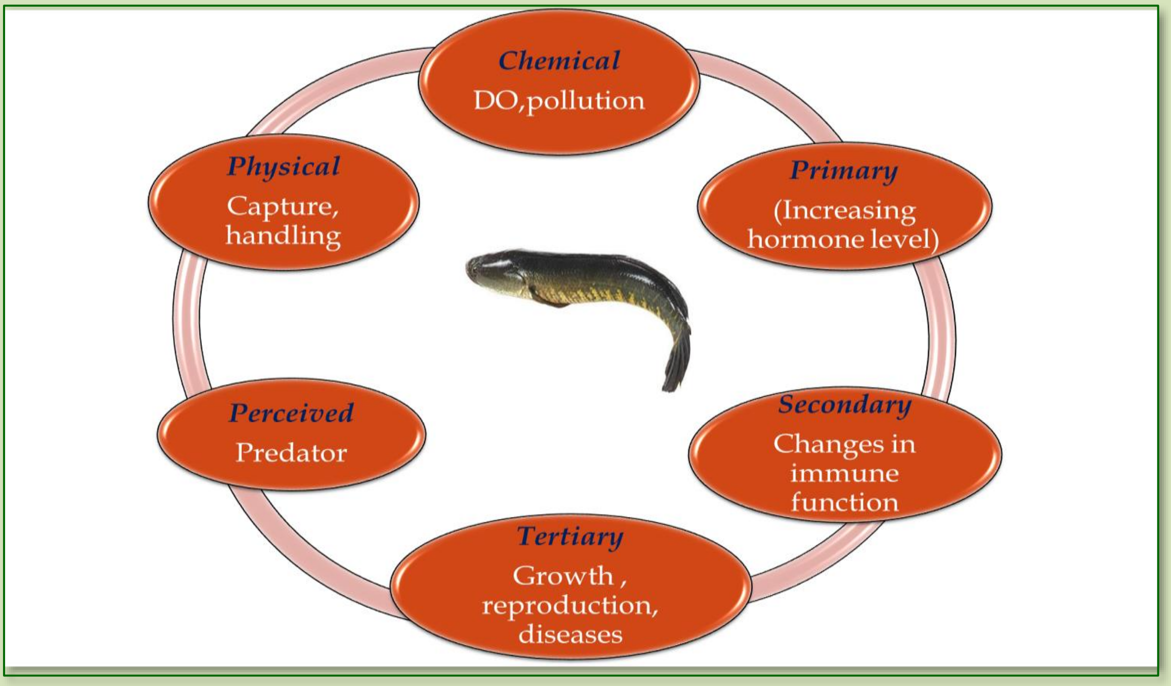


Fig. 2. Response of fish to environmental stresses.

3. Strategies for Coping with Abiotic Stresses in Indian Agriculture

As discussed in the previous section, different abiotic stresses are threatening the sustainability of agricultural production components and the situation is likely to worsen with predicted climate change. For combating the effects of the resultant abiotic stressors, various strategies can be employed by exploiting exciting advanced science and policy initiatives. These include improved agricultural practices such as water saving technologies such as *in-situ* and *ex-situ* moisture conservation, water harvesting for supplemental irrigation, residue incorporation, developing and adopting/cultivating tolerant crop varieties, livestock & fish breeds, conservation agriculture, site specific nutrient management practices etc. Among these developing and promoting crop varieties or livestock & fish breeds with tolerance to abiotic stresses like drought, floods, heat, cold, salinity for the target vulnerable areas plays a crucial role. Further, strengthening institutional interventions in promoting collective action and in building resilience among communities through improved GRFA along with appropriate national resource management policies will go a long way in sustaining the agricultural production system in the country.

The diverse GRFA, particularly threatened plant species, wild and weedy relatives (Li and Pritchard, 2009), endangered and rare species of fish and local indigenous breeds and farmers crop varieties including land races, primitive cultivars, local cultivars or native crop varieties which are being conserved and cultivated by local/ tribal farmers since many years are fundamental sources of genes/traits associated with abiotic stress tolerance. These diverse GRFA are important for genetic improvement due to their high potential to adapt to specific environmental conditions. Though these are less productive than commercial cultivars/improved breeds of crops, animals and fish, they have become important as sources of genetic variability in the search for genes for tolerance or resistance to biotic and abiotic stresses. A systematic evaluation, characterization and utilization of these diverse GRFA for identification of traits/genes/alleles associated with abiotic stress tolerance.

On the other hand, the complexity of mechanisms controlling the traits associated with abiotic stress tolerance and the limited availability of diverse germplasm for tolerance to certain stresses have restricted genetic advancement in crop, livestock and fish. However, some level of success has been achieved in understanding crop tolerance to abiotic stresses; for instance, identification of abscisic acid (ABA) receptors (e.g., ABA-responsive element (ABRE) binding protein/ABRE binding factor (AREB/ABF) transcription factors), and other regulons e.g., WRKYs, MYB/MYCs, NACs, HSFs, bZIPs and nuclear factor-Y has shown potential promise to improve plant tolerance to abiotic stresses. Further, molecular studies on the post-transcriptional regulation of stress-responsive genes have provided additional opportunities for addressing the molecular basis of cellular stress responses in plants (Onaga G and Wydra, 2016).

Plant’s response to different abiotic stresses is crop and variety specific. For example, in case of pigeonpea, higher temperatures will shorten crop duration so that it matures when the wet season is still active, while sorghum experiences shortening of the vegetative phase relative to the grain-filling phase resulting in increased harvest index. Understanding of photoperiod sensitivity, genetic variation for transpiration efficiency will help in identifying short duration high yielding varieties that escape the terminal drought as well as other impending abiotic and biotic stresses (Maheswari et al., 2019). Similarly understanding the stress response and tolerance mechanism or traits in farm animals and fishes will gage the breeding of improved breeds of livestock and fish. Indian National Agricultural Research System (NARS) including various ICAR institutes and state agricultural universities are making concerted efforts over the years for developing improved varieties and breeds of different crops, animals and fishes with enhanced tolerance to multiple abiotic stresses. These varieties/ breeds could be utilized by the farming communities in the event of extreme weather situations. Abiotic stress tolerant crop varieties, local and improved breeds of livestock and fish along with suitable adaptation and mitigation strategies will help to overcome the adverse impact of abiotic stresses on productivity of crops, livestock and fisheries. Further, this enables sustainable and self-sufficient food production even under changing climate scenarios.

4. Crop Varieties for Different Abiotic Stresses

Sustaining and enhancing the crop production is very essential to enhance the productivity and doubling the farmer's income by minimizing risk in agriculture in order to improve the livelihoods of millions of people dependent on agriculture. Many intellectuals and experts worldwide have suggested that development and identification of abiotic stress tolerant climate resilient varieties with enhanced tolerance to different abiotic stresses such as extreme moisture stress (drought and flooding), extreme temperature (heat and chilling/frost), salinity and metal or mineral toxicity are crucial to sustain and improve crop yields under changing climate scenario. In this regard Indian National Agricultural Research System (NARS) including various ICAR institutes and State Agricultural Universities are making concerted efforts over the years for developing climate resilient crop varieties with enhanced tolerance to multiple abiotic stresses. And some the institutes including public and private organizations are succeeded in developing tolerant crop varieties for different abiotic stresses. For instance, ICAR-NRRI, Cuttack, Odisha evaluated, identified and developed several tolerant rice varieties (Pathak, 2019) for submergence (CR Dhan 801, CR Dhan 802 h, Pooja-Sub1, Maudamani-Sub1, Pratikshya-Sub1, and LalatMAS-Sub1), stagnant flooding (Pooja, Sarala, and Gayatri, Kalashree, Varshadhan, and Hansheswari), aerobic condition (varieties with better root architecture), high temperature (Lunasanki). Amassing such information on abiotic stress tolerant varieties in agricultural crops will be helpful for different stakeholders like researchers, students, farmers, extension & agriculture officers and policy makers.

4.1. Drought

Deficit moisture condition or drought stress is one of the serious challenges in most parts of India particularly in arid and semiarid regions. There are various negative effects on plant growth and yield occurs under drought conditions. Therefore, plants have different responses for adaptation and survive with drought conditions such as morphological, biochemical, physiological responses, and a molecular mechanism. Plants adapted various strategies such as escape, avoidance and tolerance for survival even under drought conditions. Number of adaptive traits have been studied and used for improvement of drought tolerance like early vigour, short duration, osmotic adjustment, leaf senescence, stay green etc. Stay green habits in plants, usually refer to tolerance against drought-induced post-flowering senescence. Roots also play an important role in adaptation to drought stress. Plant breeders of various ICAR institutes and state agricultural universities exploited such traits to develop high yielding varieties of different crops with enhanced tolerance drought over years which can be utilized by the farming communities. Major field and horticultural crops including cereals, pulses, oilseeds, fodders, vegetable, fruits, plantation, medicinal and spices varieties with tolerance to drought stress, released by various Institutes/Universities are given in Table 1. Root stocks tolerant to drought/moisture stress were given in the Table1a.

Table 1. Crop varieties tolerant to drought.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Cereals					
Rice					
1.	Kalinga 1	1973	ICAR-NRRI, Cuttack	JH, OR	Cold tolerant
2.	Kalinga 2	1973	ICAR-NRRI, Cuttack	OR	-
3.	Prabhat	1978	ICAR-NRRI, Cuttack	OR	-
4.	Vandana	1992	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL and BS
5.	CAUR-1	1999	CAU, Imphal	MN	Tolerant to BL, BLB
6.	MTU-1010	2000	RARS, Maruteru	CH, AP, TS	Tolerant to BL
7.	Pant Dhan 16	2001	GBPUAT, Pantanagar	UP	Moderately resistant to BL, BS
8.	Barani Deep	2001	CRS, Faizabad	UP	Tolerant to LF
9.	Anjali	2002	ICAR-NRRI, Cuttack	BH, JH, OR, AS, CG	Resistant to BLB & SB
10.	Naveen	2005	ICAR-NRRI, Cuttack	OR	Resistant to BL, Moderately resistant to SB and BS
11.	Abhishek	2007	ICAR-NRRI, Cuttack	AS, BH, JH, UP	Resistant to BL, moderately resistant to BS and GM
12.	Shabhagidhan	2008	ICAR-NRRI, Cuttack	JH, OR	Suitable for DSR, Resistant to BL moderately resistant to BS, SB and LF
13.	Kamesh	2008	ICAR-NRRI, Cuttack	JH,MS	Moderately resistant to BS, BL, GM
14.	ShuskSamrat	2009	ICAR-NRRI, Cuttack	Eastern UP, BH, CG	Early duration, tolerant to SB, GM, LF
15.	Satyabhama	2012	ICAR-NRRI, Cuttack	OR	Resistance to SB, LF. Tolerant to BL, RTV, BPH, WBPH and GM
16.	Indira Barani Dhan-1	2012	IGKV, Raipur	CH	Tolerant to BL, BLB
17.	CR Dhan 40	2014	ICAR-NRRI, Cuttack	CVRC, JH and MS	Tolerant to BS, BL
18.	CR Dhan 202	2014	ICAR-NRRI,	JH, OR	Tolerant to BL, BS, SB,

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Cuttack		LF, suitable for Aerobicconditions
19.	DRR Dhan 42	2015	ICAR-IIRR, Hyderabad	TN, AP, TS, MP, CH, JH	Early maturity
20.	DRR Dhan 44	2015	ICAR-IIRR, Hyderabad	UT, HA, BH	Early maturity
21.	Sabour Shree	2015	BAU, Ranchi	BH	Highly resistant to BPH, GLH SB
22.	Purna	2017	ICAR-NRRI, Cuttack	GJ	Tolerant to SB, LF
23.	DRR Dhan 47	2018	ICAR-IIRR, Hyderabad	TS, AP, KA, KL, PY	Early maturity
24.	DRR Dhan 50	2018	ICAR-IIRR, Hyderabad	AP, TS, TN, KA,BI,OR, CH, UP, MP	Submergence tolerance
25.	Tripura Khara 1	2018	Research Complex for NEH Lembucherra	TR	-
26.	CR Dhan 801	2019	ICAR-NRRI, Cuttack	AP, TS, OR, UP and WB	Submergence tolerant.Tolerant to BL, NB, BLB, SB, LF
27.	Sahbhagi	-	ICAR-NRRI, Cuttack	JH, OR	Resistant to BL
28.	BirsaVikasDhan 111	-	BAU, Ranchi	JH	Tolerant to BL and BS
Varieties Suitable for Aerobic Rice Conditions					
29.	CR Dhan 203	2014	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, BS SR,SB,
30.	CR Dhan 200	2014	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, BS, SB and LF
31.	CR Dhan 201	2014	ICAR-NRRI, Cuttack	CH and BH	Moderately resistant to LB, SR, SB, LF
32.	CR Dhan 204	2019	ICAR-NRRI, Cuttack	JH, TN	Tolerant to BL, BS, SB, LF, WM
33.	CR Dhan 205	2019	ICAR-NRRI, Cuttack	TN, OR, WB	Resistant to LB, BS, SR, SB and LF
34.	CR Dhan 206	2019	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, BS, SB, and LF
35.	CR Dhan 207	2019	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, NB, BS, SR, SB, LF,GLH, GM
36.	CR Dhan 209	2019	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, NL, BS, RTV, SB, LF, GLH, WBPH

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
37.	CR Dhan 210	2020	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, NB, BS, SB, SR, LF, GLH
			Wheat		
38.	A-9-30-1	1974	AAU ARS, Arnej	CZ	Heat stress tolerant
39.	K 65	1974	CSAUA&T, Kanpur	UP	-
40.	HD1467	1976	JNKVV RS, Powarkheda	CZ	-
41.	K7410	1980	CSAUA&T, Kanpur	NEPZ	Suitable for alkaline soils
42.	N59	1982	JNKVV RS, Powarkheda	CZ	-
43.	Ajanta	1983	CoA, Badnapur	MS	Tolerant to high temperature
44.	K-72	1985	CSAUA&T, Kanpur	UP	-
45.	K-78	1985	CSAUA&T, Kanpur	UP	-
46.	K 9465	1998	CSAUA&T, Kanpur	NEPZ	Resistance to BR
47.	HD 2160	1998	CSAUA&T, Kanpur	NEPZ	Resistant to BR
48.	HI 1531	2006	IARI RS, Indore	CZ	Resistance to BR
49.	MP (JW) 3173	2009	JNKVV, Jabalpur	CZ	-
50.	Ratan	2009	IGKV, Raipur	CH	Resistant to Black and BR
51.	Netravati	2011	MPKV, Rahuri	MS, KA	Resistant to lodging
52.	HD 2987	2011	IARI, New Delhi	MS, KA, AP, GA, TN	-
53.	KRL-213	2012	ICAR-CSSRI, Karnal	AS, BH, DL, HR, UP, RJ, PB, WB, UK	Resistant to salinity, alkalinity and Karnal bunt
54.	HD 3043	2012	IARI, New Delhi	HR, RJ, UP, DL, RJ, UK,MP	Resistant to BR and YR
55.	PBW 644	2012	PAU, Ludhiana	DL, HR, HP, J&K, PB, RJ, UP, UK	-
56.	WH 1142	2015	CCS, Hissar	NWPZ	Tolerant to lodging
57.	SabourNirjal	2017	BAU, Sabour	BH	-

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
58.	HUW 669	2018	BHU, Varanasi	UP	-
59.	DBW 252	2020	ICAR-IIBWR, Karnal	UP, BH, JH, OR, WB, AS	Resistant to wheat Blast
Barley					
60.	PL419	1996	PAU, Ludhiana	PB, SK	Moderately susceptible to stripe diseases.
61.	JB-58	2005	JNKV, Jabalpur	MP	Resistant to YR and black rust
62.	RD 2660		ARS, Durgapur	RJ, HR, UP	Resistant to rusts
63.	RD-2592		ARS, Durgapur	RJ, HR, UP	-
Maize					
64.	Mahi Dhawal	1995	AICMIP, BANSWARA.	RJ	Resistant to MLB, DM
65.	JM-216	2000	ZARS, Chhindwara	KA	Tolerant to TLB
66.	Pratap Hybrid Makka-1	2003	AICMIP, Udaipur	RJ	Moderate resistant to DM, resistance to SB
67.	Pratap Makka-3	2005	AICMIP, Udaipur	GJ, MP, RJ	Tolerant to MLB, TLB and SB
68.	Pratap Makka-5	2006	AICMIP, Udaipur	GJ, MP, RJ	Tolerant to MLB, TLB and SB
69.	HQPM-1	2007	AICRP maize	CH, HR	-
70.	Bajauramakka	2008	Hill ARS, Himachal Pradesh	HP, AS, J&K, SK, UK	-
71.	HQPM-5	2020	IARI, New Delhi	AP,KA,GJ,TS,TN,MP,UP,RJ	-
72.	NAH-1147	-	UAS, Bengaluru	KA	-
73.	PEHM-1	-	IARI, New Delhi	Sub-humid southern plains and Aravali Hills	-
Pearl Millet					
74.	WCC-75	1982	UAS, Bengaluru	KA	Dual purpose variety
75.	GHB-538	2005	JAU, Jamnagar	GJ	Tolerant to lodging
76.	GHB-538	2005	MRS,	GJ	Resistant to DM

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Jamnagar		
77.	GHB-719	2007	JAU, Jamnagar	GJ	Resistant to DM
78.	GHB-719	2007	MRS, Jamnagar	GJ	Early maturity
79.	GHB-757	2008	MRS, Jamnagar	GJ	Resistant to DM, tolerant to Smut and Ergot
80.	RHB-154	2009	AICPMIP, Durgapura	RJ, GJ, HR	Early maturity, Resistant to DM
81.	HHB 223	2010	AICPMIP, CCS, HAU, Hissar	RJ, GJ, HR. PB, DL, UP and MP	Resistant to DM
82.	HHB-216	2010	CCS, HAU, Hissar	RJ, GJ, HR	Resistant to DM, tolerant to rust. Tolerant to lodging
83.	HHB-226	2011	CCS, HAU, Hissar	RJ, GJ, HR, MP, PB	Resistant to DM
84.	RHB-177	2011	AICPMIP, Durgapura	RJ, GJ, HR	Tolerant to lodging
85.	Bio 70	2012	Biore Pvt.Ltd. Hyderabad	RJ, GJ, HR	-
86.	HHB-234	2013	CCS, HAU, Hissar	RJ, GJ, HR	Tolerant to lodging
87.	PBH 306	2017	PrabhatAgriBiotech Ltd	MS, KA, AP,TS, TN	Non-lodging
88.	Balwan	2018	Nuziveedu seeds Ltd. Hyderabad	RJ	Non lodging, Tolerant to major pest and diseases
89.	NBH 4903	2018	Nuziveedu seeds Ltd. Hyderabad	MS, KA, AP, TS, TN	Non lodging, Tolerant to major pest and diseases
90.	CZP 9802	-	CAZRI Jodhpur	RJ, GJ, HR	Resistant to DM
91.	Pusa Composite 443	-	IARI, New Delhi	RJ, GJ, HR	Early maturing, resistant to DM
92.	Pusa Hybrid 415	-	IARI, New Delhi	RJ, GJ, HR, UP,PB, DL	Resistant to DM
Sorghum					
93.	M35-1	1930	AICRP, Sorghum	MS, KA	Tolerant to ChR and SF
94.	CSH-5	1976	AICRP, Sorghum	CVRC, KA	Resistant to all major diseases
95.	CSV-4	1978	AICRP, Sorghum	CVRC, KA	Resistant to all major diseases
96.	CSH-9	1982	AICRP,	CVRC, KA	Resistant to all major

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Sorghum		diseases
97.	Phule Chitra	2008	MPKV, Rahuri	MS, KA	Tolerant to ChR and SF
98.	CSV-17	2009	AICRP, Sorghum	RJ, AP, KA, TN	Resistant to rust, anthracnose
99.	Pant Chari 5	2010	GBPUAT, UK	UK	Tolerant to rust, anthracnose
100.	Pant Chari 7	2011	GBPUAT, UK	UK	Tolerant to rust, anthracnose
101.	CSV 26 R	2012	ICAR-IIMR (CRS), Solapur	All rabi Sorghum growing states	Tolerant to ChR, rust, DM
102.	Phule Panchami	2012	MPKV, Rahuri	MS, KA	Tolerant to ChR and SF
103.	CSH 31R	2013	Dev Gen seeds	All rabi Sorghum growing states	Non lodging, non-shattering
104.	DSV-2	-	AICRP, Sorghum	CVRC, KA	Resistant to all major diseases
105.	Phule Vasudha	-	MPKV, Rahuri	MS, KA	Tolerant to ChR and SF
106.	Parbanimoti	-	VNMKV, Parbhani	MS	Tolerant to major diseases and pest
107.	PS-4	--	UAS, Bengaluru	KA	-
108.	SIA-326	-	UAS, Bengaluru	KA-	
Pulses					
Pigeonpea					
109.	Palnadu	1982	ANGRAU, Hyderabad	AP	Tolerant to Wilt
110.	Co 5	1984	TNAU, Coimbatore	TN	Early maturity,
111.	ICPL-87	1986	AICRP and ICRISAT	MP, AP, KA	Resistant to Wilt and Sterility mosaic virus
112.	Maruti	1986	AICRP and ICRISAT	MP, AP, KA	Resistant to Wilt and Sterility mosaic virus
113.	Pragati (ICPL 87)	1986	AICRP and ICRISAT	All India	Tolerant to wilt
114.	Abhay	1989	ARS Lam & ICRISAT	AP	Tolerant to Pod borer
115.	ICPL-151	1989	AICRP and ICRISAT	MP, AP, KA	Resistant to Wilt and SMV Sterility mosaic virus
116.	Jagrati	1989	AICRP and	All India	Tolerant to wilt

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
	(ICPL 151)		ICRISAT		
117.	Asha	1993	AICRP and ICRISAT	KA, AP, CG	Tolerant to Wilt
118.	Paras	1997	CCS, Haryana	HR	-
119.	MAL 13	2005	BHU, Varanasi	UP,WB	Tolerant to salinity and major pest and diseases
120.	BRG-1	2006	USA, GKVK, Bengaluru	KA, AP	Moderately resistant to wilt and Sterility mosaic virus
121.	BRG-2	2007	USA, GKVK, Bengaluru	KA, AP	Moderately resistant to wilt and SMD
122.	PRG-158	2007	PJTSAU, Hyderabad	TS, AP	Resistant to *Fusarium* Wilt
123.	VL Arhar-1	2007	VKPS, Almora	UK	Resistant to wilt and alternaria blight
124.	Rajeev	2011	IGKV, Raipur	CG	Resistant to wilt & sterility mosaic disease
125.	BDN-711	2012	ARS, Badnapur	MS	Resistant to wilt and Sterility mosaic virus
126.	BDN-716	2014	ARS, Badnapur	MS	Resistant to wilt and Sterility mosaic virus
127.	GT-102	2016	NAU, Navasari	GJ	Tolerant to pest and diseases
128.	LRG-52	2017	ANGRAU, Guntur	AP	Tolerant to pest and diseases
129.	GRG 811	2018	UAS, Raichur	KA	Resistant to wilt
130.	BDN-708	-	ARS, Badnapur	MS	Resistant to wilt
131.	BRG 5	-	UAS, Bengaluru	KA	Tolerant to pest and diseases
132.	PRG 176	-	PJTSAU, Hyderabad	TS	Resistant to wilt and pod borer
133.	Prakash	-	ICAR-IIPR, Kanpur	UP, BH, MP	Tolerant to pest and diseases
Blackgram (Urd)					
134.	Shekhar-2	2001	CSAUAT, Kanpur	UP, MH, DL, HR, RJ	Tolerant to YMV
135.	Azad-3	2006	CSAUAT, Kanpur	UP, MH, RJ	Tolerant to YMV
136.	Pratap Urd-1 (KPU 07-08)	2013	ARS Kota	RJ	Moderately resistant to MYMV
137.	BDU-1	-	VNMKV, Parbhani	MS	Tolerant to YMV
138.	Pant Urd-35	-	GBPUAT,	UK	Tolerant to pest and

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Pantanagar		disease
Greengram (Moong)					
139.	RMG-268	1999	ARS, Durgapura,	RJ	-
140.	Pratap	1999	RARS, Shilongani	AS	Resistant to pod borer
141.	PDM-139	2001	ICAR-IIPR, Kanpur	UP	Tolerant to YMV
142.	RMG-344	2001	ARS, Durgapur	RJ	Tolerant to blight disease
143.	Pusa Vishal	2001	IARI, New Delhi	PB, HR, RJ, HP, J&K, UP	Tolerant to Jassids and white fly
144.	GM-4	2003	GAU, Sardar Krushinagar	GJ	Early and also suitable for spring season cultivation
145.	CO. (Gg) 8	2013	TNAU, Coimbatore	TN	Resistant to YMV
146.	Yadadri	2016	PJTSAU, Hyderabad	TS	Resistant to MYMV
147.	VBN 4 VGG 10-008	2019	(NPRC), Vamban	TN	Tolerant to pod borer
148.	BM-2003-2	-	BAU, Ranchi	UP	Tolerant to YMV
Chickpea					
149.	JG-315	1984	JNKV, Jabalpur	MP, CG	Drought tolerant, wilt resistant
150.	Phule G-81-1-1 (Vijay)	1994	MPKV, Rahuri	MP,MS, GJ	Resistant to wilt
151.	Pant G 186	1996	GBPUAT, Pantanagar	UK	Tolerant to wilt, grey mold
152.	JG-11	1999	JNKV, Jabalpur	MP, CG	Tolerant to wilt diseases
153.	JG -6	2006	JNKV, Jabalpur	MP, CG	Tolerant to wilt diseases
154.	JAKI 9218	2006	JNKV, Jabalpur	MP	Resistant to root rot, collar rot and wilt
155.	Akash (BDNG 797)	2007	ARS, Badnapur	MS	Desi variety, resistant to wilt, tolerant to Pod Borer.
156.	RSG 896	2007	ARS, Durgapura	RJ	Resistant to wilt and dry root rot
157.	JGK-2	2007	JNKV, Jabalpur	MP	Resistant to collar rot, root rot, MR to wilt and DRR
158.	JGK-3 (JGK 19)	2007	JNKV, Jabalpur	MP	Resistant to Wilt.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
159.	Lam shanaya (LBeG 7)	2007	LAM, ANGRAU, Guntur	AP	Tolerant to wilt and rot condition.
160.	Jawahar Gram 226 (JG 226)	2007	JNKVV, Jabalpur	MP	Resistant to wilt and root rot complex
161.	JG 14	2008	JNKV, Jabalpur	MP	Resistant to root rot, collar rot and wilt and heat tolerant
162.	GNG 1581	2008	ARS, Sriganganagar	NWPZ	Water logging tolerant
163.	BGD 103	2009	UAS, Dharwad	KA	Resistant to *Fusarium* Wilt
164.	Gujarat Junagadh gram 3	2010	ARS, Junagarh	GJ	Resistant to wilt and stunt
165.	AKG 9303-12	2012	PDKV, Akola	Vidarba region of MS	Tolerant to wilt
166.	PKV Harita (AKG 9303-12)	2012	PDKV, Akola	Vidarba region of MS	Tolerant to wilt and useful for culinary purpose.
167.	NBeG 3	2013	ARS, Nandyal	AP	Tolerant to Wilt
168.	JG 36	2016	JNKVV, Jabalpur	MP	Tolerant to wilt
169.	Pant Kabuli gram-2	2017	GBPUAT, Pantanagar	UK	Tolerant to wilt and grey mold
170.	Pant gram-4	2017	GBPUAT, Pantanagar	UK	Tolerant to wilt, grey mold and dry root rot
171.	Indira Chana 1	2017	IGKVV, Raipur	CG	Tolerant to wilt
172.	Nandyal Gram 49	2017	ARS, Nandyal	AP	Tolerant to wilt
173.	JG 16		JNKV, Jabalpur	MP	Resistant to root rot, collar rot and wilt
Cowpea					
174.	UPC 618	2006	GBPUAT, Pantanagar	UK	Resistant to MVMV and anthracnose
175.	UPC 622	2007	GBPUAT, Pantanagar	UK	Resistant to MVMV and anthracnose
176.	C 519(Himachal Lobiya 11)	2008	HPKV, Palampur	HP	Resistant to cercospora leaf spot
177.	IT-38956-1	2009	UAS, GKVK, Bengaluru	KA	Tolerant to leaf rust and other foliar diseases
178.	UPC 628	2010	GBPUAT,	UK	Resistant to MVMV and

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Pantanagar		anthracnose
179.	Hidrudaya	2010	ARS, Kerala	KL	Tolerant to leaf rust
Field bean					
180.	H-4	2010	UAS, GKVK, Bengaluru	KA	Photo-insensitive
Khesari (*Lathyrus sativa*)					
181.	Bidhan Khesari-1	2019	BCKV, WB	WB	Resistant o PM and Wilt
Moth Bean					
182.	CAZRI MOTH-1 (CZM-79)	1999	ICAR-CAZRI, Jodhpur	RJ, GJ	Tolerant to blight
183.	RMO-225	1999	ARS	RJ, GJ, MS	Mutant variety
184.	RMO-423	2002	ARS, Beechwal, Bikaner	RJ	Tolerant to diseases and pests
185.	CAZRI Moth -3 (CZM-99)	2005	ICAR-CAZRI, Jodhpur	RJ, GJ, HR	Resistant to YMV, DRR diseases.
186.	RMO-257	2006	ARS, Beechwal, Bikaner	RJ	Mutant variety
Horsegram					
187.	PHG-9	2001	UAS, Bengaluru	KA	Tolerant to PM, YVMV
188.	CRIDA-18R	2009	ICAR-CRIDA, Hyderabad	AP, KA,TN, KL	Tolerant to PM, YVMV
189.	Indira Kulthi-1 (IKGH-01-01)	2010	IGKV, Raipur	CG	Tolerant to DRR and white fly
190.	CRIDALATHA (CRHG-4)	2010	ICAR-CRIDA, Hyderabad	South India	Tolerant to YVMS
191.	VL Gahat-19 (VLG-19)	2010	VKPS, Almora	North zone	Tolerant to diseases and pests
192.	GHG-5	2012	SDAU, Sardarkrushinagar	GJ, UP, RJ, UK, MS, JH	Tolerant to PM, YVMV
193.	Bilasa Kulthi (BSP 15-1)	2019	IGKV, Raipur	CG, GJ, JH, MH	Tolerant to DRR and white fly
194.	Dapoli Kulthi-1		BSKV, Dapoli	MS	Tolerant to PM, YVMV
Lentil					
195.	Kota Masoor 3 (RKL 605-03)	2020	AU, Kota	RJ	High temperature tolerant

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
196.	L 4729	2020	IARI, New Delhi	CG, RJ, MP, UP	Low incidence of major pests and diseases
French Bean					
197.	Arka Anoop	-	ICAR-IIHR, Bengaluru	KA, AP, CG, HP, J&K, UK, KL, TN, OR	Resistance to rust and bacterial blight.
Oilseeds					
Groundnut					
198.	TAG-24		BARC, Bombay		Water use and partitioning efficient.
199.	Spanish Improved	1905	UAS, Dharwad	MH, KA	Tolerant of ELS
200.	TMV-1 (A.H.-25)	1940	TNAU, Coimbatore	TN	-
201.	T-28 (Type-28)	1960	CSAUA&T, Manipuri	UP	Resistant to ELS
202.	S.B.-11	1965	Oilseeds RS, Jalgaon		High shelling percentage
203.	TMV-7	1967	TNAU, Tindivanam	TN	High shelling (75%)
204.	S-230 (Selection-230)	1969	UAS, Raichur	Northern KA	-
205.	Kadiri-71-1	1971	APAU, Kadiri	AP	Efficient in fixing atmospheric nitrogen
206.	GAUG-10	1973	GAU, Junagadh	GJ	Resistant to ELS, LLS and rust
207.	Dh-3-30	1975	UAS, Dharwad	KA	
208.	Dh 3-30	1975	UAS Dharwad	KA	Pod with prominent beak and construction bold kernel
209.	Kadiri-3	1978	APAU, Kadiri	AP	Early maturity, tolerant of LLS
210.	GG-2	1983	JAU, Junagadh	GJ	Water use efficient
211.	JGN-2	1983	JNKVV, Khargone	MP	-
212.	ICGS-11 (ICGV-87122)	1986	ICRISAT, Hyderabad	MP, MH, AP, KA	Tolerant of PBND and end-of-season drought; photoperiod insensitive
213.	BG-3	1986	BAU, Kanke	BR	Early maturity; drought tolerant
214.	ICGS-44	1988	ICRISAT,	GJ, AP, KA,	Tolerant of ELS, PBND

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
	(ICGV-87128)		Hyderabad	OR, TN	& high seed protein (25%)content
215.	ICGS-76 (ICGV- 87141)	1989	ICRISAT, Hyderabad	Southern parts of MS	-
216.	MH-4	1989	HAU, Hissar	HR	Tolerant of LLS
217.	Tirupati-1	1989	APAU, Tirupati		Early maturing
218.	ICGS-1 (ICGV-87119)	1990	ICRISAT, Hyderabad	UP, BH, HR, PB, RJ	Tolerant to leaf spots and PBND.
219.	ICGS-37 (ICGV-87187)	1990	ICRISAT, Hyderabad	GJ, northern MS, MP	Photo-period insensitive; tolerant to LLS, rust and PBND.
220.	ICG (FDRS)-10 (ICGV-87160)	1990	ICRISAT, Hyderabad	AP, KA,KL, MS, TN	Resistant to rust, LLS and PBND
221.	ICGV-86031	1991	ICRISAT, Hyderabad	AP	Photoperiod insensitive and resistant to iron deficiency.
222.	Pragathi (RSHY-1)	1991	IARI, New Delhi	OR& coastal AP	suitable for *rabi* residual moisture situation
223.	Tirupati-2	1991	APAU, Tirupati	AP	Possesses high peg strength; tolerant of nematode incidence
224.	ICGS-5 (ICGV-87121)	1992	ICRISAT, Hyderabad	UP	Resistant to rust
225.	Tirupati-3 (TCG-1518)	1993	APAU, Tirupati	AP	Resistant to kalahasti nematode
226.	Kopergaon-1	1993	MPKV, Kopergaon	MS	Suitable to medium to heavy soils
227.	JCG-88 (Jagtial-88)	1993	APAU, Jagtial	AP	Tolerant of *Aspergillus flavus*, *Aspergillus niger* and PBND
228.	Mukta (DRG-17)	1994	DOR, Hyderabad	RJ, PB, UP, HR	Tolerant to rust, LLS and PBND
229.	Vemana (K-134)	1995	APAU, Kadiri	AP and TN	Tolerant to leaf spots, PBND
230.	TG-26	1995	BARC, Trombay	GJ, northern MS& MP	Possesses fresh seed dormancy, tolerant to rust, LLS and PBND
231.	Tirupati-4 (TCGS-30)	1995	APAU, Tirupati	AP	Early maturity (100-105) Days
232.	Smruti (OG-52-1)	1995	OUA&T, Chiplima	OR	Resistant to collar rot, stem rot, rust and leaf spots
233.	GG-5	1997	GAU,	GJ	Leaflets stay green at

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Junagadh		maturity
234.	JGN-3	1997	JNKVV, Khargone	MP	Tolerant to sucking pests and leaf spots(ELS, LLS)
235.	Co (gn)- 4 (TNAU 269)	2001	TNAU, Coimbatore	TN	Resistant to LLS & Rust
236.	TG-37A	2004	BARC, Trombay	RJ, UP, PB, GJ, OR, WB, BR, NEH states	Possesses fresh seed dormancy, tolerant to collar rot, rust and LLS
237.	Kadiri-5	2005	ANGRAU, Kadiri	AP	Tolerant to leaf spots
238.	Co (GN)-5	2005	TNAU, Coimbatore	TN	Tolerant to rust, PBND, leaf miner and *Spodoptera litura*, high oil content.
239.	Pratap Mungphali-1 (ICUG-92035)	2005	MPUA&T, Udaipur	RJ	Early maturing, Tolerant of ELS, LLS, PBND, *Spodopteralitura*, leaf miner and thrips.
240.	TVM (Gn)13	2006	TNAU, Coimbatore	TN	Resistance to ELS, rust & PBND.
241.	ICGV-91114 (Anantha Jyothi)	2007	ICRISAT, Hyderabad	AP, OR, KA.	Early maturity, tolerant to rust and LLS
242.	Abhaya (TPT-25)	2007	ANGRAU, Tirupati	AP	Tolerant to LLS, sucking pests & Spodoptera.
243.	Narayani (TCGS-29)	2007	ANGRAU, Tirupati	AP	Tolerant to mid-season moisture stress conditions.
244.	Prasuna (TCGS-341)	2007	ANGRAU, Tirupati	AP	Tolerant to Kalahasti nematode
245.	TMV-13	2007	TNAU, Coimbatore	TN	Tolerant of early and mid-season drought, tolerant of LLS, rust & PBND
246.	AK-265	2007	PDKV, Akola	South MS, KA, AP, TN	Resistant to rust and LLS
247.	SG-99	2007	PAU, Ludhiana	PB	Tolerant of PBND
248.	VRI (Gn)-7	2008	TNAU, Vriddhachalam	TN	Tolerant of leaf miner, LLS and rust
249.	Ajeya (R-2001-3)	2008	UAS, Raichur	Southern MS, KA, AP, TN	Resistant to PBND, drought tolerant; wider adaptability.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
250.	Girnar-2 (PBS-24030)	2008	NRCG, Junagadh	UP, PB, RJ	Tolerant of rust, LLS, PSND and sucking pests; leaves remain green till harvest
251.	TG-51	2008	BARC, Trombay	WB, OR, JH, AS	Tolerant of stem rot and root rot diseases
252.	Kadiri-7	2009	ANGRAU, Kadiri	AP	Tolerant to sucking pests and LLS
253.	Co (Gn)-6	2009	TNAU, Vriddhachalam	MH, KA, AP, TN	Tolerant of LLS, rust and PBND
254.	JGN-23	2009	JNKVV, Khargone	MP	Tolerant of ELS, LLS and drought
255.	Kadiri-9	2009	ANGRAU, Kadiri	AP	Tolerant of early and end-of-season drought
256.	Greeshma	2009	ANGRAU, Tirupati	AP	Early maturity; tolerant to high temperature & aflatoxin contamination
257.	Mallika (ICHG-00440)	2009	RAU, Hanumangarh	All India	Bold seeded (73.0 g /100 kernel); resistant to collar rot and PBND
258.	Kadiri Haritandhra (K-1319)	2010	ANGRAU, Kadiri	KA, MS	Seed dormancy resistant to rust, ELS, LLS, stem rot, *PBND*, thrips, *Spodoptera*, jassids&*Helicoverpa*.
259.	GJG-HPS-1 (JSP-HPS-44)	2010	JAU, Junagadh	GJ	Bold kernels
260.	Raj Durga (RG 425)	2010	SKRAU, Bikaner	RJ	Resistance against tikka, rust, PBND, collar rot and stem rot.
261.	Girnar-3 (PBS-12160)	2010	DGR, Junagadh	WB, OR, MN	Tolerant of leaf miner and thrips, low SLA and high SCMR and WUE
262.	Vijetha (R-2001-2)	2010	UAS, Raichur	WB, OR, JH, AS, MS, KA, AP, TN	Resistant to PBND
263.	RARS-T-1	2011	ANGRAU, Tirupati	AP	Bold seeded pods; tolerant to early season drought with high proline, RWC and quick regenerative capacity.
264.	RARS-T-2	2011	ANGRAU, Tirupati	AP	Early maturity, it is water-use efficient.
265.	Divya (CSMG-2003-	2011	CSUAT, Kanpur	RJ, UP	Tolerance to collar rot, PBND, ELS and LLS.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
	19)				
266.	Raj Mongfali-1 (RG-510)	2012	SKRAU, Bikaner	RJ, PB	It has low SLA and high SCMR and WUE; resistance to collar rot, stem rot, ELS, rust, PBND &thrips.
267.	Dharani (TCGS 1043)	2013	ANGRAU, Tirupati	AP	Tolerant to stem and dry root rots
268.	Birsa Groundnut 4 (BAU - 25)	2015	BAU, Ranchi	BH	Tolerant to occasional dry spell, resistant to early leaf spot
269.	Dheeraj (TCGS 1073)	2019	ANGRAU, Tirupati	AP	Possess WUE traits- low SLA, high SCMR, RWC, WUE, CSI, root length, and also heat tolerance.
270.	DH-257	2020	UAS Dharwad	KA, MS	Tolerant of rust
271.	Dh 256	2020	UAS, Dharwad	TN, AP, KA, TS	Tolerant to LLS, rust, Spodoptera and sucking pests.
Soybean					
272.	Pant Soybean 24 (PS 1477)	-	GBPUA&T, Pantanagar	UP, UK	-
273.	VL SOYA-2	1989	VPKLS, Almora	Northern hill zone	Free from major diseases. Susceptible bacterial pustule and CLS.
274.	JS-80-21	1991	JANKVV, JABALPUR	Central plains	-
275.	JS 71-05	1991	JNKVV, Jabalpur	AP, KA, MP, MH, TN	Resistant for bacterial-pustule, pod blight, MLS and in virus to bud blight, tolerance for girdle beetle and stem fly
276.	Ahilya-3 (NRC-7)	1991	-	Central plains, MP	Resistant to bacterial blight, GMV, bacterial pustules, phyllody, SMV, MLS, CLS, stem fly, girdle beetle, green and grey semilooper, leaf minor
277.	JS-335	1994	JNKVV, Jabalpur	GJ, RJ, MP, parts of MS,	Resistant to bacterial pustules, bacterial blight, GMV & ALS, moderately susceptible

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					to pod blight jassids.
278.	Indira Soya- 9	1999	IGKV, RAIPUR.	MP, Central plains	Resistant to rust, moderately resistant to stem tunneling girdle beetle, leaf folder.
279.	PS-1092	1999	GBPUA&T, Pantanagar	Tarai, Babar regions of north plains, UP	Resistant to YMV, bacterial pustules and CLS.
280.	MACS-450	1999	ARI, Pune	KA, MS, TN, AP	Tolerant to major diseases under field conditions.
281.	Parbhani Sona (MAUS-47)	2000	MAU, Parbhani	MP, MS, RJ	Tolerant to SMV, bud blight, collar rot, anthracnose, CLS, Rhioctonia, semilooper, tobacco caterpillar, leaf miner
282.	Ahilya-4 (NRC-37)	2001	ICAR-IISS, Indore	MP, MS, UP, RJ	Moderately resistant to collar rot, bacterial pustule, pod blight and bud blight, stem fly and leaf miner
283.	MAU-71	2002	MAU, Parbhani	MS, CH, JH, BH,OR, ML, WB, MN	Resistant bacterial pustules, bud blight, YMV, leaf spots, SMV, RAB. Moderately resistant to girdle beetle, leaf miner, semilooper
284.	JS-9305	2002	JNKVV, Jabalpur	MP, MS, RJ, UP	Early, resistance to bacterial pustules, MLS, SMV,YMV, pod blight, root rot, PMD; Moderately resistant to defoliators
285.	JS-95-60	2006	JNKVV, Jabalpur	*Kharif*season, areas & uplands	Resistant to root rot, bacterial pustules. MLS, RAB, leaf spot, YMV, stem fly, girdle beetle, defoliators & blue beetle.
286.	PS-1225	2007	GBPUA&T, Pantnagar	Western Himalayan Region, UK	Resistant to YMV, bacterial pustules, RAB, charcoal rot; moderately resistant to anthracnose and SMV.
287.	Pratap Soya-	2007	MPUA&T,	KA, MS, TN	Moderately resistant to

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
	2(RKS-18)		ARS, Kota		bacterial pustules, moderately resistant to girdle beetle and leaf miner.
288.	RKS-24	2010	ARS, Kota	RJ	MR to BP, CR, YMV, resistant against stem fly, lepidopterous defoliators, girdle beetle, tobacco caterpillar.
289.	Pratap Soya 45 (RKS 45)	2013	ARS, Kota.	Heavy soil regions	MR to BP, CR, YMV; resistant against stem fly, lepidopterous defoliators, girdle beetle, tobacco caterpillar.
Sunflower					
290.	KBSH-44	1996	UAS, Bengaluru	KA	Resistant to major diseases and reaction
291.	JWALAMUKHI (PSCL-5015)	1996	Proagro Reed Company, Hyderabad	GJ, MS and MP	Resistant to leaf rust, ALS, Jassids; susceptible to DMD and Phoma blight.
292.	MLSFH-47 (AH-11-34)	2001	Mahendra Hybrid Seeds, Jalna.	Zone I and III	Resistant to DMD, ALS, rust, jassids, white flies, head borers, *Heliothis* etc.
293.	KBSH-41	2002	UAS, Bengaluru	KA	Resistant to major diseases and reaction
294.	KBSH-42	2002	UAS, Bengaluru	KA	Resistant to major diseases and reaction
295.	DRSF-108	2005	IIOR, Hyderabad	All India	moderately resistant to DMD, alternaria, necrosis and rust
296.	PRORUN-09 (PRO-009)	2005	Pro-Agro, Hyderabad	AP, KA, MS, TN	Highly tolerant to DMD, moderately tolerant to all major insect-pest.
297.	Bhanu	2006	ZARS, Solapur (MPKV, Rahuri)	MS	Tolerant to head borer and moderately tolerant to sucking pests, rust, alternaria leaf spot and necrosis.
298.	KBSH-53	2008	UAS, Bengaluru	KA	Tolerant to PMD
299.	Bhaskar	2015	ZARS, Solapur (MPKV, Rahuri)	MS	Early maturing, dark black shiny seed, moderately tolerant to PMD, Alternaria leaf

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					spot & bud necrosis.
Safflower					
300.	Phule Kusum (JLSF-414)		Oilseeds RS, Jalgaon	AP, KA, MP, MS	Tolerant to moisture stress
301.	Bhima	1982	MPKV, Rahuri	MS	Moderately tolerant to aphid & Fusarium wilt, flower colour at bloom-white and at faded stage dirty white with red spot.
302.	MalviyaKusum 305 (HUS-305)	1986	BHU, Varanasi	UP, WB	Moderately tolerant to Alternaria leaf blight, wilt root rot, salinity tolerant
303.	JSI-7	1997	AICORPO, Safflower, Indore.	MP	moderately resistant to rust, aphids, PMD, alternaria; highly tolerant to wilt
304.	Parbhani Kusum (PBNS-12)	2006	MAU, Parbhani	MS	Moderately Resistant to Alternaria, Aphids.
305.	PBNS-40	2007	MAU, Parbhani.	MS	Non-spiny, moderately tolerant to alternaria and Fusarium wilt, aphid
306.	ISF-764	2018	ICAR-IIOR, Hyderabad	MS, KA,TS, AP, MP, CR, BH, UP, RJ	-
Niger					
307.	Birsa Niger-1	1995	BAU, Kanke, Ranchi	MP, BR, MS, KA, RJ	Responsive to chemical fertilizers.
308.	JNC-6	2002	JNKVV, ZARS, Chhindwara	MS, KA	Less infection of CLS, ALS and PMD; tolerance to semi-looper and caterpillar
309.	JNC-9	2006	JNKVV, ZARS, Chhindwara	MP, BH, MS, KA, OR	Less infection of CLS, ALS and PMD; tolerance to semi-looper and caterpillar
310.	KBN-1	2007	UAS, Bengaluru	KA	Moderately Resistant to ALS, leaf eating caterpillars
311.	Phule Karala (IGPN 2004-1)	2008	ZARS, Nasik	KA, MS	Resistant to cercospora leaf spots, ALS, PMD and root rot diseases.
312.	Brisa Niger-1 (BNS-10)	2008	BAU, Ranchi	AP, CH,JH,KA, MP, MS, OR	Non lodging & shattering, responsive to chemical fertilizer,

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					suitable for both early and late sown condition.
313.	Birsa Niger-3 (BNS-11)	2010	BAU, Ranchi	JH, CH, MP, OR, MS, AP, WB, KL	Early maturing variety (85 days)
Castor					
314.	GCH-2	1986	GAU, S.K. Nagar	All India	
315.	GCH-5 (SHB-145)	1995	GAU, S.K. Nagar	All India	Resistant to wilt, root rot; tolerant to jassids, whitefly, capsule borer
316.	Kranthi (PCS-4)	1996	PJTSAU, Hyderabad	TS and AP	Suitable for late sown conditions, Bold seed.
317.	Kiran (PCS-136)	2002	PJTSAU, Hyderabad	TS and AP	Moderately tolerant to Botrytis, medium duration, suitable for rice fallows
318.	48-1 (Jwala)	2007	ICAR-IIOR, Hyderabad	All India	Resistant to Fusarium wilt, Tolerant to Botrytis, Tolerant to saline
Linseed					
319.	Jawahar-552 (R-552)	1980	IGKV, Jabalpur	CT plains zone	Resistant to wilt; Moderately susceptible to rust and PMD.
320.	KL-31 (Nagarkot)	1995	CSKPKV, Palampur	HP, PB, UP, BR,WB, AS	Resistant to rust, wilt and PMD
321.	NL-97	1997	AICRP on Oilseeds, Nagpur.	MH	
322.	Shekhar (LCK 9313)	2001	CSUA&T, Kanpur	UP (excluding Bundelkhand) BR, WB, AS	Resistant to rust, PMD, wilt; moderately susceptible to alternaria blight.
323.	Sharda (LMS-4-27)	2004	CSUA&T, Kanpur	CH, OR, MH, KA	Moderately resistant to wilt and PMD.
324.	JLS-27 SUYOG (SLS-27)	2004	JNKVV, RARS, Sagar	MP, CR, RJ, MH, OR, KA	Moderately resistant-wilt, PMD, rust; moderately susceptible to alternaria blight.
325.	Binwa (KL-210)	2005	CSKKVV, Palampur	HP, HR, PB,JK	Resistant to rust and wilt, moderately resistant to alternaria blight and PMD.
326.	Indira Alsi-32 (RLC-81)	2005	KGKV, Raipur	CH, MH, OR	Resistant to PMD, moderately susceptible

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					to wilt and alternaria blight.
327.	Deepika (RLC-78)	2006	IGKV, Jabalpur	CT plains zone	Moderately resistant to rust, wilt and alternaria blight. Resistant to PMD
328.	RLC 92 (IC 555926)	2008	IGKV, Jabalpur	MS, CH, OR, KA	Moderately resistant to linseed bud fly
329.	Himani (KL-214)	2008	CSKHPKV, Palampur	HP, PB, HR, JK	Moderately resistant to rust, PMD, moderately susceptible to blight.
330.	JLS-67 (Shival)	2010	JNKVV, RARS, Sagar	UP, MP, RJ	Resistant to PMD and rust.
331.	JLS-73 (SLS-73)	2011	LNKVV, Jabalpur	MP, RJ, UP, GJ and MS	Moderately resistant to PMD, alternaria blight and rust.
332.	Mau Azad Alsi-2 (LMS - 149-4)	2011	CSUA&T, Kanpur.	CR, MS, KA, OR	Resistant to rust and moderately resistant to alternaria blight &PMD and moderately susceptible to wilt.
333.	Jawahar Linseed-165 (PKDL-165)	2020	JNKVV, ZARS, Horhangabad	J&K, HP, UK, PB, HR	Being medium late maturing variety escapes from biotic & abiotic stresses
			Sesame		
334.	GT-10	-	ZARS, JNKVV, Powarkheda	CH	
335.	PB NO.1	1966	-	-	Mildly tolerant to waterlogging; uniform in maturity.
336.	TYPE-13	1968	-	-	Selection from local material of Hamirpur.
337.	JT-21	1993	RARS, JNKVV Tikamgarh,	Eastern U.P. M.P, BR, OR, WB,NES	Resistant to BLS, phyllody, leaf curl, moderately resistant to phytophthora blight, macrophomina stem, root rot, ALS and PMD.
338.	TKG-22	1995	ZARS, JNKVV Tikamgarh,	Eastern U.P. M.P, BR, OR, WB,NES	Early maturity, moderately resistant to phytoptherea blight, macrophomina stem, root rot; resistant to leaf curl, bacterial blight, capsule borer, thrips.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
339.	JTS-8	2001	ZARS, JNKVV, Powarkheda	MS, MP, UP, KA, AP, RJ, GJ	Moderately resistant macrophomina stem root, capsule borer, blight
340.	Nirmala (OR-Sel-164)	2003	OUAT, Bhubaneswar.	TN, AP, KL and OR	Tolerant to phyllody, BLS, wilt, lodging & capsule shattering, moderately resistant to stem and root rot, moderately susceptible to ALS,susceptible to phytopthoraa,
341.	Pragati (MT-75)	2003	CSAUA&T, Kanpur	KA, UP, GJ, AP, RJ, HR,	Resistant to phyllody, leaf curl, PMD, moderately resistant to phytophthora blight and Macrophomina stem/root rot, shoot Webber/capsule borer, bud fly.
342.	Jawahar Til PKDS-11 (Venket)	2006	ZARS, Powarkheda	AP, TN, WB, MP,	Moderately resistant to leaf borer, capsuele borer, tolerant to lodging, shattering.
343.	TKG-306	2006	JNKVV, Tikamgarh	MP	Resistant phytopthoraa blight, phyllody and moderately resistant to Macrophomina, CLS, ALS, PMD; resistant to antigastra at capsule stage.
344.	Amrit [ORC 24(95)2-1-3]	2007	AICRP on Sesame OUAT, Bhubaneswar.	AP, TN, CR, WB, MP	Resistant to Macrophomina stem/root rot, phyllody, PMD, ALS, bacterial rot, leaf roller/capsule borer and mite, moderately tolerant to antigastra.
345.	TKG-308	2008	JNKVV, Tikamgarh	MP	Moderately resistant to *macrophomina*, CLS, BLS, & leaf curl, resistant to antigastra at capsule stage.
346.	RJ Til -346 (RT 346)	2009	AICRP on Sesame, RJAU,	RJ, HR, HP, PB, GJ, MS, KA	Resistant to phyllody& leaf curls, moderately resistant to

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Mandor		Macrophomina stem & root rot, ALS, CLS, capsule borer
347.	G Til-4	2010	ARS, JAU, Amreli	GJ	Resistant to leaf spot
348.	RJ Til 351 (RT 351)	2011	ARS, RJAU, Mandor	RJ, UP, MS, GJ, KA, HP, PB, HR, JK	Resistant to Macrophomina stem and root rot, leaf curl, phyllody; moderately resistant to cercospora leaf spot.
349.	CUMS-17 (Suprava)	2018	IAS, Uni. of Calcutta	WB	
350.	RT 372	2019	ARS, Mandor, Jodhpur.	RJ, HR, PB, GJ, HP, U.P, MS,NL, KA and TG	Moderately resistant to Macrophomina stem & root rot, phyllody and resistant to ALS, CLS, BLS and PMD and leaf Webber& capsule borer.
Rape Seed & Mustard (Mustard, Rapeseed, Rai, Taramira, Toria & Brown Sarason)					
351.	Geeta [RB-9901 (RB-24)]	-	CCSHAU, Hisar,	HR, PB, parts of RJ	Moderately resistant to white rust at leaf and pod stage.
352.	Pusa Bold	-	IARI, New Delhi	JH	-
353.	Puas Tarak	-	IARI, New Delhi	MP	-
354.	Rohini	1986	CSAUAT, Kanpur	UP	-
355.	PT-507	1990	GBPUA&T, Pantanagar.	BR, WB, OR	Responsive to higher dORes of nitrogen
356.	KBS-3	1996	CSKHPKVV, Palampur	HP	Resistant to white rust but susceptible to alternaria blight, aphids
357.	Agrani (SEJ-2)	1998	IARI, New Delhi	BR, WB, OR, AS	Early maturing, grown in rice fallows with one irrigation at flowering.
358.	Aravali (RN-393)	2001	AICRP (R&M) RJAU, Alwar	RJ, parts of HR & PB.	Moderate reaction for alternaria blight and white rust, resistance to aphid, sawfly and webworm.
359.	Karan Tara (RTM-3140)	2001	RJAU, Jobner	Loamy sandy to sandy loam soils	Moderately resistant to downy and powdery mildew.
360.	RGN 48	2006	ARS, Sri	RJ, PB,HR,	-

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
			Ganganagar	DL, West UP	
361.	CR Sarson	2007	IGKV, Raipur	CH	Resistance to foliar diseases such as white rust and powdery mildew under field conditions.
362.	Pusa Mustard-21 (LES-1-27)	2007	IARI, New Delhi	JK,PB, HR, RJ, DL, western UP	Perform well under limited moisture conditions, low aphid infestation.
363.	Divya-33	2013	M.R. Seeds Pvt. Ltd., Sriganganagar	DL, HR,PB, JK, RJ	Tolerant to white rust and alternaria, thermo-tolerant.
364.	Pant Rai 20	2015	GBPUA&T, Pantanagar	UK	-
365.	RH 761	2019	CCS HAU, Hisar	JK, PB, HR, Delhi and northern RJ	Superior performance under timely sown rainfed conditions. Responsive to higher fertility does.
366.	DRMR 150-35 (Bharat Sarson 7)	2020	ICAR-DRMR, Bharatpur	BR, WB, OR, AS, CR, JH and MN.	Shown <20% reduction in RWC,
Fodder/Forage Crops					
Anjan Grass/ Buffalo Grass					
367.	Marwar Anjan (CAZRI-75)	1985	ICAR-IGFRI, Jhansi	Arid and Semi-arid areas in the country	Resistant to logging
368.	Bundel Anjan-1	1989	ICAR-IGFRI, Jhansi	All over India	Frost hardy
369.	Bundel Anjan 3 (IGFRI 727)	2006	ICAR-IGFRI, Jhansi	All over India	Tolerant to major diseases and pests
Dhaman Grass/Bird Wood Grass					
370.	Marwar Dhaman (CAZRI-76)	1985	ICAR-IGFRI, Jhansi	Arid and Semi-arid areas in the country	Resistant to logging
Dinanath Grass					
371.	Bundel-1	1987	ICAR-IGFRI, Jhansi	All over India	Quick regeneration
372.	Bundel Dinanath-2	1989	ICAR-IGFRI, Jhansi	All over India	Tolerant to lodging
Setaria Grass					

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
373.	Setaria-92	2005	ICAR-IGFRI, Jhansi	HP, UK	Tolerant to logging and frORt
374.	S-18	2012	ICAR-IGFRI, Jhansi	HP, UK	Resistant to cold and frORt
375.	Him Palam Setaria Grass - 2 (S -25)	2020	CSKHPKV, Palampur	HP, UK	Cold and frost tolerant
Tall Fescue					
376.	EC-178182	2009	ICAR-IGFRI, Jhansi	Sub temperate and Temperate grasslands and pastures of Hill zone of the country	Tolerant to acidic & alkaline soils
377.	Hima 4	2013	ICAR-IGFRI, Jhansi	Temperate grasslands of HP	Tolerant to acidic & alkaline soils
Lucerne (Alfalfa)					
378.	Alamdar-51	2020	---	AP, KA, TS, TN	Moderately resistant to DM
Sorghum (Fodder)					
379.	CSV 42 (SPV 2423)	2020	AICRP & UAS, Dharwad	KA, MS, GJ, MP	Tolerant to SB, SF
Horticultural Crops: Fruits					
Aonla					
380.	Goma Aishwariya	-	ICAR-CIAH, Bikaner	-	A selection from plus trees. It is early and drought tolerant.
Bael					
381.	GomaYashi		ICAR-CIAH, Bikaner		It is semi dwarf tree and suitable for dry land areas
382.	Thar Divya	-	ICAR-CIAH, Bikaner	-	Vigorous in growth pattern, less spines. Comparatively earliest. Precocious bearer and highly suitable for growing under dryland/rainfed hot semi-arid ecosystem
Banana					
383.	Kaveri Saba	-	NRC, Banana	-	It grows well both in plains and higher

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					altitudes. suitable for both culinary and dessert purposes. Saba is more suitable for marginal cultivation and saline sodic soils with pH ranging from 8.8 to 9.0.
Ber					
384.	Thar Sevika	-	ICAR-CIAH, Bikaner	-	Early maturing variety. Average fruit yield is 30-32 Kg/tree.
385.	Thar Malti	-	ICAR-CIAH, Bikaner	-	Tolerant to low temperatures (frost; subzero -2 ^{0}C) as plant growth. Fruit ripens in 145-150 days from fruit set
386.	Thar Bhubharaj	-	ICAR-CIAH, Bikaner	-	The fruits are very juicy, sweet with a TSS content of 22-23%.
Citrus					
387.	Nagpur mandarin	2003	PDKV, Akola	-	Less susceptible to canker, yield-77Kg/plant
388.	Nagpur Seedless	2003	PDKV, Akola	-	Less susceptible to canker, yield-62Kg/plant
389.	PDKV lime	2004	PDKV, Akola	-	Less susceptible to canker, yield-2000-2500 fruits/plant
390.	Katol Gold	2005	PDKV, Akola	-	Low incidence of pest and diseases, 123kg/tree
Jamun					
391.	GomaPriyanka	-	ICAR-CIAH, Bikaner	-	Fruits are good in test having 16.86 TSS ^{0}Brix. Fruits are rich in Vitamin C (45.44 mg/100g). Yield potential is 30 kg/plant.
392.	TharKranti	-	ICAR-CIAH, Bikaner	-	It is a dwarf, Fruit ripens in 75 days from fruit set. Fruit yield: 65.00 kg per plant. Early ripening (last week of May) and drought tolerant.
Karonda					
393.	Thar Kamal	-	ICAR-CIAH, Bikaner	-	The variety is developed through selection from

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					existing germplasm. The selected genotype was tested under field conditions for 9 years (2005-2014).
Khirni					
394.	Thar Rituraj	-	ICAR-CIAH, Bikaner	-	. It is comparatively dwarf, precocious bearer and suitable for high density planting
Lasoda					
395.	Thar Bold	-	ICAR-CIAH, Bikaner	-	A prolific and early bearing . It bears bold fruits in cluster with high production
Mahua					
396.	Thar Madhu	-	ICAR-CIAH, Bikaner	-	It is comparatively dwarf, precocious bearer and suitable for high density planting
Phalsa					
397.	Thar Pragati	-	ICAR-CIAH, Bikaner	-	It is dwarf, early precocious bearer (bearing in 3rd year), drought tolerant and suitable for high density planting
Pomegranate					
398.	Goma Khatta	-	ICAR-CIAH, Bikaner	-	The variety is developed for Anardana purpose. Yield potential is 6.59 kg/plant and anardana yield is 1.18 kg/plant.
399.	Ganesh	1952	MPKV, Rahuri	MS	Resistant to the water stress condition and well suited for arid regions. It has wide adaptability and bears well in all the seasons
400.	P-23	1986 -87	MPKV, Rahuri	MS	Most suited for plantation in medium soil. Fruits are smooth, yellow with red tinge, round in shape, arils are light pink in colour.
401.	P-26	1986	MPKV,	MS	Fruits are smooth,

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
		-87	Rahuri		yellow with red tinge, round in shape arils are light pink in colour
402.	Mridula	1994	MPKV, Rahuri	MS	Fruits are medium in size (300-350g) with reddish brown skin colour
403.	Phule Arakta	2003	MPKV, Rahuri	MS	It flowers in all the three seasons. Fruits are medium (182.70g) in size with red skin colour. The arils are bold with deep blood red colour
404.	Bhagwa	2003	MPKV, Rahuri	MS	Fruits are bigger in size (405.00 – 420.00 g). Fruit surface is glossy & attractive saffron rind colour, rind thickness is 0.35 cm, seeds are soft, days for maturity (180-190)
Vegetables					
Ash Gourd					
405.	KashiDhawal	2005	IIVR, Varanasi	UP	Resistance to anthracnose disease
Bottle Gourd					
406.	TharSamridhi	-	CIAH, Bikaner	RJ	Fruits weighing 450 – 700 g are ready for first harvesting after 50 to 55 days from sowing
407. 82	Kashi Ganga	2006	IIVR, Varanasi	UP, PB, and JH	Tolerant to anthracnose
Brinjal					
408.	PKM-1	1984	TNAU, Coimbatore	TN	The fruits are small with green stripes. It is drought tolerant and can withstand long distance transport
409.	KashiSandesh	2004	IIVR, Varanasi	UP, MP and JH	
410.	KashiTaru	2005	IIVR, Varanasi	UP	Fruits are long, purple, length 31 cm and diameter 5 cm
411.	KashiHimani	2019	IIVR, Varanasi	UP	Tolerant to fruit and shoot borer, have medicinal value for diabetic patients

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Carrot					
412.	Ooty-1	1997	TNAU, Coimbatore	Temperate regions	Resistant to powdery mildew, leaf spot and drought
Cassava					
413.	H-97	1971	CTCRI, Trivandrum	KL	Tolerant to leaf spot, spider mite and scale insect
414.	SreeSahya	1977	CTCRI, Trivandrum	KL	Moderate resistant to leaf sport
415.	SreeHarsha	1996	CTCRI, Trivandrum	KL	Tolerant to leaf spot, spider mite and scale insect
Chilli					
416.	Samrudhi		UAS(B)		
417.	KashiAnmol	2004	IIVR, Varanasi	UP, UK, OR, KA and TN	Plants are determinate, dwarf (60-70 cm) with nodal pigmentation on stem and bear green attractive pendant fruits
Cluster bean					
418.	RGC-936, RGC-1017		ARS, Durgapur, Jaipur	RJ	
419.	RGC-1017, RGC-1003, RGC-1066		RSSC, NSC, SKRAU, Bikaner	RJ	
420.	TharBhadavi		CIAH, Bikaner	RJ	High yielding variety. Pod yield potential is 75 g/plant and 9.0 cluster/plant.
Colocasia					
421.	White Goriya		IGKV, Jabalpur	CG	
422.	HalooKesoo		IGKV, Jabalpur	CG	
Cowpea					
423.	IT-38956-1, TVX -944-02E		UAS(B)	KA	
424.	RC-19, RC-101		RSSC, Rajasthan	RJ	
Dolichos Bean					
425.	Arka Jay		IIHR, Bengaluru	KA, TN, KL	Plants are dwarf, bushy, erect and photo

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					insensitive
426.	Arka Vijay		IIHR, Bengaluru	KA, TN, KL	Plants are dwarf, bushy, erect and photo insensitive
Drumstick					
427.	Bhagya	2017	UHS, Bagalkot	KA	
Elephant Foot Yam					
428.	NDA-5		IGKV, Jabalpur		
429.	Gajendra	1991	APAU, Hyderabad	AP, WB, BH, AS, UP	Tolerant to blight
Onion					
430.	Agrifound Dark Red		NHRDF, Nashik	UP, BH, PJ	
431.	Arka Kalyan		IIHR, Bengaluru	BH, PB, GJ, HR, MS, KA, TN	Resistant to purple blotch disease
432.	Raseedpura local		NSC & RSSC		
Snap Melon					
433.	AHS-10		CIAH, Bikaner	RJ	
434.	AHS- 82	2016	CIAH, Bikaner	RJ	
Sweet Potato					
435.	H-41		CTCRI, Trivandrum	KL	High yielding hybrid variety of sweet potato with sweet, low fiber and excellent cooking quality tubers
436.	Sree Nandhini	1987	CTCRI, Trivandrum	KL	It is suitable for paddy fallows as a catch crop
Tomato					
437.	ArkaMeghali	2006	IIHR, Bengaluru	-	Fruits medium (65g), oblate with light green shoulder and deep red fruits. Bred for rainfed cultivation.
438.	ArkaVikas		IIHR, Bengaluru	GJ, HP, KA, MP, MS, OR, UP, WB	Adapted to both rainfed and irrigated conditions.
439.	TharAnnant		CIAH, Bikaner	-	Indeterminate type, suitable for table and processing purpose

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Plantation Crops					
Coconut					
440.	ALR C-1	2002	Coconut Research station, Aliyar Nagar	KL, AP, TN, KA	Early bearer, tolerate to all pests
441.	ALR C-2	2010	Coconut Research Station, Aliyar Nagar.	KL, AP, TN, KA	Moderately resistant to rhinoceros beetle, red palm weevil and leaf blight
442.	KalpaDhenu	2008	CPCRI Kasargod	KL TN, A&N, AP	Regular bearer, bear large green nuts.
443.	KalpaPratibha	2008	CPCRI Kasargod	KL, MS, TN, AP	Suitable for tender nut and copra
444.	KalpaMitra	2008	CPCRI Kasargod	KL, WB	Suitable for ball copra
445.	KeraKeralam	2007	CPCRI Kasargod	TN, KL, WB	Comes to flowering in 58 months and first harvest in 70 months (at Veppankulam)
446.	Kalpasamrudhi	2009	CPCRI Kasargod	KL AS	Good tender nut water quality
447.	Chandra Kalpa	2009	CPCRI Kasargod	KL, KA, AP, MS	Grows in all types of soil
448.	KalpaTaru	2009	UHS Bagalkot AICRP Palms	KA, KL,TN	Suitable for ball copra
449.	Kalpasree	2008	CPCRI Kasargod	KL, MS, TN, AP	Suitable for tender nut and copra.
450.	KalpaSankara	2012	ICAR-CPCRI Kasargod	KL	Suitable for root (wilt) disease prevalent tract
Cocoa					
451.	VTLCH-4	2006	ICAR-CPCRI (RS), Vitttal Karnataka	KL, KA, AP	Early, heavy bearer colour of the pod is yellow
452.	VTLCH-3	2006	ICAR-CPCRI(RS) Vittal, Karnataka	KL, KA, AP	Early, heavy bearer, drought tolerant. The colour of the pod is yellow.
Cashew					
453.	VRI 2	1985	CRS, Vridhachalam TN	MS, KA, KL	High shelling percentage of 28%. Resistant to tea mosquito bug
454.	Vengurla -7	2018	RFRS, Vengurla	MS, KA, KL, AP	moderately susceptible to tea mosquito

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Tea					
455.	UPASI-2 UPASI-9 UPASI-20 UPASI-26	-	UPASI, TRF TN	TN, AS	High yield clones
456.	BSS-1 - BSS-5		UPASI, TRF TN	TN, AS	High yield
457.	TRI-2025	-	Toklai Tea Experiment Station, Assam	TN, WB, AS	Superior yielding clone
458.	TS 378	-	Toklai Tea Experiment Station, Assam	TN, WB, AS	Suitable for cultivation in all soils, fairly tolerant o mites and blister blight
Coffee					
459.	Selection-7	-	CCRI, Balehonnur	KA, KL	Arabica type, susceptible to leaf rust, suitable for marginal lands
460.	Selction-9	-	CCRI, Balehonnur	KA, KL	Arabica type, wide adoptable, 65% A grade beans
461.	Selection-11	-	CCRI, Balehonnur	KA, KL	Arabica type, more B grade beans, resistance to leaf rust
Spice Crops					
Black Pepper					
462.	Panniyur 6	2000	Pepper Research Station, KAU, Kerala	All growing areas	Suitable for open condition as well as partial shade
463.	Panniyur 7	2000	Pepper Research Station, KAU, Kerala	All growing areas	Suitable open and shaded conditions.
464.	Panniyur 8	2013	Pepper Research Station, KAU, Kerala	All growing areas	Field tolerant to Phytophthora foot rot.
Cardamom					
465.	ICRI-5	2006	ICRI Myladumpara	KL, KA	First hybrid variety, Capsule size 68% more than 70 mm,
466.	ICRI-6	2006	ICRI Myladumpara	KA, KL	High percentage of bold capsules Capsule size 71% ; more than 7mm

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
467.	ICRI-4	2004	ICRI Myladumpara	KA, KL	Relatively olerant to rhizome rot and capsule borer
Ginger					
468.	Suruchi	1990	OUA &T, Pottangi, Orissa	OR, HP, UP	Profuse tillering, bold rhizome,
469.	Suravi	1991	OUA &T, Pottangi, Orissa	OR, HP, UP	Plumpy rhizome, dark skinned yellow fleshed
470.	Himgiri	1996	YSPUJ&F, Solan, HP	HP	Best for green ginger, less susceptible to rhizome rot
Turmeric					
471.	CO-2	1982	TNAU, Coimbatore	TN	waterlogged, hilly areas saline and alkaline areas
472.	BSR-1	1986	TNAU, Coimbatore	TN	suitable for problem soils
Cinnamon					
473.	YCD.1	1996	Hort. Research station TNAU	All growing areas	Good bark recovery adopted to wide range of soil and rainfed conditions
Coriander					
474.	CO-1	1997	TNAU, Coimbatore	All growing areas	A dual purpose variety
475.	RCr-20	1997	RAJAU, Jobner	All growing areas	Moderately resistant to stem gall
Fennel					
476.	Co-1	-	TNAU, Coimbatore	TN, RJ, GJ	Suitable for intercropping and border cropping with chilli and turmeric. Suitable water logged, saline and alkaline conditions
477.	GF-1	1984	SDAU Jagudan	GJ, RJ	moderately tolerant to sugary disease
478.	S-7-9	1996	-	RJ	-
Ajwain					
479.	Ajmer Ajwain-1	2004	ICAR-NRCSS Ajmer	RJ, MP, KA, AP	Moderately resistant to powdery mildew and to downy mildew
480.	Ajmer Ajwain-2	2004	ICAR-NRCSS Ajmer	RJ, MP, KA, AP	Plant tall, late maturity group (160 days)

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
481.	Ajmer Ajwain-93	2014	ICAR-NRCSS Ajmer	RJ, MP, KA, AP	A bushy plant, early maturing group (147 days)

Table 1a: Rootstocks of fruit crops tolerant to drought/ moisture stress.

Sl. No.	Crop	Name of the Root stock	Reference
1.	Apple	M7, M11, M26	Fernandez et al., (1994), Tatarinov (1992)
2.	Cherry	*P. avium*	Goncalues et al., (2000)
3.	Citrus	Sour Orange, Rough Lemon, Sweet Lime, Rangpur Lime, Cleopatra, Marmalade orange	Ananda (2001)
4.	Peach	GF 577, GF 667	Mannini and Galliana (2001)
5.	Pear	Oregon 211 and 249, Oregon 260, 261, 264, Quince A, Provence Quince,	Ananda (2001), Khalil (1999)
6.	Plum	Myrobalan 27, Mariana 4001, Peach-Almond Hybrid GF 667 and GF 577	Ryazanova (2002) Ananda (2001)

4.2. Waterlogging/flooding/submergence

In recent decades, due to climate change the duration and frequency of heavy rainfall events are increasing. This leads to waterlogging conditions in crop fields which affects the plant growth, eventually leading to death of plants if the flooding persists for several days. Most food crops except sorghum are very sensitive to flooding, and thus cause dramatic yield losses (Singh et al. 2011). Most studies related to waterlogging have been done on maize, barley, and soybean. The physiological and molecular responses of rice to flooding have been extensively studied (Colmer et al., 2014), providing evidence for several traits associated with submergence tolerance. The most promising traits that might enhance crop flooding tolerance are anatomical adaptations such as aerenchyma formation, the formation of a barrier against radial oxygen loss, and the growth of adventitious roots. With several approaches including genomics and molecular or genome-wide association (GWA) studies, the quantitative trait locus (QTL) is associated with tolerance traits that can be easily assessed. However, exploration of flooding-tolerant relatives or ancestral cultivars of the crops can enhance the chances of finding useful tolerance traits to be used in breeding (Mustroph, 2018).

Flooding caused by sea-level rises in coastal areas and the predicted increased intensity of tropical storms with climate change will likely hinder rice production. At present, about 20 million hectares of the world's rice-growing area is at risk of occasionally being flooded to submergence level, particularly in major rice-producing countries such as India and Bangladesh. Despite these complex set of challenges to the plant in flooded soils, some progress is being made in developing flood tolerant varieties of cereals. The most striking progress was the discovery and deployment of the SUBMERGENCE 1 (SUB1) locus in rice conferring tolerance to complete inundation (submergence) (Xu et al., 2006; Ismail et al., 2013). Subsequently, several submergence tolerant rice varieties have been developed by various organizations including NRRI, Cuttack, IRRI, Hyderabad etc. (Pathak et al, 2019 and). In the context of increasing frequency of floods since the last two decades various ICAR institutes and state agricultural universities started breeding programmes for development of flood tolerant varieties in different crops over years which can be utilized by the different stakeholders including farmers. The information about flood tolerant crop varieties developed by various organizations in India is given in Table 2.

Table 2: Crop varieties tolerant submergence/water logging/flooding/submergence.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Cereals					
Rice					
1.	Durga	2000	ICAR-NRRI, Cuttack	OR	Tolerant to diseases
2.	MTU 1010	2000	RARS, Maruteru	AP, TS, OR	Tolerant to drought
3.	Sarala	2000	ICAR-NRRI, Cuttack	OR	Non-lodging
4.	Swarna Sub1	2009	ICAR-NRRI, Cuttack	OR, WB, AP	-
5.	Reeta	2011	ICAR-NRRI, Cuttack	OR, AP, TN	Resistant to SB and LF
6.	CR Dhan 500	2012	ICAR-NRRI, Cuttack	OR, WB, UP	Moderately resistant to BL, BS
7.	Jalamani	2012	ICAR-NRRI, Cuttack	OR	Tolerant to BS, BL
8.	Jayantidhan	2012	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL
9.	CR Dhan505	2014	ICAR-NRRI, Cuttack	OR	Tolerant to BS, BL, ShB
10.	Sabour Shree	2015	BAU, Ranchi	BH	Highly resistant to BPH, GLH and SB
11.	Samba sub-1	2015	ICAR-NRRI, Cuttack	TS, AP, OR	-
12.	MTU 1140	2017	RARS, Maruteru	WB	-
13.	BahadurSub-1	2018	AAS, RARS, Titabar	AS	-
14.	DRR Dhan 50	2018	ICAR-IIRR, Hyderabad	AP, TS, OR, KA, BH, CH	Drought tolerant
15.	Tripura Jala	2018	ICAR Research Complex for NEH Region, Lembucherra	TR	-

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
16.	CR Dhan 801	2019	ICAR-NRRI, Cuttack	AP, TS, OR, UP, WB	Moderately resistant to BL, NB,BLB, SB,LF
17.	CR Dhan 802 (Subhas)	2019	ICAR-NRRI, Cuttack	BH, MP	Resistant to SB, LF,CW and tolerant to MR to LB, SR,
18.	Ksheera	2019	RARS, Maruteru	AP, TS, OS, CH	Tolerant to BL
19.	CSR43	-	ICAR-CSSRI, Karnal	UP	Short duration
Wheat					
20.	KRL 19	2011	ICAR-CSSRI, Karnal	All India	Salinity tolerant
21.	KRL 210	2012	ICAR-CSSRI, Karnal	BH, DL, HR, UP, RJ, PB, WB, UK	Salinity tolerant
22.	KRL 283	2018	ICAR-CSSRI, Karnal	UP	Salinity tolerant
Maize					
23.	Jawahar Maize 218	2018	JNKV, Jabalpur	MP	-
24.	Pusa Jawahar Hybrid Maize-1	2019	IARI, New Delhi	MP	-
25.	Pragati	-	GBPUAT, Pantanagar	UK	
Pulses					
Pigeonpea					
26.	Maruti	1985	AICRP & ICRISAT	AP,KA	Tolerant to wilt
27.	Asha	1993	AICRP & ICRISAT	AP,KA	Tolerant to wilt
28.	Mal 13	2005	BHU, Varanasi	UP,WB	Tolerant to major pest and diseases
29.	ICPL 84023	-	ICRISAT, Hyderabad	AP, KA	Tolerant to wilt
Chickpea					
30.	Pusa240	1985	IARI, New Delhi	CG, MP, UP, BH, WB	Moderately resistant to wilt and pod borer
31.	GNG 1581	2007	ARS, Sriganganagar	NWPZ	Semi erect habit
32.	DCP92-3	-	IGKV, Raipur	CG, MP	-
33.	GNG16	-	ARS, Sriganganagar	NWPZ	-
Oilseeds					

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Soybean					
34.	AHILYA-4 (NRC-37)	2001	ICAR-IISS, Indore	MP, MS, UP, RJ	Moderately resistant to collar rot, bacterial pustule, pod blight and bud blight, stem fly and leaf miner
35.	Jawahar Soybean 97-52 (JS 97-52)	2008	JNKVV, Jabalpur	JH, CH, AS, WB	Resistant to YMV, RRR, BP, CR, CLS and TLS; moderately resistant against stem fly, girdle beetle and defoliators.
Sesame					
36.	JS 97-52	2008	DSR Indore and JNKVV, Jabalpur	Central Zone and North Eastern Zone	Resistance to YMV and Collar rot, moderately resistant to *Rhizoctonia* aerial blight, moderately resistance to insects
Fodder/Forage Crops					
Buffalo Grass					
37.	MarwarAnjan (CAZRI-75)	1985	ICAR-CAZRI, Jodhpur	Arid and Semi-arid areas	Drought tolerant
Setaria Grass					
38.	Setaria-92	2005	CSKHPKV, Palampur	HP, UK	Provides 3-4 cuts

4.3. High temperature

Extreme temperatures due to climate change are affecting crop performance in several regions of the world. Exposure of plants to high temperatures during crop growth period is a major challenge to agricultural production. High temperatures affect plants at various organizational levels, primarily accelerating phenology to limit biomass production and shortening reproductive phase to curtail flower and fruit numbers, thus resulting in severe yield losses. High temperature besides affecting the normal growth and development, it also disrupts cellular metabolism, and gene expression, which alters morphological, physiological and biochemical changes in plants. The high temperature at reproductive growth stage, particularly flowering/anthesis, pollination, fertilization and seed formation and development processes are negatively affecting the seed set and thus reducing yield in several crops. The adverse effects of heat stress can be mitigated by developing thermo-tolerant crop varieties through genetic improvement. Genetic variation exists among genotypes of various crops to resist impacts of heat stress. Screening large populations of various crops using various traits, related to shoots (including leaves), flowers, fruits (pods, spikes, spikelets), and seeds (or grains), leads to identification of heat-tolerant and heat-sensitive genotypes. Heat tolerant genotypes generally possess adaptive traits related to thermotolerance in leaves (membrane thermostability, photosynthetic efficiency, chlorophyll content, chlorophyll fluorescence, stomatal activity), flowers (pollen viability, pollen germination, fertilization, ovule viability), roots (architecture), biomolecules (antioxidants, osmolytes, phytohormones, heat-shock proteins, other stress proteins). The traits linked to heat tolerance can be introgressed into high yielding but heat-sensitive genotypes of crops to enhance their thermotolerance (Chaudhary et al., 2020). Some successful attempts have been made by conventional breeding methods to improve crop plants with heat tolerance. However, the key to evolve heat tolerant crops lies in an integrated approach combining both traditional and molecular breeding techniques. Marker-assisted selection for heat tolerance as well as cloning and characterization of underlying genetic factors could be highly useful in this context. Despite the above discussed challenges in breeding heat stress tolerance various Institutes/ Universities developed and released varieties with some degree of tolerance to heat in few major food, vegetable and horticultural crops (Table 3).

Table 3. Crop varieties tolerant to high temperature.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Cereals					
Rice					
1.	DRR Dhan 47	2018	ICAR-IIRR, Hyderabad	TS, AP, KA, TN	Drought tolerant
2.	DRR Dhan 52	2019	ICAR-IIRR, Hyderabad	HR, GJ, OS	Drought tolerant
Wheat					
3.	Lok-1	1981	-	MS	Early maturity
4.	Ajantha	1983	CoA, Badnapur	MS	Drought tolerant
5.	HD 2402	1988	IARI, New Delhi	NEPZ	-
6.	K9465	1998	CSAUA&T, Kanpur	NEPZ	Resistance to BR and tolerant to drought
7.	HD 2160	1998	CSAUA&T, Kanpur	NEPZ	Resistant to BR
8.	HW 2045	2002	IARI, New Delhi	UP, BH, JH	Resistant to blight and rust
9.	Pusa gold	2003	IARI, New Delhi	NCR, Delhi	Resistant to rust
10.	RAJ 3765	2006	RARI, Durgapura	NWPZ	-
11.	DWR17	2007	ICAR-IIWBR, Karnal	NWPZ	Resistance to YR
12.	K 0307	2007	CSAUA&T, Kanpur	NEPZ	-
13.	WH 1124	2014	ICAR-IIWBR, Karnal	NWPZ	Resistance to yellow rust, brown rust
14.	DBW 107	2015	ICAR-IIWBR, Karnal	UP, BH, JH, WB	Resistance to brown rust

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
15.	DBW 173	2018	ICAR-IIWBR, Karnal	NWPZ	Resistant to yellow and brown rust
16.	DBW73	-	ICAR-IIWBR, Karnal	NWPZ	Resistant to yellow and brown rust
Maize					
17.	Suwan	-	BAU, Sabur	BH	-
18.	PMH-7	-	PAU,Ludhaiana	PB	-
19.	RCRMH2	2016	UAS, Raichur	KA	-
Pearl Millet					
20.	GHB-558	2003	JAU, Jamnagar	GJ	Tolerant to pest and diseases
21.	GHB-732		JAU, Jamnagar	GJ	Tolerant to pest and diseases
22.	GHB-538	2005	JAU, Jamnagar	GJ	Resistant to DM
Pulses					
Pigeonpea					
23.	Bahar	1986	RAU, Pusa	UP, BH	Salinity tolerant, Resistant to SMD
24.	Rajeev Lochan	2011	IGKV, Raipur	CG	
25.	UPAS-120	1976	GBPUA&T, Pantanagar	NWPZ and NEPZ	Tolerant to salinity and pod borer
Chickpea					
26.	Indira Chana	-	IGKV, Raipur	CG	Moderately resistant to wilt & tolerant to PB
27.	JG-315	1984	JNKV, Jabalpur	MP, CG	Drought tolerant, wilt
28.	Pant G 186	1996	GBPUAT, Pantanagar	UK	Drought to wilt, BGM
29.	JG-11	1999	JNKV, Jabalpur	MP, CG	Drought tolerant, wilt
30.	JG -6	2006	JNKV, Jabalpur	MP, CG	Drought tolerant, wilt
31.	JAKI 9218	2006	JNKV, Jabalpur	MP	Resistant to root rot, collar rot and wilt
32.	JG-14	2009	JNKV, Jabalpur	MP, CG	Drought tolerant, wilt
Moth Bean					
33.	RMO-425	-	ARS, Bikaner	RJ	-
34.	RCG1033	-	ARS, Bikaner	RJ	-
35.	RMO-40	1994	ARS, Bikaner	RJ	-
36.	RMO-225	1999	ARS, Bikaner	RJ, GJ, MS	Mutant variety
37.	CAZRI MOTH-1 (CZM-79)	1999	ICAR-CAZRI, Jodhpur	RJ, GJ	Tolerant to blight

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Lentil					
38.	Kota Masoor 3	2020	AU,Kota	RJ	Drought tolerant
Oilseeds					
Groundnut					
39.	Kadiri-3	1978	APAU, Kadiri	AP	Early maturity; tolerant of LLS
40.	Phulepragati (JL-24)	1978	MPKV, Jalgaon	MS, GJ	Early maturity; wider adaptability
41.	ICGS-44 (ICGV-87128)	1988	ICRISAT, Hyderabad	GJ, AP, KA, OR, TN	Tolerant of ELS, PBND and high seed protein (25%) content
42.	ICGS-76	1989	ICRISAT, Hyderabad	MS, KA	Resistant of ELS
43.	ICGV-86031	1991	ICRISAT, Hyderabad	AP	Multiple resistances to *Spodoptera*, leaf miner, jassids, thrips, PBND. Photoperiod insensitive and resistant to iron deficiency chlorosis
44.	TG- 22	1992	BARC, Mumbai	BH	Suitable for *kharif*rainfed condition
45.	Ambar (CSMG-84-1)	1992	CSAUA&T, Mainpuri	UP, RJ, HR	Resistant to rust and leaf spots
46.	Vemana (K-134)	1995	APAU, Kadiri	AP and TN	Tolerant of leaf spots, PBND and drought
47.	Kadiri-6 (K-1240)	2005	ANGRAU, Kadiri	AP	Tolerant of leaf spots
48.	ICG-1236, ICGV-86021, ICGV-87281, ICGV-92121, TNAU-325, ICG-3793 and Chico	-	-	-	As a donors for heat tolerance
Soybean					
49.	JS-335	1994	JNKVV, Jabalpur	GJ, RJ, MP, parts of MS,	Resistant to bacterial blight, GMV & ALS, to stem fly
Sunflower					
50.	DRSF-113	2007	ICAR-IIOR, Hyderabad	AP, MS, TN	White flies thrips and leaf hoppers
51.	PSFH-118	2002	PAU, Ludhiana.	Suitable For Late Sown	Tolerant to stem rot and head rot, *heliothis* and

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
				Conditions	white flies.
Linseeds					
52.	Jawahar-552 (R-552)	1980	IGKV, Jabalpur	Central plains zone	Resistant to wilt; Moderately susceptible to rust and PMD.
53.	Deepika (RLC-78)	2006	IGKV, Jabalpur	CH plains zone	Moderately resistant to rust, wilt and alternaria blight. Resistant to PMD
54.	Indira Alsi-32 (RLC-81)	2005	KGKV, Raipur	CR, MS, OR	Resistant to PMD, moderately susceptible to wilt and alternaria blight.
55.	RLC 92 (IC 555926)	2008	IGKV, Jabalpur	MS, CH, OR, KA	Moderately resistant to linseed bud fly
Sesame					
56.	CUMS-17 (Suprava)	2018	IAS, Uni. of Calcutta	WB	
Rape Seed & Mustard (Mustard, Rapeseed, Rai, Taramira, Toria & Brown Sarason)					
57.	Pro 5222 Bayer Mustard 5222	2019	Bayer BioScience Pvt. Ltd. Hyderabad	WB	Moderately Resistant to WR, Resistant to aphid infestation
58.	Pusa Tarak	2009	IARI, New Delhi	Delhi	Bold seeded, High temperature tolerant
59.	Pusa mustard 25 (NPJ 112)	2010	IARI, New Delhi	DL, HR, PB, J&K, RJ, UP	Suitable for early sown irrigated conditions, high temperature tolerance at juvenile stage
60.	NRCDR 601 (DMR 601)	2010	DRMR, Bharatpur	DL, HR, PB, RJ	Tolerant to
61.	RGN 229	2011	RAU,ARS, Sriganganagar	DL, HR, PB, J&K, RJ	Tolerant to salinity
62.	RGN 236	2011	RAU,ARS, Sriganganagar	DL, HR, PB, J&K, RJ	Tolerant to salinity
63.	PR 20061 (Pant rai 19)	2012	GBPAUT, Pantanagar	DL, HR, PB, J&K, RJ	Tolerant to high temperature at early stage
64.	Pusa Vijay (NPJ 93)	2008	IARI, New Delhi	DL	Tolerant to salinity and high temperature during seedling stage
65.	Pusa Mustard 28 (NPJ-124)	2012	IARI, Karnal	DL, HR, PB, J&K, RJ, UP	Tolerant to salinity
66.	Pusa Mustard 22 (LET - 17)	2008	IARI, New Delhi	Delhi	Low incidence of white rust, *sclerotinia* stem rot, downy and powdery mildew. It is tolerant to

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					salinity up to 12 ds/m.
67.	NRCDR-02	2007	ICAR-DRMR, Bharatpur	RJ, HR, PB, DL	Tolerant to salinity, tolerant to white rust, *sclerotinia* rot and *alternaria*, DM
68.	Vasundhara		CCS HAU, HISSAR	UP, UR, MP, RJ	-
69.	Divya-33	2013	M.R. Seeds Pvt. Ltd. Sriganganagar, Rajasthan	DL, HR, PB, J&K, RJ	Tolerant to WR and *alternaria*, thermo-tolerant.
70.	Pusa MUSTARD 29 (LET - 36)	2013	IARI, New Delhi	DL, HR, J, PB,RJ	Tolerates salinity
71.	Pusa Mustard 30 (LES-43)	2013	IARI, New Delhi	UP, UK, MP, RJ	Tolerates salinity
72.	RH 0406	2013	CCSHAU, Hissar,	HR, PB,DL, RJ	Less severity against white rust and *Alternaria* blight, Tolerant to high salinity at seeding stage.
73.	Pant Rai-19 (PR-2006-1)	2012	GBPAUT, Pantanagar	J&K, PB, HR, DL	Escapes Aphid infestation due to early maturity
74.	Pusa Mustard 26 (NPJ-113)	2012	IARI, Regional Station, Karnal	J&K, PB, RJ, DL, HR	Possess terminal heat tolerance
75.	Pusa Mustard 27(EJ 17)	2011	IARI, Regional Station, Karnal	UP, MP, UK, RJ	Tolerant to white rust alternaria blight, downy mildew, PM, *sclerotinia* stem rot;
Horticultural Crops: Vegetables					
Bell Pepper					
76.	ArkaGaurav	1984	IIHR, Bengaluru	KA	Indeterminate plant habit, average fruit weight 130-150g, fruits erect which turn orange yellow on ripening
77.	PSM-1		PAU, Ludhiana	PB	-
Bottle Gourd					
78.	TharSamridhi		CIAH, Bikaner	RJ	Fruits weighing 450 – 700 g are ready for first harvesting after 50 to 55 days from sowing
79.	PusaSantushti	2005	IARI, New Delhi	DL, PB, UK, BH, MP, MS	Fruits attractive green, smooth, pearShaped, sets fruit under

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
					hightemperature (35-40 ˚C)
Brinjal					
80.	KashiSandesh,	2004	IIVR, Varanasi	UP, MP, JH	
81.	KashiTaru	2005	IIVR, Varanasi	UP	Fruits are long, purple, length 31 cm and diameter 5 cm
82.	TharRachit		CIAH, Bikaner	RJ	
83.	HLB-12		CCSHAU, Hisar	HR	Tolerant shoot and fruit borer
Cabbage					
84.	Pusa Ageti		IARI, New Delhi	All India	Tropical type produces seeds under sub-tropical conditions, forming marketable heads at a temperature range of 15-30°C.
85.	Pusa cabbage hybrid 1	2012	IARI, New Delhi	HP, JK, MP, PB, UK	Resistant to black rot, Its headshave better staying capacity in the field (non-splitting habit)
Carrot					
86.	Pusa Meghali	1994	IARI, New Delhi	MP, MS	Only variety having orange coloured flesh in the tropical group. Produces seeds in the plains.
87.	Pusa Vrishti	2009	IARI, New Delhi	North Indian plains	Roots are triangular in shape and red coloured.
Cauliflower					
88.	Pusa Himjyoti		IARI, New Delhi	All India	Plants are erect,500-600 g in weight, takes 60-75 days from planting to harvesting
89.	Pusa Meghana	2004	IARI, New Delhi	NCR	Extra early variety for September maturity group (temperature 22-27 ˚C).
90.	SabourAgrim	2015	BAU, Sabour	BH	-
Chilli					
91.	Kashi Abha	2019	IIVR, Varanasi	UP	Tolerant anthracnose, CLCV, thrips and mites
Cluster Bean					

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
92.	RGC-197, RGC-936		RSSC, Rajasthan	RJ	
93.	RGC-936		RSSC, NSC, SKRAU, Bikaner	RJ	
94.	Thar Bhadavi		CIAH, Bikaner	RJ	High yielding variety. Pod yield potential is 75 g/plant and 9.0 cluster/plant.
95.	Goma Manjri		CIAH, Bikaner	RJ	
Cowpea					
96.	Kashi Kanchan	2007	IIVR, Varanasi	UP	Resistant to golden mosaic virus
97.	Kashi Nidhi	2012	IIVR, Varanasi	BH, JH, PB, UP	Golden mosaic virus and *Pseudocercospora cruenta* tolerant
98.	Arka Garima		IIHR, Bengaluru	MP, MS, KA, TN, KL	Plants are tall, photo insensitive. Pods are light green, long, thick, round, fleshy and stringless.
Cucumber					
99.	PusaBarkha	2012	IARI, New Delhi	North Indian plains	Tolerant to Downy mildew
Drumstick					
100.	Thar Harsha		CIAH, Bikaner	RJ	Resistant to leaf eating caterpillar and moderately resistant to fruit fly under field condition
Ivy Gourd					
101.	Thar Sundari	2018	CIAH, Bikaner	RJ	Plants continue flowering even when temperature reached to max. 480˚C, however, slightly affecting the fruit size and shape
Long Melon					
102.	Thar Sheetal		CIAH, Bikaner	RJ	They are tender, attractive, light green at the edible stage and free from bitter principle which is highly accepted by the growers.
Okra					
103.	KashiPragati	2004	IIVR, Varanasi	BH,CG,JH,	Resistant to YVMV and

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
				MP, OD, UP, WB	OLCV
104.	KashiKranti	2012	IIVR, Varanasi	BH, JH, PB, UP	Resistant to YVMV and OLCV
Onion					
105.	NP53		CIAH, Bikaner	RJ	
Palak					
106.	Pusa Harit		IARI, New Delhi	All India	Plants are erect leaves upright, thick, dark green, slightly wavy margins, short petiole quick rejuvenation after cuttings; bolting very late.
107.	Thar Hariparna	2018	CIAH, Bikaner	RJ	It produces excellent quality and bigger size tender leaves for fresh vegetable use
Pea					
108.	Matar Ageta-6		PAU, Ludhiana	PB	-
109.	Azad Pea G 10		RSSC, Rajasthan	RJ	-
Potato					
110.	Kufri Surya Surya		CPRI, Shimla	BH, PB, RJ, UP, B, DL, HR, HP, JK, TN, KA, GJ, MP, OD, CG, KL, AP, MS	Tubers are white cream, oblong with shallow eyes. This is a heat tolerant variety that can be grown in areas having night temperature above 20ºC.
111.	Kufri Lauvkar		CPRI, Shimla		For plateau, early maturity, heat tolerant
Radish					
112.	Pusa Chetaki	1988	IARI, New Delhi	All India	Roots pure white, smooth, soft in texture, less pungent in summer sowings
113.	Kashi Mooli-40	2019	IIVR, Varanasi	UP	Delayed bolting less pithiness, iciclical root shape, attractive white colour
Ridge Gourd					
114.	Thar Karni		CIAH, Bikaner	RJ	Resistant to mosaic disease and melon fruit fly

Sl. No.	Varieties	Year	Organizations/ Institute	Area of Adoption/ State	Other Features
Sponge Gourd					
115.	Pusa Sneha	2004	IARI, New Delhi	Delhi and NCR	Having tender flesh and hard skin, suitable for long distance transportation
116.	Thar Tapish	2018	CIAH, Bikaner	RJ	Potential for kitchengardening. It is suitable both for rainyand summer season cultivation
Tomato					
117.	Pusa Sadabahar	2004	IARI, New Delhi	Delhi and NCR	Suitable for growing under a wide range of temperature (8˚C-30˚C)
118.	ArkaMeghali	2006	IIHR, Bengaluru	KA	Fruits medium (65g), oblate with light green shoulder and deep red fruits. Bred for rainfed cultivation.
119.	Varkha Bahar-1	2009	PAU, Punjab	PB	Resistant to tomato leaf curl virus
120.	Varkha Bahar-2	2009	PAU, Punjab	PB	Resistant to tomato leaf curl virus
121.	ArkaVikas		IIHR, Bengaluru	GJ, HP, KA, MP, MS, OR, UP, WB	Adapted to both rainfed and irrigated conditions
Turnip					
122.	Pusa Sweti		IARI, New Delhi	DL	It has attractive pure white roots
Water Melon					
123.	Thar Manak	2016	CIAH, Bikaner	RJ	It is very early. First marketable harvesting 75-80 DAS

4.4. Low Temperature (Cold/Frost)

Staple food crops such as maize, rice are highly sensitive to low temperatures. The growth and development of these crops is severely affected when temperatures fall below 10^0 C resulting in considerable yield loss or even crop failure. When the temperature decreases to less than 5^0 C for more than three consecutive days it is considered as cold wave/stress in areas where normal temperature remains 10^0 C or above, while in areas where normal temperature is below 10^0 C, if temperature goes below 3^0 C for more than three days it is considered as cold wave (Venkateswarlu et al., 2011). Crop plants which are native to warm habitat, exhibit symptoms of injury when subjected to low non-freezing temperatures. Various symptoms in response to cold/chilling stress include reduction of leaf expansion, wilting, chlorosis and necrosis. Severe and longer colds during flowering and seed maturation also affect the seed quality in agricultural crops. However, the studies on these aspects are limited to only a few crops such as chickpea, wheat and soybean. In chilling stress, primary injury is the initial rapid response that causes a dysfunction in the plant, but is readily reversible if the temperature is raised to non-chilling conditions (Kratsch and Wise 2000). Major field and horticultural crop varieties with tolerance to cold/frost released by various Institutes/ Universities are given in the Table 4.

Table 4: Crop varieties tolerant to low temperature (cold/frost).

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
Cereals					
Rice					
1.	Kalinga 1	1973	ICAR-NRRI, Cuttack	All India	Drought tolerant
2.	Tellahamsa	1975	ANGRAU, Hyderabad	AP, TS	-
3.	Pant Dhan 11	1993	GBPUAT, Pantanagar	UK	Resistant to BLB
4.	Varun Dhan	2008	CSKHPKV, Palampur	HP	-
5.	HPR2143 HPR1068 RP2421	-	CSKHPKV, Palampur	HP	-
6.	Gizza-14 K-39 K-343 K-448	-	SKUA&T, Jammu	J&K	-
7.	NE Megha Rice 1, NE Megha Rice 2	-	ICAR Barapani	MG	-
Wheat					
8.	Buland		PAU, Ludhiana	PB	
9.	Mansarovar	1999	SKUAST, Srinagar	J&K	Moderately resistant to YR
10.	Shalimar wheat-1	2005	SKUA&T, Jammu	J&K	Resistant to SR
11.	RSP 561	2015	SKUA&T, Jammu	J&K	-
Barley					
12.	BHS352	-	IARI, Shimla	HP, UK	-
Pearl Millet					
13.	GHB-538	2005	JAU, Jamnagar	GJ	Resistant to DM
Pulses					
Pigeonpea					

Sl. No .	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
14.	Bahar	1986	RAU, Pusa	NEPZ	Resistant to SMD
Chickpea					
15.	PDG 4	2003	GBPUAT, Pantanagar	UK, PB	Tolerant to major pest and diseases
Oilseeds					
Rape Seed & Mustard (Mustard, Rapeseed, Rai, Taramira, Toria & Brown Sarason)					
16.	RGN-73	2007	RAU,ARS, Sriganganagar	UP, MP, RJ, UR	Suitable for Irrigated, frost conditions
17.	RH-9801 (SWARNA)	2003	CCS HAU, HISSAR	UP, MP, RJ, UR, HR	Moderately Tolerant To Frost.
18.	RGN-48		ARS, Sriganganagar.	RJ, PJ, HR	Suitable for Rainfed Situations; better tolerance against white rust Sclerotinia stem rot and downy mildew
Forage/Fodder Crops					
Anjan Grass/ Buffalo Grass					
19.	Bundel Anjan-1	1989	IGFRI, Jhansi	All over India	Drought & frost hardy
Dhaman Grass/ Bird Wood Grass					
20.	Bundel Dinanath-2	1989	IGFRI, Jhansi	All over India	Tolerant to lodging & drought conditions
Rye Grass					
21.	Pb. Ryegrass No.1	1991	PAU, Ludhiana	PB	Quick growing with soft stem and leaves.
Setaria Grass					
22.	Setaria-92,	2005	CSK HPKVV, Palampur	HP, UK	Drought and frost tolerant
23.	S-18	2013	ICAR-IGFRI, Jhansi	HP, UK	Drought and frost tolerant
24.	PSS-1, Nandi	1983	CSK HPKVV, Palampur	HP	-
25.	Him PalamSetaria Grass - 2 (S - 25)	2020	CSK HPKVV, Palampur	HP, UK	Drought and frost tolerant
Tall Fescue Grass					
26.	EC 178182	2010	CSK HPKVV, Palampur	HP, UK, J&K	Frost resistant and non-lodging
Horticultural Crops: Vegetables					
Bottle Gourd					

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
27.	Pusa Santushti	2005	IARI, New Delhi	-	Fruits attractive green, smooth, pear Shaped, sets fruit under low -temperature (10-12 ˚C)
Carrot					
28.	Ooty-1	1997	TNAU, Coimbatore	Temperate regions	Roots are long and slightly tapering with attractive deep orange color. Suitable for growing in hilly areas at altitude above 1800m.
29.	Pusa Yamdagni	1986	IARI, New Delhi	Low temperature regions	Roots long slightly tapering, cylindricalwith small tops and orange colour roots
30.	Pusa Nayanjyoti	2009	IARI, New Delhi	Low temperature regions	First hybrid developed by Public Sectorwith orange colour roots. Roots are orange, smooth, stumpy with a small indistinct self-colouredcore.
Knol-khol					
31.	Pusa Virat		IARI, New Delhi	DL	The Knobs remain non-pithy and without fiber for longer periods
Tomato					
32.	Pusa Sheetal	1987	IARI, New Delhi	North Indian plains	-
33.	Pusa Sadabahar	2004	IARI, New Delhi	DL and NCR region	Suitable for growing under a wide range of temperature (8˚C-30˚C)

4.5. Salinity

Salinity another major threat to crop production in arid and semi-arid regions where water scarcity and inadequate drainage of irrigated lands. Increased salinization of arable lands is expected to have devastating effects on agricultural production in many countries including India. High salinity causes both hyper-ionic and hyperosmotic stress and can lead to plant death (Munns and Tester 2008). Salinity in a given land area depends on the amount of evaporation in relation to the amount of precipitation leading to increase in salt concentration. Intrusion of seawater also is another major cause for increase in salinity. Sodicity is a secondary result of salinity in clay soils, where leaching washes soluble salts into the subsoil, while sodium is left bound to the negative charges of the clay (Wang et al., 2003).

Salt accumulation inhibits plant growth and reduces the ability to uptake water and nutrients, leading to osmotic or water-deficit stress. Salt is also causing injury of the young photosynthetic leaves and acceleration of their senescence, as the Na+ cation is toxic when accumulating in cell cytosol resulting in ionic imbalance and toxicity of transpiring leaves. To cope with salt stress, plants have evolved mainly two types of tolerance mechanisms based on either limiting the entry of salt by the roots, or controlling its concentration and distribution. Understanding the overall control of Na+ accumulation and functional studies of genes involved in transport processes, will provide a new opportunity to improve the salinity tolerance of plants relevant to food security in arid regions. A better understanding of these tolerance mechanisms can be used to breed crops with improved yield performance under salinity stress (Hanin et al, 2016).

A number of mapping studies have been attempted to identify QTLs located on different chromosomes for salinity tolerance in rice. A major QTL designated as 'SALTOL' was mapped on chromosome 1 which accounts for more than 40 per cent of the variation in salt uptake. Several lines containing SALTOL QTL were developed through marker assisted breeding. ICAR- CSSRI, Karnal working in the area of crop improvement for problematic soils breed and released varieties in wheat, rice, mustard and chickpea for saline and acid soils. Major crop varieties with tolerance to salinity stress released by various Institutes/ Universities are given in the Table 5. The reported root stocks of fruit crops tolerant to salinity are given in Table 5a.

Table 5: Crop varieties tolerant to salinity.

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
Cereals					
Rice					
1.	Vikas DRR Dhan 9	1983	ICAR-IIRR, Hyderabad	AP, MP, WB, KE	Tolerant to Alkalinity
2.	CSR 10	1989	ICAR-CSSRI, Karnal	HR, UP	Tolerant to sodicity
3.	CSR 13	1998	ICAR-CSSRI, Karnal	HR, UP	Tolerant to sodicity
4.	CSR 27	1999	ICAR-CSSRI, Karnal	HR	Moderately resistant to BL, BLB
5.	Basmati CSR 30	2001	ICAR-CSSRI, Karnal	HR, PB, UP	Moderately resistant to BL
6.	CSR 23	2004	ICAR-CSSRI, Karnal	HR, UP	Tolerant to sodicity
7.	CSR 36	2005	ICAR-CSSRI, Karnal	HR, UP, Pondicherry	Tolerant to sodicity
8.	Jarava DRR Dhan 33	2005	ICAR-IIRR, Hyderabad	WB, AN, PY	Alkaline tolerant
9.	Luna Suvarna CR Dhan 403	2010	ICAR-NRRI, Cuttack	OR	Tolerant- SB, BPH and LF
10.	Luna Sampad CR Dhan 402	2010	ICAR-NRRI, Cuttack	OS	Resistant to BL, tolerant to SB, BPH, LF
11.	DRR Dhan 39	2010	ICAR-IIRR, Hyderabad	OR, KL, GJ	Alkaline tolerant
12.	CSR 43	2011	ICAR-CSSRI,	UP	Tolerant to sodicity

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
			Karnal		
13.	Luna Barial (CR Dhan 406)	2012	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL, LF and ShB
14.	Luna Sankhi (CR Dhan 405)	2012	ICAR-NRRI, Cuttack	OR	Moderately resistant to BL and ShB
15.	GNR-5	2018	NAU, Navsari,	GJ	Tolerant to major diseases
16.	CSR 46	2018	ICAR-CSSRI, Karnal	UP	Tolerant to sodicity
17.	CSR 60	2018	ICAR-CSSRI, Karnal	UP, PU	Tolerant to major diseases
18.	CSR 56	2018	ICAR-CSSRI,Karnal	HR, UP	Tolerant to sodicity
19.	CSR 52	2019	ICAR-CSSRI, Karnal	UP	Tolerant to sodicity
20.	CSR 56	2019	ICAR-CSSRI, Karnal	HR, UP	Tolerant to sodicity
21.	Panvel 3	-	BSKV, Dapoli	Konkan region of MS	Tolerant to major diseases
22.	CARI Dhan 5		CARI , Port Blair	AN	Tolerant to major diseases
Wheat					
23.	KRL 1-4	1990	ICAR-CSSRI, Karnal	All India	-
24.	KRL 19	2000	ICAR-CSSRI, Karnal	All India	Water logging tolerant
25.	KRL 210	2012	ICAR-CSSRI, Karnal	BH, DL, HR, UP, RJ, PB, WB, UK	Resistant to rust and Karnal bunt, Water logging tolerant
26.	KRL 283	2018	ICAR-CSSRI, Karnal	UP	Resistant to Karnal bunt and LB, Water logging tolerant
27.	KRL-213	2011	ICAR-CSSRI, Karnal	BH, DL, HR, UP, RJ, PB, WB, UK	Resistant to alkalinity and Karnal bunt
Pulses					
Pigeonpea					
28.	UPAS 120	1976	GBPUAT, Pantanagar	NWPZ and NEPZ	Tolerant to pod Borer
29.	Jagriti (ICPL 151)	1989	ICRISAT, Hyderabad	NWPZ	Tolerant to major pest and diseases
30.	C 11	-	ANGRAU, Hyderabad	AP	Tolerant to major pest and diseases
Chickpea					

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
31.	Karnal chana-1	1998	ICAR-CSSRI, Karnal	PB, HR, DL, western UP	Resistant to ABL, root rot, wilt and pod borer
Cowpea					
32.	Hissar Cowpea-46 (HC 98-46)	2009	CCS, Hissar	Coastal saline areas	Tolerant to white fly and leaf hopper
Rice Bean					
33.	Bidhan Rice bean-3	-	BCKV, West Bengal	JH, WB, OR, MN, KL	-
Faba Bean					
34.	Vikrant (VH-82-1)	1999	CCS, Hissar	HR	-
Lentil					
35.	PSL-9	2020	IARI, New Delhi, ICAR-CSSRI Karnal	UP, HR	Resistant to major pest and diseases
36.	PDL-1	2020	IARI, New Delhi, CSSRI Karnal	UP, HR	Resistant to major pest and diseases
Oilseeds					
Rape Seed & Mustard (Mustard, Rapeseed, Rai, Taramira, Toria & Brown Sarason)					
37.	CS 52	1998	ICAR, ICAR-CSSRI Karnal	HR, PB,GU,RAJ,UP	
38.	CS 54	2005	ICAR, CSSRI Karnal	HR, PB,GU,RAJ,UP	
39.	CS 56	2008	ICAR, CSSRI Karnal	HR, PB,GU,RAJ,UP	Late sown (up to 15 Nov)
40.	CS 58	2017	ICAR, CSSRI Karnal	HR, PB,GU,RAJ,UP	Oil content 40%
41.	CS 60	2018	ICAR, CSSRI Karnal	HR, PB,GU,RAJ,UP	Oil content 41%
42.	Pusa Vijay (NPJ 93)	2008	IARI, New Delhi	DL	Tolerant to high temperature during seedling stage
43.	NRCDR 601 (DMR 601)	2010	DRMR, Bharatpur	DL, HR, PB, RJ	Tolerant to high temperature during seedling stage
44.	RGN 229	2011	RAU,ARS, Sriganganagar	DL, HR, PB, RJ	Tolerant to high temperature during seedling stage
45.	Pusa mustard 25 (NPJ 112)	2010	IARI, New Delhi	DL, HR, PB, RJ, UP, J&K	High temperature tolerance at juvenile stage
46.	RH0119	2010	CCS HAU, HISAR	-	-

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
47.	RGN-145	2009	RAU,ARS, Sriganganagar	DL, HR, PB, RJ, UP, J&K	Tolerance tot White Rust, *Alternaria*
48.	RGN 236	2011	RAU,ARS, Sriganganagar	DL, HR, PB, RJ	Tolerant to high temperature during seedling stage
49.	Pusa Mustard 22 (LET - 17)	2008	IARI, New Delhi	DL	Tolerant to DM ,PM, WR High temperature
50.	NRCDR-02	2007	ICAR-DRMR Bharatpur	RJ, HR, PB, DL	Tolerant to DM ,PM, WR, *Alternaria* and High temperature
51.	NARENDRA RAI (NDR-8501)	1990	NDAUT Faizabad.	DL	Moderately resistant to *Alternaria* blight and WR, and resistant to DM
52.	Divya-33	2013	M.R. Seeds Pvt. Ltd., Sriganganagar (Rajasthan)	RJ, HR, PB, DL, J&K	Tolerant to DM ,PM, WR
53.	Giriraj (DRMRIJ 31)	2013	DRMR, Bharatpur	RJ and HR	Responsive to high fertilizer doses (125% of RFD)
54.	Pusa MUSTARD 29 (LET - 36)	2013	IARI, New Delhi	DL, HR, PB, RJ	Lesser reduction in germination and seedling dry weight
55.	Pusa Mustard 30 (LES-43)	2013	IARI, New Delhi	UP, UK, MP, RJ	Lesser reduction in germination (%) and seedling dry weight
56.	RH 0406	2013	CCS,HAU, Hissar	HR, PB, DL, RJ	Less severity against WR and *Alternaria* blight, tolerant to high temperature at seedling stage.
Fodder/Forage Crops					
Napier Bajra					
57.	Narendra Chara Bajra-2 (NDFB-2)	2009	NDAUT, Faizabad	BH, JH, UP. OR, WB	Resistant to leaf spot and DM
58.	NDFB-3(Narendra Chara Bajra-3)	2011	NDAUT, Faizabad	BH, JH, UP. OR, WB	Resistant to leaf spot and DM
Fodder Oat					
59.	NDO-1 (Narendra Jayee-1)	2010	NDAUT, Faizabad	UP	Resistant to lodging, non-shattering
60.	NDO-2 (Narendra Jayee-2)	2013	NDAUT, Faizabad	UP	Moderately resistant to leaf blight

Sl. No.	Varieties	Year	Organizations/ Institute	Area of adoption/ state	Other features
Sorghum (Fodder)					
61.	CSV- 44F (SPV-2445/ S713)	2020	CCS, Hisar	KA, MS, TN	Tolerant to pest and diseases

Table 5a: Rootstocks of fruit crops tolerant to salinity stress

Sl. No.	Crop	Genotypes/Varieties/Lines/Genetic Stocks	Reference
1.	Almond	Bitter almond (No. 31, 41)	Najafian et al. (2008)
2.	Avocado	West Indian race	Cooper (1951)
3.	Citrus	Rangpur lime, Marmlade orange, Rough Lemon, Cleopatra mandarin, Sour Orange, KarnaKhatta, Nasnaran, attani 2, Gou Tou Cheng	Syvertsen et al. (1989); Ghosh, (2007); Patel et al. (2011); Levy et al. (1999); Storey (1995)
4.	Guava	Crioula'	Sa et al. (2016)
5.	Grapes	*V.champini*, *V. vinifera*, Dogridge, salt creek (Ramsey), *V. berlandieri* × *V. rupestris* (110R, 1103P, 99R, B2/56), 1613, 1103 Paulsen	Leon et al. (1969); Sauer (1968); Palaniappan, (1986); Upreti and Murti (2010); Jogaiah et al. (2014); Walker et al. (2004)
6.	Ber (Indian Jujubi)	*Z. rotundifolia*, *Z. nummularia*, *Z. spina-christi*	Gupta et al. (2002), Meena et al. (2003), Sohail et al. (2009)
7.	Mango	Peach, 13-1, Olour, Bappakai, Nekkare, Terpentine, Gomera-1, *M. zeylanica*, ML-2, GPL-1	Kadman et al. (1976), Fayek et al (2018), Palaniappan, 2001, Pandey et al. (2014), Duran et al. (2003), Schmutz (2000), Damodaran et al. (2013)
8.	Peach	GF677, Myrobalan, Bright's Hybrid	Massai et al. (2004), El-Motaium et al. (1994)
9.	Pear	*Pyrusbetulifolia*	Okubo and Sakuratani (2000)
10.	Pistachionut	*P. atlantica*, UCB-1	Ferguson et al. (2002)
11.	Pomegranate	Tab-o-Larz	Karimi and Hassanpour (2017)

5. Strategies to Speed Up Genetic Enhancement of Crop Plants for Abiotic Stress Tolerance

Most of the crop varieties enlisted in the above section are developed through conventional methods. In general, most heritable and adaptive & phonological traits like early flowering/ maturity, root traits and other morphological traits were exploited for developing climate resilient varieties. Despite this use of such abiotic stress tolerant crop varieties do not meet expectations of end users. This is mainly due to limited information or popularity of varieties, difficulty in accessing the quality seed of promising varieties at the right time, poor and variable genetic potential resulting in low yield or poor performance compared to other high yielding varieties under normal conditions and susceptibility to biotic stresses. Therefore, it is very essential to develop climate smart varieties with high yielding and perform well under both stress and normal conditions with tolerance to both biotic and abiotic stress factors. This task of breeding such varieties is very difficult since abiotic stress tolerance is a complex trait and is controlled by many genes/quantitative trait loci (QTLs). With novel findings and fast development of many new techniques and tools, great progress has been made in the last decade in understanding abiotic stress tolerance mechanisms in plants. However, such progress has not resulted in any considerable significant output. Therefore, it is very crucial to adapt new tools and strategies to speed up genetic enhancement of crop plants to breed climate smart and multiple stress tolerant varieties.

5.1. Genomic strategies

The current status of understanding of abiotic tolerance in plants reveals the general role of some regulatory factors in the environmental adaptation mechanisms. Therefore, it is also possible to find some common QTLs/genes influencing more than one type of stress at a time. Identification of these factors will not only contribute to the understanding of plant biology but also to achieve stable crop production around the world through breeding approaches. Recent advances in molecular biology with statistical tools (quantitative genetics), made it possible to dissect the genomic regions associated (QTLs/genes) with stress tolerance in several crops. For instance, several QTLs associated with drought tolerance have been identified in groundnut by Huang et al. (2020); Ravi et al. (2011); Varshney et al. (2009). The forward genetics tools like fine mapping, map based cloning, insertional mutagenesis and random mutations are also being used to unravel the genetic basis of phenotypic variation. Further, the recent cost effective sequencing tools enables to decode the sequences of coding regions of genome at tissues specific level using tissue specific expression for different abiotic stress responses using microarray technology. The advanced technologies or tools in molecular biology such as RNAi, CRISPR/CAS genome editing, TIILLING, Antisense RNA) also simplify the decoding of the function of genes by analysing phenotypic variations (occurs due to different abiotic stresses) with reverse genetics approach.

Further, the massive amount of data or information from ‘omic’ tools provides a basis for identification of more functional genes, which could contribute directly to cellular drought stress tolerance. In addition, understanding expression networks of genes encoding for the stress response or induced proteins/enzymes/chaperones involved in cellular structure stabilization, detoxification of reactive oxygen species, biosynthesis of protectants (sugars, wax and dehydrins) may helpful the in realization of significant genetic gains in breeding for plant tolerance to different abiotic stresses. Further, genomic level investigations will enable understanding of transcriptional regulators behind co-expressed genes and their association with particular genomic regions (QTLs). Although QTL identification for tracing drought or other abiotic tolerance remains a challenge due to the large number of genes governing the targeted traits. However, the continued investigation into the basis of tolerance in model crops or arid and semi-arid crops, xerophytes, halophytes will undoubtedly provide a clearer understanding of abiotic stress tolerance mechanisms.

5.2. High-throughput phenotyping (Phenomic tools)

Assessing the genotypes (G), phenotype (P), enviro type (E) components and utilization comprehensive information is very essential for improvement of resilience to abiotic stresses in crops. Even after decoding or dissecting the genotype of plants using modern and new tools which are mentioned in the above section, understanding a clear picture of phenotype is very important and it stands foremost among all the three components. Therefore, since last decade, reliable, automatic, multifunctional, and high-throughput phenotyping technologies are increasingly considered as important tools for rapid advancement of genetic gain in breeding programs. The crop phenotyping community not only needs to build a multi-domain, multi-level, and multi-scale crop phenotyping to generate big database, but also to standardize technical methodologies and systems for identification of phenotypic traits and to develop bioinformatics tools for information extraction from the overwhelming amounts of omics data. In this context crop scientists need to look for novel solutions to the major challenges of multi-omics data, such as intelligent data-mining analysis, which offers a powerful tool to unravel the biological processes governing plant growth and development and to advance the plant breeding approaches for much needed climate-resilient and high-yielding crops.

5.3. Integrating omics tools with conventional and molecular breeding

Unraveling the genetic, molecular and physiological mechanisms or biochemical pathways involved in abiotic stress tolerance by integrating different omics (phenomics, genomics, proteomics, metabolomics) with bioinformatics tools is very crucial in developing climate smart varieties. Thus understanding the complexity of drought by dissecting genetic nature and action (including pleiotropy if any) of the QTLs/genes identified through QTL mapping/ other approaches plays an important role. This aids in genetic enhancement of various crops is being carried out through transfer of QTLs/genes using different approaches like marker assisted selection (MAS), marker assisted recurrent selection (MARS), genome wide selection (GWS), genetic engineering/transgenics.

In view of the remarkable progress in these areas in recent years, integration of biotechnological approaches like molecular breeding with conventional breeding along with different omics tools (particularly genomics and phenomics) should be the major emphasis in development drought resistance crops (Fig 3). Further, linking biophysical and genetic models to integrate physiology, molecular biology and plant breeding helps in dissecting or unravelling the complex traits associated with the drought resistance and thus further to speed up the breeding programme to develop climate smart varieties with great resilience to abiotic stresses.

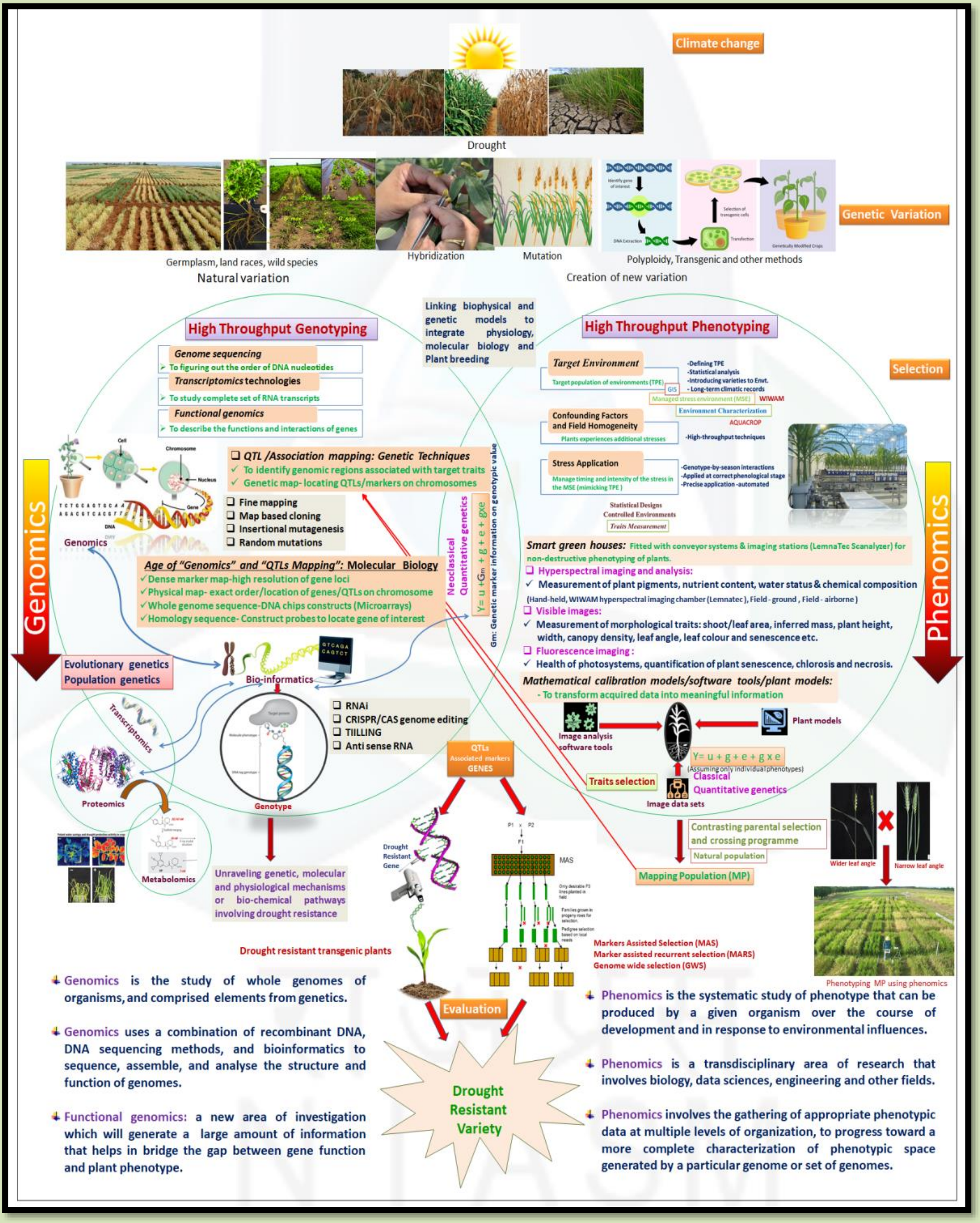


Fig 3. Linking biophysical and genetic models to integrate physiology, molecular biology (omics- genomics, proteomics, and metabolamics), phenomics and conventional plant breeding to speed up the breeding programme to develop drought resistant varieties.

6. Climate Resilient Livestock Breeds

Livestock plays an important role in Indian economy. About 20.5 million people depend upon livestock for their livelihood. Livestock contributed 16% to the income of small farm households as against an average of 14% for all rural households. Livestock provides livelihood to two-third of the rural community. It also provides employment to about 8.8 % of the population in India. India has vast livestock resources. Livestock sector contributes 4.11% GDP and 25.6% of total Agriculture GDP. Like the crop production livestock sector also influenced by weather/climate abnormalities. The major abiotic stresses which affect the livestock production are extreme temperature (Heat and cold), excess rainfall etc. However, heat stress is the main climatic factor, which affects the productivity of livestock.

6.1. Heat Stress

Animal health is affected directly or indirectly, mainly due to heat stress. The direct effects are related to the increase of temperature, which increases the potential for morbidity and death. The indirect effects are spreading of vector-borne diseases, food-borne diseases, host resistance, and feed and water scarcity. Warm and humid conditions that cause heat stress can affect livestock mortality. Temperature increases could accelerate the growth of pathogens and/or parasites, which negatively affects livestock. West et al. (2003) simulated the impacts of climate change on Australian livestock and reported that livestock lost about 18% of their weight due to increased tick infestations. Howden et al. (2008) reported that increases in temperature between 1 and 50C might induce high mortality in grazing cattle. The United States livestock industry has an annual economic loss between 1.69 and 2.36 billion US dollars due to heat stress, of which 50% occurs in the dairy industry (St-Pierre et al., 2003).

Heat stress on livestock is dependent on temperature, humidity, species, genetic potential, life stage, and nutritional status. Heat stress decreases forage intake, the efficiency of feed conversion which impacts milk production, and ultimately growth and reproduction/fertility.

6.1.1 Effect of Heat on Growth and Fertility

Global warming may reduce body size, carcass weight, and fat thickness in ruminants (Mitl oehner et al., 2001). The growth of larger pigs will be affected more in terms of reduction in growth, carcass weight, and feed intake. Piglets' survival may be reduced because of a reduction of sows feed intake during suckling periods with temperatures greater than 25 0C, which reduces the milk yield of the sow.Cow fertility is affected by negative energy balance and heat stress. Heat stress also negatively affects reproductive function (Amundson et al., 2006). Heat stress has also been associated with lower sperm concentration and quality in pigs. The effects are more pronounced in buffaloes than cattle which may be due to high thermal load in this species as a result of difficulty in heat dissipation due to unavailability of place for wallowing and lesser number of sweat glands (Vaidya et al., 2010). The expression of estrus and conception rate was recorded low during summer in crossbred cattle and buffaloes (Upadhyay et al., 2009). Heat stress reduces the length and intensity of estrus besides increase in incidence of anestrous and silent heat in farm animals. During severe heat stress, only 10-20% of inseminations resulted in normal pregnancies (Roth et al 2000). The significant seasonal difference in semen characteristics was reported by. Heat stress significantly lowers conception as well as fertility rates per insemination of male and subsequently reduces male's fitness (Bhakat et al 2014).

6.1.2 Effect of Heat on Milk Production and Quality

High-producing dairy cows generate more metabolic heat than low-producing dairy cows. When metabolic heat production increases in addition to heat stress, there will be decrease in milk production. Buffalo exposure to high temperatures also reduces milk production because it affects the animal's physiological functions, such as pulse, respiration rate and rectal temperature (Seerapu et al., 2015). West (2003) reported a reduction in dry matter intake by 0.85 kg with every 1°C rise in air temperature above a cow's the thermo neutral zone. Thus climate change has significant effect on lactation milk yield and lactation length. All the climatic variables accounted for 75 % and 65 % direct variation on lactation milk yield and lactation length, respectively. Dairy cows reduce feed intake which is directly associated with negative energy balance, which largely responsible for the decline in milk synthesis (Wheelock et al 2010). Mote et al. (2016) reported that maximum temperature has significant correlation with lactation milk yield; whereas maximum temperature, minimum temperature, sunshine hours and wind speed have significant correlation with lactation length. Hot and humid environment not only affects milk yield but also effects milk quality.

6.2. Resilient Animals

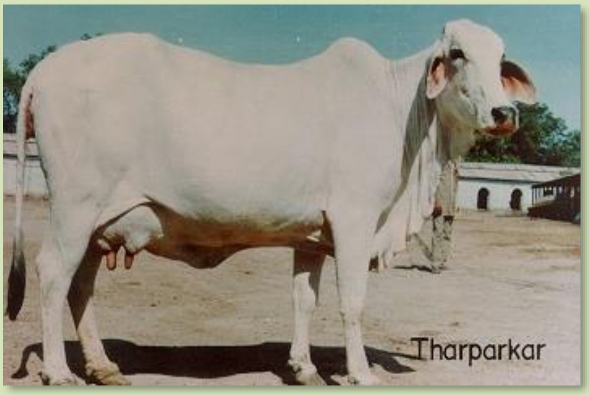
Resilient capacity of an animal refers to the ability of an animal to recover its normal biological functions after the exposure to the adverse stressful condition. This coping ability helps the animal to bounce back to the original state and perform better than expected. Resilience is rather a process, and not a trait of an individual. The traits of inherent resilient and adaptive capacity are: long legs, short hair coat, higher sweating rate, large surface area, body conformation, higher capacity for maintenance of heat balance, lower metabolic rate and higher feed efficiency, higher tolerance to dehydration and adipose tissue depots and capacity to alter the hormone and biochemical profiles to adapt to a particular environment (Rashamol and Sejian 2018).

Verma et al. (2016) suggested that GA genotype of SNP g.507G>A of HSPB8 gene has a probable role in heat tolerance in Sahiwal cattle and can therefore be utilized as a marker in propagation of thermos tolerance cattle in hot tropical and subtropical climate. Nevertheless, the involvement of other regulatory mechanisms cannot be overruled. It is reported that HSP70 is possibly involved in heat stress adaptive response in Tharparkar cattle and the biphasic expression pattern may be providing a second window of protection during chronic heat stress. Maibam et al. (2017) reported that the skin of zebu cattle (Tharparkar) is more resistant to summer stress than crossbred (Karan Fries), providing greater protection against heat stress during summer season. Superior skin protective mechanism of zebu (Tharparkar) than crossbred (Karan-Fries) cattle against heat stress may contribute to superior adaptability of zebu cattle to tropical climatic conditions than crossbreed. Heat shock proteins (Hsp) play a crucial role in cellular thermotolerance and heat stress response. (Sajjanar et al., 2015) found that, the role of *HSP90AB1* polymorphisms in the regulation of heat stress response and consequent effect on production traits. Nevertheless, involvement of other regulatory mechanisms cannot be overruled. Deoni cattle is dual purpose cattle breed and one of the most important dairy breeds in Maharashtra with an average standard milk yield of 868 kg with highest recorded 1,229 kg (NBAGR).

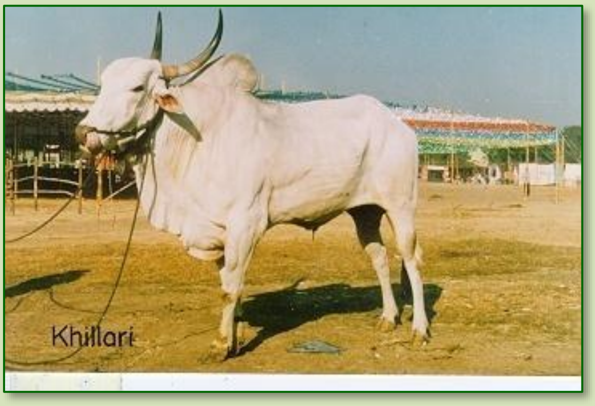
6.2.1. Abiotic Stress Tolerance in Indigenous Cattle Breeds

There are 40 recognized breeds of cattle in India, in addition to a large number of non-descript population. These indigenous cattle are well known for better disease resistance; survive better in the local environment, suitable for drought work and more suitable for low input management systems. Most of the indigenous dairy animals in the tropics evolved through natural selection, for adaptability and survival to local environments. The use of multi-species and multi-breed herds is one strategy that many traditional livestock farmers use to maintain high diversity in on-farm niches and to buffer against climatic and economic adversities. The best method of reducing the impact of stressful climatic conditions and preparing a climate resilient herd is by improving productivity and animal welfare through selection and breeding of those animals that are productive in the presence of that stressful condition. As livestock play a very important role in shaping our economy and livelihood of people, emphasis should be given for rearing climate resilient breeds for sustainable production in fluctuating climate (Nayak et al., 2018).

The brief information on indigenous and climate resilient animals is given below.

	• **Name of breed:** Sahiwal (Lola/Montgomery/Multani) • **Origin and distribution:**Montgomery district (Pakistan), India: Punjab, Haryana • **Characteristics:**Loose skin, Reddish dun, pale red or brown colour, Horns are short and stumpy, Large udder. Milk yield – 1350 kg (Village), 2100 kg (Commercial scale), AFC: 32-36 M,CI – 15 M
	• **Name of breed:** Tharparkar (Thari / White Sindhi) • **Origin and distribution:** Jodhpur, Kutch and Jaisalmer • **Characteristics:** White or light grey colour, head moderate thick, broad and flat forehead, curving horns, large udder
	• **Name of breed:** Gir • **Origin and distribution:**Gir forest areas of South Kathiawar • **Characteristics:** Red or speckled red colour, Forehead broad and convex, Prominent hip bones, Long and pendulous ears like tiny curled leaf, Curved horns.

- **Name of breed :** Deoni
- **Origin and distribution:** Mainly found in North western and western parts of A.P., Maharashtra and Karnataka
- **Characteristics:** White or white with black spots, Well develop dewlap and sheath, Drooping ears



- **Name of breed:** Khillar
- **Origin and distribution:** Kohlapur, Sholapur, Sangli, Satana (Maharashtra)
- **Characteristics:** Grayish white colour, long forehead, compact body, massive head, well developed hump, long and lean face

- **Name of breed:** Murrah
- **Origin and distribution**: Punjab (Nabha, Patala), Haryana (Rohtak, Hissar, Jind), Delhi
- **Characteristics:** Jet black with occasional white marking on tail, face and extremities, Massive body, neck and head comparatively long, horns short and tightly curled, Udder well developed, hip broad and fore- and hind quarters drooping. Tail: upto fetlock. AMY: 1,500to 2,500 kg/lactation. Fat: 7%.

- **Name of breed :** Nagpuri
- **Origin and distribution:** Nagpur,Akola, Amrawati (Maharastra)
- **Characteristics:** black, Horns: long, flat and curved, bending, backwards on each side of the back almost to shoulders.

	• **Name of breed: Osmanabadi** • **Origin and distribution:** Tuljapur and Udgir taluka of Osmanabad district of Maharashtra,AP,Karnataka • **Characteristics:** Tall animals, majority of the animals are black and the rest are white, brown or spotted. Ears are medium long. Most males (89.5%) are horned; females may be horned or polled, tail is medium long and thin twins & Triplets are most common during kidding

(Source: NBAGR; http://14.139.252.116/agris/breed.aspx)

6.3. Indigenous breeds for genetic enhancement of livestock for aberrant weather/ climate

Sustainable use of the indigenous breeds may lower external inputs and improve the profit in changing climatic situations. This will consequently contribute towards achieving sustainable development goals. To make use of traits of indigenous breeds, in terms of hardiness and disease tolerance, the elite indigenous sires must be selected and used for breeding programmes and all unselected bulls should be castrated or sold. The indigenous cattle should be allowed to continuously evolve and reproduce, and produce while adapting to the changing environment. Taking into consideration the multiple roles and objectives, it is important to develop multiple trait selection indices for simultaneous improvement of traits of economic importance. Breeding indices should be balanced to include traits associated with heat resilience, fertility, feed conversion efficiency, disease tolerance and longevity in addition to higher productivity, and give more consideration to genotype by environment interactions (GxE) in local environment (Naskar et al 2012). The use of modern technologies such as artificial insemination, multiple ovulation and embryo transfer, cryopreservation, and cloning the indigenous breeds can be used for conservation. To avoid extinction of indigenous breeds, should also establish regional ex situ gene banks for preservation and use of cattle genetic resources. Creating awareness among cattle, farmers and policy-makers about the uniqueness of the indigenous breeds, importance of maintaining purity of the breeds, and potential roles of the breeds in climate change adaptation will further promote utilization of indigenous animal genetic resources

7. Climate Resilient Fish Species and Genetic Stocks

As discussed in section 2.5, short-term climate change impacts on aquaculture can include losses of production and infrastructure arising from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms. Long-term impacts can include reduced availability of wild seed as well as reduced precipitation leading to increasing competition for freshwater. Therefore, the development work on selective breeding for more robust strains and abiotic stress tolerance fishes in aquaculture baskets need to be strengthened for better temperature and disease resistance, is anticipated and already initiated. Better tolerance of stress may also lead to improved fecundity, egg quality, post-spawning survival, and flesh quality. But the genetic improvement of fish for abiotic stress tolerance depends on the availability of diverse genetic resources. The different species of fishes reported to be abiotic stress tolerant given below.

	1. Common Name: Walking catfish 2. Scientific Name: *Clarias magur* 3. Abiotic Stress Tolerance: hypoxia-tolerant
	1. Common Name: Genetically Improved Farmed Tilapia (GIFT) 2. Scientific Name: *Oreochromis niloticus* 3. Abiotic Stress Tolerance: Tolerant to salinity/temperature
	1. Common Name: Pangasius 2. Scientific Name: *Pangasionodon hypophthalmus* 3. Abiotic Stress Tolerance: Tolerant to temperature/salinity
	1. Common Name: Jayanti 2. Scientific Name: Labeo rohita 3. Abiotic Stress Tolerance:Tolerant to salinity 4. It is a Genetically improved rohu
	1. Common Name: Stinging cat fish 2. Scientific Name: *Heteropneustes fossilis* 3. Abiotic Stress Tolerance: hypoxia-tolerant

	1. Common Name: Striped murrel 2. Scientific Name: *Channa striata* 3. Abiotic Stress Tolerance: hypoxia-tolerant
	1. Common Name: Great snakehead murrel 2. Scientific Name: *Channa marulius* 3. Abiotic Stress Tolerance: hypoxia-tolerant
	1. Common Name: Spotted snakehead 2. Scientific Name: *Channa punctata* 3. Abiotic Stress Tolerance: hypoxia-tolerant
	1. Common Name: Red-bellied pacu 2. Scientific Name: *Piaractus brachypomus* 3. Abiotic Stress Tolerance: hypoxia-tolerant
	1. Common Name: Climbing perch 2. Scientific Name: *Anabas testudineus* 3. Abiotic Stress Tolerance: hypoxia-tolerant

	1. Common Name: White leg shrimp 2. Scientific Name: *Litopenaeus vannamei* 3. Abiotic Stress Tolerance: Tolerant to salinity

Source: https://www.fishbase.in/search.php

7.1. Exploring fish genetic diversity for climate resilient fisheries

Adaptation measures should consider the response of fish species and make amends. For example, seasonal closure of fishing, introduction of wide tolerant species, system based culture systems such as RAS, Biofloc, Assessing vulnerability of fish species, integrated prediction model etc. Incremental adaptation may be encouraged to small adjustments to maintain the essence and integrity of an existing fishery and aquaculture system, such as changing gear, fishing method or processing and preservation method. Transformational adaptation involves fundamental changes to the system, often at greater scales and with greater effort than incremental adaptation, and can include migrating or changing livelihoods, as well as governance adaptation. In areas increasingly subjected to droughts, especially where population increases are great, competition for freshwater will likely increase, promoting the use of water saving recirculating aquaculture system (RAS) technologies. Among the feedstuffs used are fishmeal and fish oil derived from fisheries vulnerable to climate change, raising concerns about the resilience of aquaculture to climate change.

The expected increase in extreme weather events resulting from climate change raises the likelihood of an increase in escapees from aquaculture farms and the prospect of adverse impacts on biodiversity. These biodiversity to adapt and respond to changing conditions will be governed by the compound constraints posed by multiple abiotic stressors as well as the physiological tolerance and genetic plasticity of individuals. Small populations that have been bottlenecked or genetically homogenized are more susceptible to abiotic stressors. To promote and encourage the hatchery raised of abiotic stress tolerant fish species which lack genetic diversity, and spawning with wild populations can reduce a population's genetic fitness and ability to cope with stressors such as increased temperature, salinization etc. Genomic scans have been used to identify the genetic architecture of disease resistance (Miller et al., 2014) and have illustrated a genetic basis for species' intolerance to particular disease.

Most of the Indian farmed species in ponds have their optimal thermal range between 24-30°C. It is expected that Indian aquaculture will benefit from increased temperatures in general through increased growth rates and a longer production period. However, the increased occurrence of extreme weather events may stress aquatic organisms, depreciate physical infrastructure. Prolonged high temperatures and drought cause severe evaporation in lakes and ponds. Altered precipitation patterns may further induce conflicts between fish farmers and operators of the irrigation sector over the use of renewable freshwater resources.

Aquaculture is still in a relatively early stage of development and the production of new strains and races of food fishes will require careful management of available genetic resources. The lesson learnt from extensive breeding in crop plants and in domestic animals is that a narrowing in the genetic base of the species is inevitable. In such processes, genetic determinants which are likely to be lost at an early stage include those controlling disease-resistance and fitness in marginal environments. It is hence prudent for breeders to be especially mindful of the need to protect and preserve, at the earliest stage possible, broad genetic diversity within those species most likely to come under intensive breeding pressure. The compilation of information on diverse species/ strains of fishes from local water bodies and rivers will be helpful for exploring potential genetic resources for conservation and utilization for basic studies related to adaptability mechanisms/traits to different multiple stresses.

8. Strategies for Ensuring Access to Abiotic Stress Tolerant Crop Varieties, Livestock Breeds and Fish Species

The abiotic stresses which are triggered by climate change are major limiting factors for sustaining agricultural productivity especially to small and marginal farming communities. For instance, even loss of a single crop due to unforeseen abiotic stresses such as drought, floods, cyclone etc. can lead to starvation or malnutrition of the family. If these stresses occur at early season, the loss of standing crop at initial stages could be compensated by re-sowing immediately. However, there may not be sufficient seed left with the farmer for re-sowing. Moreover, it would be difficult for the public and private seed sectors to meet the demand of seeds to farmers, especially those residing farther from the seed source. To overcome such a situation, development of community seed banks may be useful as a contingency measure to meet local seed demand. Ensuring the supply of quality seeds of crop varieties tolerant to different abiotic stresses at right time at right place with rate price essential to make agriculture more sustainable in the era of climate change. Rainfed agriculture in arid and semi-arid regions of the country is more vulnerable to drought and heat stresses, needs a robust decentralized seed system that is able to provide quality seed of diverse crop varieties tolerant to drought or heat stress to sustain the productivity. This will aid in buffering contingencies of climate risks such as repeat sowing in case of crop failure. Therefore, seed production and supplying agencies (State Departments of Agriculture, State Agriculture Universities, Krishi Vigyan Kendras, State Seeds Corporation, National Seeds Corporation, State Seeds Certification Agencies) can play a pivotal role in a coordinated effort during climate risks/abiotic stress conditions by supplying by quality seeds of climate resilient varieties through seed bank or village concept. Seed village and seed banks concept is being implemented successfully in different parts of the country which can further be up scaled to cope with climate variability such as, community seed banks for flood tolerant rice varieties of Bihar and Bengal, submergence tolerant rice varieties of Orissa (Wajih 2008).

Identifying and conservation of the local agro biodiversity which has inbuilt tolerance to various stresses has great significance in agriculture against climate risks. Several tribal communities and farmers organizations, NGOs, SHGs conserving the large number of climate resilient local varieties, land races of crops and indigenous and local breeds of livestock since long back. There are a number of rare fish species prevailing in diverse water bodies known to tribal communities which are in near extinction. It is very essential to maintain and conserve such immense and valuable resources scientifically through intervention NARS. Though some national and international organizations already undertake such tasks, they are not exclusively collecting, conserving and maintaining such genetic resources tolerant to abiotic stresses. Further it is also difficult to collect genetic resources from every nook and corner of the country. Easy and timely access to abiotic stress tolerant crop varieties, livestock and fish species i.e climate resilient GRFA by scientific communities, students for research and crop improvement purposes is very essential. The compiled information on crops varieties, livestock breeds and fish species tolerant to different abiotic stresses may be helpful in accessing related information and also seeds of crop varieties tolerance to different stresses. This may upscale ongoing basic and strategic research to understand the physiological, molecular and genetic basis of mechanisms/traits associated with abiotic stress tolerance.

9. Conclusion

Among various mitigation and adaptation strategies, adoption of abiotic stress tolerant crop varieties and livestock and fish breeds has become very important in the present context of climate change to feed the ever increasing population of the country. Most of the abiotic tolerant crop varieties are developed through conventional breeding and sometimes accidentally bred. Recent advances in molecular breeding approaches hastened the process of development of varieties/ breeds of crops, animals and fish which are climate smart. In this direction, the National Agricultural Research System (NARS) developed climate resilient varieties in several crops by exploiting phonological, morphological and adaptive traits. However, accessing the quality seeds of such varieties in the era of climate change plays an important role in mitigating climate adverse effects such as drought, floods, salinity and cold.

10. Way Forward

In the context of increasing global warming, it is predicted that Indian agriculture has to prepare for enhanced frequencies of adverse climatic situations in the near future. Thus, in order to safeguard the food and nutritional security crop scientists have to develop more climate smart and multiple stress tolerant resilient varieties. With advanced tools and techniques in molecular science, there should be enhanced and concerted efforts for better insights into physiological mechanisms/traits associated with abiotic stress tolerance. Genotypes already identified as stress tolerant resources can serve as donor lines in crop breeding programmes. The insights into the stress tolerance mechanisms and the promising lines should be translated into climate smart varieties tolerant to various abiotic stresses individually as well as those with multiple stress tolerance (biotic and abiotic also). Cultivation/ adoption of abiotic stress tolerant varieties/breeds of crops, livestock and fishes with proper management practices can play a significant role in enhancing and sustainable food production under changing climate scenarios.

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Abbreviations

ABL - Aschochyta Blight
AICRP - All India Coordinated Research Project
AICPMIP - All India Coordinated Pearl millet Improvement Project
ALS - *Alternaria* Leaf Spot
A&N - Andaman and Nicobar
AP - Andra Pradesh
AR - Arunachal Pradesh
ARI - Agharkar Research Institute, Pune
ARS - Agricultural Research Station
ARS - Agriculture Research Station
AS - Assam
BAU - Birsa Agricultural University
BG - Birsa Groundnut
BH - Bihar
BHU - Banaras Hindu University
BHU - Banaras Hindu University
BLB - Bacterial Leaf Blight
BL - Leaf Blast
BLS - Bacterial Leaf Spot
BPH - Brown Plant Hopper
BR - Black Rust
BS - Brown Spot
BSKV - Baba Sahebh Krishi Vidhaytpeeth
CARI - Central Island Agricultural Research Institute
CCSHAU -
CG - Chhattisgarh
ChR - Charcoal Rot
CLS - *Cercospora* Leaf Spot
CR - Collar Rot
CSI - Chlorophyll Stability Index
CSKHPKV - CSK Himachal Pradesh Krishi Vidhyalaya
CSKKVV - CSK Krishi Vishvavidyalaya
CSUA&T - C.S. Azad University of Agriculture & Technology,
CT plains - Central Plain Zone
CZ - Central Zone
DL - Delhi
DMD - Downy Mildew Disease
DM - Downey Mildew
DRMR - Directorate of Rapesed Mustard Research
DRR - Dry Root Rot
DSR - Direct Seeded Rice
ELS - Early Leaf Spot
GBPUA&T - G.B. Pant University Of Agriculture and Technology,
GBPUAT - Govind Balla Pant university of Agriculture and Technology
GG - Gujarat Groundnut
GJ - Gujarat
GLH - Green Leaf hopper
GM - Gall Midge

GMV	- Green Mosaic Virus
HP	- Himachal Pradesh
HR	- Haryana
IARI	- Indian Agriculture Research Institute
ICAR- IIHR	- Indian Institute of Horticulture Research Institute
ICAR-CAZRI	- Cental Arid Zone Research Institute
ICAR-CSSRI	- Cental Soil Salinity Research Institute
ICAR-IGFRI	- Indian Grassland and Fodder Research Institute
ICAR-IIMR	- Indian Institute of Maize Research
ICAR-IIMR	- Indian Institute of Millet Research
ICAR-IIRR	- Indian Institute of Rice Research
ICAR-IIWBR	- Indian Institute of Wheat and Barley Research
ICAR-NRRI	- National Rice Research Institute
ICRISAT	- International Crops Research Institute for the Semi-Arid Tropics
IGKV	- Indira Ghandhi Krishi Vidhyalaya, Raipur, CG
IIOR	- Indian Institute of Oilseed Research
IIPR	- Indian Institute of Pulse Research
JAU	- Junaghard Agricultural University
JGN	- Jawahar Groundnut
JH	- Jharkhand
JNKV	- Jawaharlal Krishi Vishwa Vidhyalaya
KA	- Karataka
KGKV	-
KL	- Kerala
LB	- Leaf Blight
LF	- Leaf Folder
LLS	- Late Leaf Spot
LNKVV	- L. N. Krishi Vishwa Vidalaya
MAU	- Marathawada Agricultural University
MLB	- *Maydis* Leaf Blight
MLS	- Myrothecium Leaf Spot
MN	- Manipur
MPKV	- Mahatma Phule Krishi Vidhaypeeth
MP	- Madhya Pradesh
MPUA&T	- Maharana Pratap University of Agriculture & Technology,
MR	- Moderately Resistant
MS	- Maharashatra
MYMV	- Moongbean Yellow Mosaic Virus
NAU	- Navsari Agricultural University
NB	- Neck Blast
NEPZ	- North East Plain Zone
NES	- North Eastern States
NWPZ	- North West Plain Zone
OR	- Orissa
PAU	- Punjab Agricultural University
PB	- Punjab
PBND	- Peanut Bud Necrosis Virus
PDKV	- Panjab Rao Deshmuk Krishi Vidhaypeeth
PJTSAU	- Professor Jayashankar Telangana State Agricultural University
PMD	- Powdery Mildew Disease

PM	- Powdery Mildew
PY	- Pondicherry
R&M	- Rape Seed and mustard
RAB	- *Rhizoctonia* Aerial Blight
RARS	- Regional Agricultural Research Station
RARS	- Regional Agriculture Research Station
RJAU	- Rajasthan Agricultural University
RJ	- Rajasthan
RTV	- Rice *Tungro* virus
RWC	- Relative Water Content
RWC	- Relative Water Content
SB	- Stem Borer
SCMR	- Spade Chlorophyll Meter Reading
SF	- Shoot Fly
ShB	- Sheath Blight
SK	- Sikkim
SKRAU	- Swami Keshwsanand Rajasthan Agricultural University, Bikaner
SLA	- Specific Leaf Area
SMV	- Sterility Mosaic virus
SMV	- Soybean Mosaic Virus
SR	- Stem Rust
TLB	- *Tersicum* Leaf Blight
TN	- Tamilnadu
TS	- Telanagana
UAS	- University of Agricultural Sciences
UK	- Uttarkhand
UP	- Uttar Pradesh
WBPH	- White Backed Plant Hopper
WB	- West Bengal
WR	- White Rust
WUE	- Water Use Efficiency
YMV	- Yellow Mosaic Virus
YVMV	- Yellow Vein Mosaic Virus
YR	- Yellow Rust
ZARS	- Zonal Agricultural Research Station