

Crop interventions for abiotic and biotic stress tolerance in rainfed crops

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The growing global population and climate change are intensifying the pressure on agricultural production, particularly in rainfed regions. Rainfed agriculture plays a vital role in global food production, especially in regions dependent on irregular and unpredictable rainfall patterns. However, these crops are highly vulnerable to both biotic (pests, diseases, weeds) and abiotic stresses (drought, heat, salinity, and nutrient deficiencies). Implementing effective crop interventions is critical to enhance the resilience and productivity of rainfed crops. Different crop interventions that mitigate biotic and abiotic stress are timely sowing, crop rotation, use of resistant cultivars, intercropping, cover crops, and trap crops. Each of these interventions offer cost-effective and ecologically sustainable methods to reduce the impact of biotic and or abiotic stress while promoting crop health and productivity.

Keywords: Abiotic stress, Biotic stress, Crop interventions, Intercropping, Rainfed

THE rapidly growing global population is expected to put more pressure on the land to meet the demand of food. The change in climate is expected to increase the pressure further. Climate change is likely to exacerbate this strain, particularly in rainfed regions, which are highly susceptible to both biotic and abiotic stresses. Rainfed regions can be moulded as the hub for improved crop production despite the multitude of biophysical (soil, climate, etc.) and socio-economic constraints. Crop interventions focus on creating a balance between reducing biotic stress and enhancing tolerance to abiotic stress. For example, drought, excessive rainfall, and high temperatures can alter crop physiology, making crops more susceptible to pest infestations. Adoption of proper crop interventions like adjusted sowing times, crop rotation, intercropping, and the use of resistant cultivars, farmers can alleviate the dual impact of biotic and abiotic stresses in rainfed systems.

Timely sowing

The timing of sowing is crucial to avoiding periods of extreme weather. Sowing at the right time helps crops escape drought or heat stress during critical growth stages. Early sowing allows crops to mature before terminal droughts or heat waves become detrimental, thereby improving yields. Additionally, sowing crops at optimal times helps them take advantage of the available soil moisture and reduces the risk of moisture stress later in the season. For example, early sowing of

sorghum can reduce the incidence of shoot fly.

This practice also holds good for the biotic stresses. One of the most effective strategies is to synchronize sowing with the onset of the monsoon, which has been shown to be particularly useful in controlling specific pests like shoot fly and stem borers in rainfed crops like sorghum. Early sowing is also effective against certain viral and bacterial diseases. Incidence of groundnut bud necrosis and sesame phyllody were low in early sown crops. Pod borer incidence on pigeonpea was reported to be less when the crop was sown simultaneously by all the farmers.

Crop rotation

Crop rotation is a well-established practice that maintains the crop productivity. The rotation of crops is essentially a means of maintaining soil fertility so that an appropriate sequence of crops used in a rotation can produce better average yields than continuous cultivation of the same crop (mono cropping). Crop rotation enhances soil structure and reduces erosion, which is critical in preventing degradation under stressful conditions like heavy rains or dry spells. For example, maize followed by pigeonpea can improve the soil structure.

Moreover, this strategy also proves helpful in reducing pest infestation. By rotating crops, the life cycles of crop-specific pests and pathogens are disrupted, reducing their populations over time. For example, rotation with



Drought tolerant finger millet varieties Indira ragi-I (Chhattisgarh) and ML-365 (Karnataka)



sorghum and groundnut reduces important insect pests (sorghum stem borer and groundnut leaf miner). Apart from pest, it can also prevent the dominance of certain weed species as different crops have different growth patterns, canopy cover, and nutrient needs. Crop rotation also helps reduce the need for chemical pesticides, as pest populations can be managed naturally through the rotation of crops.

Use of stress tolerant crop cultivars

Biotic and abiotic stress tolerant crop varieties represent a critical innovation in modern agriculture, offering a highly effective means of managing stresses that impact crop growth and yield. These resistant crop varieties suppress their incidence and abundance; would be tolerant and offer a highly effective means of managing stresses in crop plants. Stress tolerant crop varieties can play a critical role overcoming the stress impact due to climatic variability. Identifying short duration varieties can be useful in avoiding terminal heat and moisture stress and ensuring harvesting of a good crop. These crops mature faster, avoiding late-season stresses that can significantly reduce yields. Central Research Institute for Dryland Agriculture (CRIDA), has identified climate-resilient crop varieties. These stress-tolerant crops are being tested and adopted in various vulnerable regions across the country. Some of the crops and their resistant varieties suitable for abiotic stresses are given in Table 1. Similarly, there are varieties that are specifically bred for biotic stress tolerance. Demonstration of climate-resilient varieties has been done across the country for horizontal diffusion of technology in a participatory technology development (PTD) mode with farmers.

Table 1. Abiotic stress tolerant crops and their varieties

Crop	Abiotic stress	Variety
Black gram	Drought	PU31, WBU108
Green gram	Heat stress	HUM16, IPM0203, Phule Vaibhav, SML668, BM200201
Groundnut	Dry spell	K6, Abhaya
Maize	Drought	SMC4, HQPM1, DHM117, Hema NAH1137, P3377
Finger millet	Moisture stress	GPU28, Indaf7
Pearl millet	Drought	VBH380, HHB67
Sorghum	Drought	CSH14, CO30

Some of the promising crop cultivars that can tolerate various biotic stresses in various rainfed crops recommended for Telangana, Karnataka, Andhra Pradesh and other states are given in Table 2.

Table 2. Promising cultivars tolerant to biotic stresses

Crop	Biotic stress	Name of cultivar
Maize	Corn leaf blight	DHM 111, 115, 117, 119, 121
	Collar/ stem rot	DHM 111, 113, 115, 117, 121
	Ear rot	DHM 111
	Rust	DHM 115
	Stem borer	DHM 113, 117, 119, 121
Sorghum	Leaf spot	NTJ 3, CSH 14, CSH 16, PSV 56
	Shoot fly	CSH 15 R
	Smut/ Mold	CSH 14, 16, 18; PSV 56
Pearl millet	Green ear	HHB 67, ICMH 356, Raj 171, ICTP 8203, ICMV 221
Finger millet	Blast	Maruti, Srichaitanya, Vakula, Hima, Tirumala, Vegavati, Indravati
	Sheath blight	Vegavati, Indravati
Pigeonpea	Wilt	ICPL 87119, ICP 8863, LRG 105, LRG 133-33
	Gram pod borer	LRG 41
Greengram	Mosaic virus	LGG 507, 460; WGG 42, IPM 2-15
	Powdery mildew	TM 96-2
Black gram	Mosaic virus	PU 31, TGB 104, GGB 1
Chickpea	Fusarium wilt	JG 11, JAKI 9218
Horsegram	Mosaic virus	CRIDA 1-18R, CRHG 22
	Powdery mildew	CRIDA 1-18R, CRHG 19, 22
	Anthracoise	CRHG 19, 22
Groundnut	Thrips	K7, Kadiri Chitravathi, Kadiri Lepakshi
	Leaf hopper	K9, Kadiri Chitravathi
	Tikka Leaf spot	K7, K9, Kadiri Amaravathi

Crop-crop diversity

Diverse cropping systems contribute to healthier soils. Different crops have varying root structures and nutrient needs, which can enhance soil structure, improve organic matter content, and promote microbial diversity. These diverse crops also have the ability to be more resilient to abiotic stresses. Crops with different rooting system (deep and shallow roots) can ensure the survival of some crops by better utilization of moisture. Crop diversity can

also help to overcome the temperature fluctuation. By planting crops that are adapted to different temperature ranges, farmers can ensure that some crops thrive even during unexpected dry spells. Pest pressures may be reduced in diversified systems for various reasons, most important being the encouragement of beneficial insect diversity and abundance and reduced ability of pests to locate their preferred feed. Several studies indicated that diversification practices such as intercropping are beneficial because of lower damage by insect pests in these systems.

The studies at CRIDA with diverse crops along with fodder highlighted that diverse crops can reduce the risk of crop failure, improve the yield, accommodate another source of income like livestock, improve soil health, reduce soil and nutrient erosion as well as reduce the incidence of pests in the crop. Sorghum + pigeonpea - hedge lucerne; sorghum + pigeonpea - guinea grass and sorghum-fodder cluster bean-fodder cowpea-fodder horse gram are the three best systems that provided fodder and grain. The fodder harvested from these systems is given Table 2. The growth behaviour of pigeonpea makes it less competitive for resources when it was grown with sorghum. Growing a perennial component further manipulated the crop environment for low pest incidence (in terms of choice of appropriate duration and intercrop). The impact of duration and intercropping on insect pests and natural enemies is well known and the significant effect of intercropping on various insect pests in majority of the systems caused the reduction of pest and proliferation of natural enemies across different field crops.

Another study at CRIDA with 13 pulse-oilseed



Sorghum + pigeonpea-hedge lucerne



Cluster bean and Sorghum (Sorghum-fodder cluster bean-fodder cowpea-fodder horse gram)

cropping systems, identified a remunerative and climate adaptive double cropping system for crop diversification and abiotic stress management. Cowpea-sesame (with rainwater management) followed by cowpea-sesame (without rainwater management) and cowpea-safflower (with rainwater management) is highly productive and remunerative. Diverse crops with appropriate rainwater management can be a better option to improve the crop productivity and livelihood security of rainfed farmers.



Sesame with rainwater managed field (left), without rainwater management (right)

Intercropping

Intercropping is most preferred in dry and rainfed regions as they reduce the risk of crop failure due to sudden change in weather. Apart from that, intercropping can improve water-use efficiency, reduces soil erosion and also enhance soil fertility. Intercropping ensures better use of available resources like light, water, and nutrients by enabling crops with different growth patterns to coexist and exploit different parts of the environment. Similarly, integrating intercropping system reduces the risk of crop failure and also improves the soil fertility. By integrating multiple crop species, intercropping reduces pest infestations through various ecological mechanisms such as physical protection from wind, shading, and the disruption of pest dispersal. The diverse plant composition can camouflage target crops from pests. For example, sorghum + pigeonpea intercropping system reported 15-18% lesser pest incidence than sole sorghum crop.

Additionally, intercropping encourages a higher abundance of natural enemies, such as predators and parasites that help control pest populations. The sorghum + pigeonpea intercropping system is regarded as successful in rainfed regions of Telangana due to the complementary nature of the two crops, which helps manage both biotic and abiotic stresses. Sorghum, being tall and drought-resistant, provides shade and physical support, while pigeonpea, a deep-rooted legume, fixes atmospheric nitrogen, improving soil fertility. The varied growth patterns reduce competition for resources, as pigeonpea accesses deeper soil layers for water and nutrients, while sorghum utilizes surface resources. This system helps control pests and diseases by disrupting their life cycles and enhances water-use efficiency, making it highly resilient in drought-prone or resource-limited environments.

Table 3. Diverse crops in the system supporting livestock

Green fodder production from different systems (q/ha)					
System	Fodder sorghum	Fodder cluster bean	Fodder cowpea	Fodder horse gram	Sorghum ratoon
Sorghum-F. Cluster bean-fodder cowpea-fodder horse gram	75.25	80.16	196.66	18.73	37.13
	Hedge Lucerne/Guinea grass			Sorghum fodder	Pigeon pea
	1 cut	2 cuts	3 cuts		
Sorghum + Pigeonpea-Hedge lucerne	12.5	14.6	14.1	46	0
Sorghum + Pigeonpea-Guinea grass	14.3	17.2	17.5	45	0



Coccinellids

Spiders

Cover crops

Cover crops are the crops that aid to suppress weeds, improve soil health, increase water availability, reduce erosion, aid in the control of pests and diseases, and boost biodiversity. They can be beneficial for abiotic stress management in different ways. Cover crops improve soil health by enhancing water infiltration and retention, a key factor in rainfed systems where water availability is unpredictable. Their root systems, particularly those of grasses and legumes, promote soil structure stability and aggregate formation, improving moisture retention. Additionally, leguminous trap crops contribute to nitrogen fixation, enriching the soil with essential nutrients that support plant growth during dry spells or nutrient-poor conditions. The microbial activity stimulated by trap crop root exudates further enhances nutrient cycling, making the system more resilient to drought and dry spells, which are common in rainfed agriculture.

They also act as a natural defense mechanism by attracting pests away from the main crops, thus reducing insect infestations and lowering the need for chemical pest control. This biotic stress management is crucial in rainfed regions where pest outbreaks can severely impact yields. For example, in a study done with cowpea, sudan grass as a cover crop, cowpea not only suppressed weeds but also reduced the need for insecticides by providing a habitat for beneficial arthropods that naturally control pest populations. Weed suppression for subsequent crops may be another benefit.

Trap crops

Trap crop refers to the crop stand that entices and attracts the pest, strategically and temporally and confines and concentrate the pest within a favoured trap crop rather than the main crop. Dense canopies of trap

crops can improve soil moisture retention by providing ground cover, reducing soil evaporation, and improving water infiltration. Leguminous trap crops like cowpea can reduce the soil evaporation due to its good ground coverage. Trap crops can also enhance soil organic matter through addition of biomass to the soil. Organic matter improves water-holding capacity, helping crops to cope better during periods of drought. Improved organic matter also improves the microbial population and soil health.

Trap crops are included in the integrated pest management. These crops are strategically planted to attract pests, such as insects and nematodes, serving as a more appealing host, thus protecting the primary crop from damage. Additionally, trap crops can disrupt pest lifecycles, enhance natural predators, and create protective barriers, minimizing the pest's ability to harm the primary crop. The trap crop can also serve as an additional reservoir of beneficial predators and parasites. Use of Indian mustard and African marigold as trap crops against diamond back moth, *Plutella xylostella* in cabbage and tomato fruit borer *Helicoverpa armigera* in tomato are examples of successful trap crop.

SUMMARY

Mitigating both biotic and abiotic stresses, including abiotic-driven biotic stress, through strategic crop interventions is essential for the future of agriculture, particularly in the face of growing population and climate challenges. Techniques discussed in this paper such as crop rotation, resistant cultivars, intercropping, and trap crops presents sustainable, cost-effective, and environmentally sound approaches to enhancing crop resilience towards the various abiotic and biotic stresses and thus improve crop productivity.

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