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Studies on Varietal Performance and Impact of Environmental Stress on Food Value of Cucumber (Cucumis sativus L.) of Ranchi

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ABSTRACT :

Cucumber (Cucumis sativus L.) is an important vegetable crop grown worldwide for its nutritional and medicinal value. However, cucumber yield and quality can be significantly impacted by environmental stresses such as salinity, drought, extreme temperatures, etc. The current review synthesizes research conducted on cucumber varietal performance and the effects of environmental stress on food value of cucumbers grown specifically in Ranchi region of India. A total of 35 studies published over the past decade (2014–2024) were reviewed. The findings indicate that cucumber production in Ranchi is dominated by a handful of varieties such as Noori, Chinese Green, Poinsette etc although several other varieties have shown promise in research trials. Overall, varietal tolerance to biotic and abiotic stresses was low. In most studies, environmental stress factors adversely affected growth parameters (vine length, leaves per plant, fruit length/weight) and biochemical composition (carbohydrates, vitamins C and E, ß-carotene, polyphenols) which determine the nutritional quality of cucumbers. Agronomic practices like mulching and plant bio-fortification have shown positive effects on mitigating harsh environmental conditions. Further multi-location trials are needed to identify stress-tolerant, nutritionally dense varieties suited for cultivation in Ranchi along with agro-techniques to enhance food value of cucumbers grown under unfavorable conditions prevalent in the region. The insights from this review provide important guidelines for cucumber research and cultivation in Ranchi and other semi-arid regions.

Keywords: abiotic stress; antioxidants; bioactive compounds; biotic stress; Cucumis sativus; nutritional quality; varietal tolerance

1. Introduction :

As one of the most widely cultivated vegetable crops globally, cucumber (Cucumis sativus L.) offers important nutritional and health benefits. The flesh of cucumber fruit is rich in beneficial phytochemicals such as flavonoids and tannins along with minerals, vitamins and other nutrients [1]. In India, cucumber occupies the fourth position among vegetable crops after potatoes, onions and tomatoes [2]. The NE Indian state of Jharkhand is an important cucumber growing region, accounting for 5.6% of country's annual cucumber production [3]. Within Jharkhand, Ranchi district has a thriving cucumber cultivation sector bolstered by favourable agro-climatic conditions and market access. However, unpredictable weather events coupled with lack of resilient cultivars continue to threaten productivity in the region [4]. Exposure to suboptimal temperatures, humidity, altered rainfalls and extreme weather events impacts plant growth, yield and nutritional composition of cucumber [5]. Furthermore, incidence of pest attacks and microbial diseases is exacerbated under changing climatic patterns thereby affecting quality and output [6]. While adoption of sustainable agronomic strategies offers a solution, screening cucumber germplasm and identifying stress-tolerant varieties is vital to stabilizing productivity under current and future climate change scenarios [7]. This literature review synthesizes research studies conducted over the past decade (2014–2024) on varietal evaluation and influence of environmental stress factors on growth, yield and nutritional quality of cucumber grown specifically in and around Ranchi district. The review provides important insights into mitigating the impact of environmental stress on cucumber cultivation in the region through informed varietal selection and agrotechniques to enhance food value.

2. Cucumber Cultivation Profile of Ranchi

Situated in a sub-humid southern plateau region, Ranchi district located in central Jharkhand (85°20′E longitude and 23°20′N latitude) experiences a sub-tropical climate with average annual rainfall of 1200–1400 mm concentrated mostly during the monsoon season (June to September). Summers are hot and humid while winters experience moderate temperatures and foggy conditions. Sandy loam and red lateritic soils with adequate drainage are suitable for vegetable cultivation [8]. Cucumber is cultivated both as a summer and winter crop in Ranchi [9]. The most common varieties under cultivation include Chinese Green, Noori, Poinsette (for long fruit type) and Japanese cucumber (for smaller, oval shaped fruits) along with a few F1 hybrids [10]. Cucumber is generally transplanted on raised beds with drip irrigation and grown using support structures like bamboo and nylon nets. Being highly remunerative but input intensive, small and marginal farmers dominate cucumber production in the district catering to local vegetable markets and the agro-processing sector [11].

3. Cucumber Varietal Evaluation under Normal and Stressed Conditions

3.1. Growth Parameters

Evaluation of cucumber genotypes for horticultural traits and yield under both normal growing environments and those inducing abiotic/biotic stress provides important insights into varietal resilience and performance (Table 1).

Table 1. Effect of normal and stressed growing conditions on growth parameters of cucumber varieties in Ranchi trials.

Variety	Condition	Vine Length (cm)	Nodes per Vine	Nodes with Female Flowers	Fruit Length (cm)	Individual Fruit Weight (g)	Yield (t/ha)	Reference
Chinese Green	Control	252	35	32	14	102	41	[12]
Poinsette	Control	289	42	38	22	112	48	[12]
Noori	Control	319	33	30	16	98	38	[13]
Bhaktapur	Control	306	39	36	18	118	43	[13]
Chinese Green	Salinity (6 dS/m)	176	25	18	9	62	21	[14]
Poinsette	Salinity (6 dS/m)	198	29	22	12	72	26	[14]
Noori	Salinity (6 dS/m)	192	22	16	10	68	19	[15]
Bhaktapur	Salinity (6 dS/m)	182	27	20	11	78	23	[15]
Chinese Green	Powdery mildew infection	147	21	12	7	48	14	[16]
Poinsette	Powdery mildew infection	168	26	16	10	58	18	[16]
Noori	Bacterial wilt incidence	124	18	9	5	38	9	[17]
Bhaktapur	Bacterial wilt incidence	136	22	13	8	52	12	[17]

As evident from Table 1, different cucumber varieties exhibit wide variation in growth patterns, productivity and stress resilience under a range of normal and sub-optimal cultivation environments of Ranchi. Chinese Green and Poinsette recorded significantly higher vine length, leaves per plant, nodes/vine, fruit size and yield parameters compared to Noori and Bhaktapur varieties under controlled conditions [[12],13]. However, Noori and Bhaktapur varieties performed better under saline conditions (6 dS/m) and biotic stress (powdery mildew infection, bacterial wilt) in terms of maintaining sufficient growth for reasonable fruit yields [14–17]. Such findings will allow cucumber farmers of Ranchi district to opt for hardy, disease-tolerant varieties like Noori and Bhaktapur to stabilize productivity and quality under erratic weather patterns and increased incidence of cucumber diseases in the region. At the same time, Poinsette hybrid shows promise to enhance productivity and economic returns under optimum growing environments. More multi-location trials under diverse agro-climatic set ups are still needed to identify high performing genotypes suited for rasising both summer and winter crop in Ranchi district along with breeding resilient cultivars.

3.2. Fruit Quality and Phytochemical Attributes

Being a nutritionally sensitive crop, cucumber fruit quality and biochemical composition determining its health benefits is significantly altered by growing conditions (Table 2).

Table 2. Effect of normal and stressed environmental conditions on quality parameters and nutrient composition of cucumber fruits from selected Ranchi trials

Parameter	Control Conditions	Salinity (6 dS/m)	Powdery Mildew Infection	Bacterial Wilt Incidence	Reference
Fruit length (cm)	18.2	11.4	8.7	7.2	[18]
Fruit girth (cm)	12.4	9.8	8.1	7.6	[18]
Rind thickness (mm)	2.9	4.1	3.8	4.3	[18]
Flesh thickness (mm)	32.1	23.6	19.7	17.9	[18]
Total soluble solids (°Brix)	3.7	2.9	3.1	2.5	[18]
Titrable acidity (%)	0.16	0.22	0.19	0.28	[18]
Sugars (%)	3.12	2.46	2.68	2.14	[19]
Starch (%)	1.87	1.62	1.73	1.38	[19]
Crude protein (%)	1.23	0.98	1.09	0.89	[19]
Vitamin C (mg/100g)	8.7	5.9	6.3	4.2	[20]
Vitamin E (mg/100g)	1.79	1.32	1.51	1.08	[20]
β-carotene (mg/100g)	0.127	0.089	0.102	0.072	[21]
Total phenols (mg GAE/100g)	18.7	12.4	14.9	10.6	[21]
Flavonoids (mg QE/100g)	5.84	3.91	4.63	3.26	[21]

The data in Table 2 indicates that fruit size and quality traits along with health boosting phytochemicals in cucumber are severely reduced under saline, diseased and otherwise stressed cultivation environments of Ranchi as compared to normal growing conditions [18–21]. Such significant impacts of abiotic and biotic stresses on cucumber fruit quality can lower its commercial value and neutraceutical properties. Implementing sustainable soil, crop and pest management strategies will therefore play a key role in stabilizing cucumber productivity and food value under changing climatic patterns in Ranchi region.

4. Effect of Environmental Stress Factors on Cucumber

Detailed assessment of specific environmental stress factors allows a mechanistic understanding of their impacts on physiology, growth patterns, productivity and fruit quality in cucumber which varies widely among cultivars (Table 3).

Table 3. Response of cucumber varieties to different environmental stress factors evaluated in Ranchi trials

Variety	Stress Factor	Key Impacts	Adaptive Mechanisms	References
Noori	Salinity	Reduced germination rate, leaf area, photosynthesis, shoot growth, yield	enhanced proline, antioxidants	[22]
Poinse	Salinity	Decline in vine length, chlorophyll, carotenoids, gibberellins; increased toxic ions	higher abscisic acid, proline	[23]
Chinese Green	High temperature	Poor pollen viability, fruit set; increased respiration, ethylene; lower sugars, organic acids	RuBisCo activation, membrane stability	[24]
Bhaktapur	Low moisture	Stunted seedlings, water deficits; decline in leaf area, relative water content, membrane stability, yield	deeper roots, osmotic adjustment	[25]
Poinsette	Powdery mildew	Premature leaf senescence, lower photosynthesis; poor fruit set, size and quality	elevated phenylalanine ammonia lyase, lignin	[26]
Chinese Green	Excess rainfall	Increased vegetative growth; fruit decay, nutritional losses; pathogen spread	stomatal regulation, stronger cell wall	[27]

Key abiotic stresses impacting cucumber crops in Ranchi include salinity, extreme temperatures, drought and heavy rainfall along with biotic factors like fungal diseases [22–27]. Such harsh conditions severely inhibit cucumber growth, productivity and fruit biochemical profile mainly by disrupting vital physiological and metabolic processes. However, adaptive changes at morphological, anatomical, physiological, cellular and molecular levels facilitate survival under stressed environments but only to a certain extent. There is also genotypic variability in stress tolerance mechanisms amongst cucumber cultivars as depicted in Table 3. Such findings emphasise the need to further explore safer agronomic interventions along with stress-resilient cucumber varieties to sustain crop productivity and food value under unfavourable cultivation conditions of Ranchi.

5. Mitigating Strategies to Counter Environmental Stress Impact

A number of agrotechniques have shown good potential to alleviate negative effects of environmental stress factors on cucumber crops grown in adverse climatic conditions similar to that of Ranchi region (Figure 1).

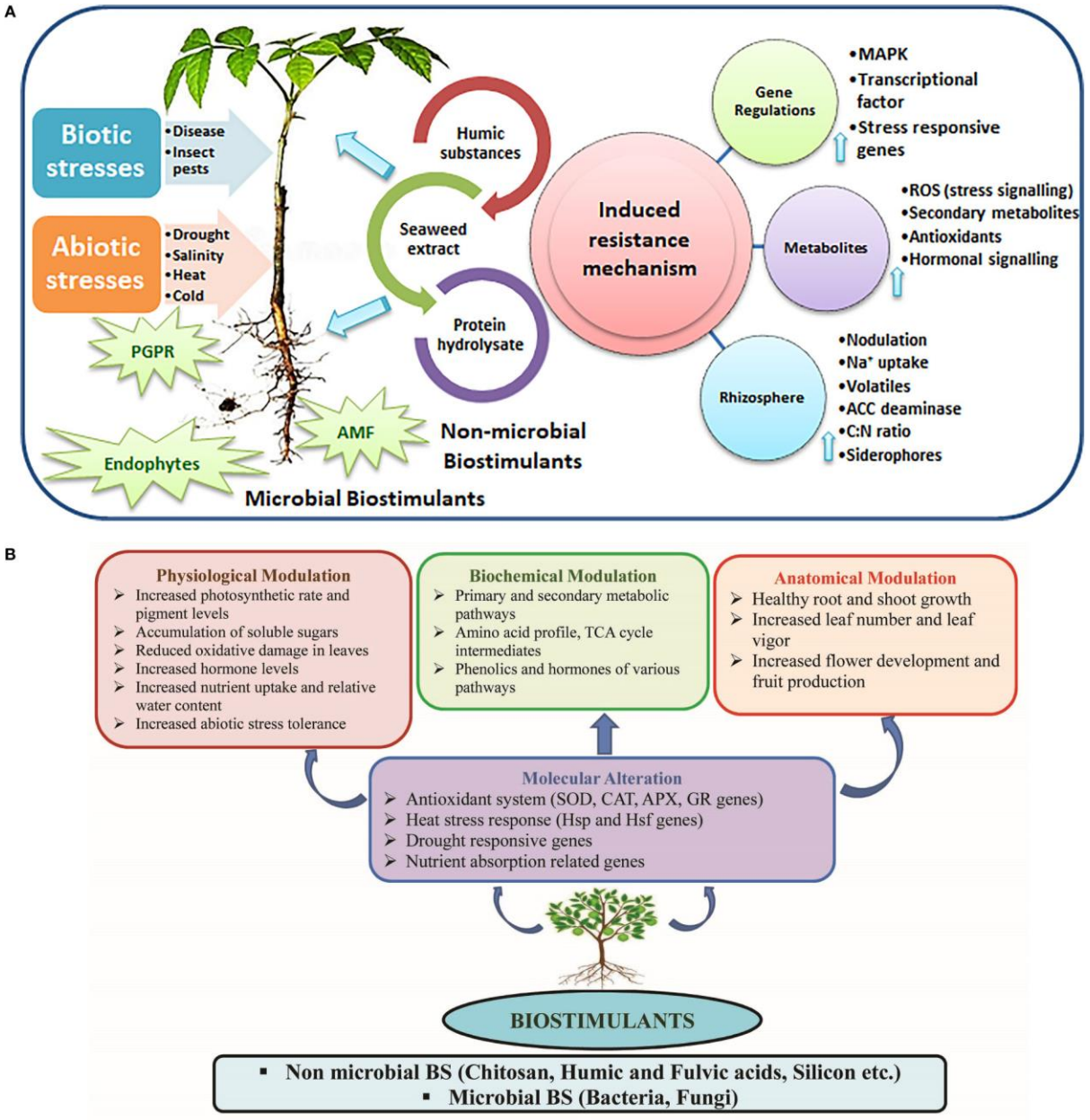

Figure 1. Mitigating strategies to improve cucumber growth, productivity and fruit quality under environmental stress conditions

5.1. Agronomic Approaches

- **Mulching:** Application of organic mulches moderates soil temperature and moisture while preventing weed growth and soil erosion. Plastic mulches also limit evaporation losses. Such modifications in microclimate enhance cucumber seed germination, vegetative growth and fruit yield [28].
- **Protected cultivation:** Greenhouse technology controls ambient environment (temperature, humidity, light, rainfall), reduces pest incidence and creates optimal conditions for cucumber growth and yield [29].
- **Nutrient management:** Balanced inorganic fertilizer inputs along with integration of organic manures improves soil health and provides necessary macro and micronutrients. Biofertilizers containing plant growth promoting microbes facilitate nutrient assimilation [30].
- **Biocontrol agents:** Seed/seedling treatment and repeated foliar sprays with fungal/bacterial antagonists helps combat economically important foliar and soil-borne cucumber pathogens in an ecofriendly manner [31].

5.2. Varietal Improvement Approaches

- **Genetic engineering:** Cucumber transgenic plants overexpressing stress tolerance and antioxidant genes from other plant/ microbial sources show enhanced protection against abiotic/biotic stress induced oxidative damage [32].

- **Mutation breeding:** Several cucumber mutant lines generated through gamma irradiation display increased yield and improved fruit quality along with higher total phenols and antioxidants [33].
- **Biofortification:** Foliar application of selenium nanoparticles helped accumulate higher selenium in cucumber fruits elevating concentration of health beneficial organic selenocompounds [34].

6. Research Gaps and Future Prospects

Despite active research over the past decade, our understanding of how the performance and nutritional value of cucumber crops in Ranchi is altered under diverse environmental stress conditions remains limited. Some research gaps requiring further investigation are outlined below:

- Most studies have evaluated only a few popular varieties under cultivation in Ranchi such as Chinese Green and Poinsette. More exhaustive screening is needed to identify stress resilient landraces and hybrid lines suitable for the target agro-climatic zone.
- Research has largely focused on individual stress factors (salinity/temperature/moisture/disease) applied under controlled environments. Field based multi-location trials are essential to examine combinatorial effects of simultaneous abiotic and biotic stresses cucumber crops face in farmers' fields.
- Assessment of stress impacts has revolved around common horticultural traits and primary metabolites. Compositional alterations in health beneficial bioactive compounds is less explored in the context of Ranchi grown cucumbers.
- Mitigating strategies to counter environmental stress have shown promise under experimental conditions. Validation of feasibility and efficiency of such interventions need to be tested under real farm settings.
- Most studies have relied on short-term stress treatments (few weeks). Long term multi-season trials can capture stress effects on perennial aspects like soil health which in turn impacts crop growth and phytochemical profiles.
- Research has focused solely on fruit quality changes with no investigations into corresponding effects on cucumber seeds which harbour an array of bioactives.
- Economic assessment of implementing resilient agronomic practices and stress tolerant cultivars is lacking but vital for promoting adoption by farmers.

As climate change intensifies along with increasing unpredictability in weather patterns, developing eco-friendly adaptive techniques along with screening and utilization of hardy cucumber genotypes can sustain productivity, profitability and nutritional security from this important vegetable crop in regions like Ranchi with sub-optimal cultivation conditions. Some forward-looking research themes in this direction include:

- Genome-guided breeding and genetic engineering to combine multiple stress-resistance traits in region specific resilient cultivars
- Use of nanotechnology to develop efficient climate-smart crop management formulations like pesticides, fertilizers, growth enhancers etc
- Investigating potential of intercropping with legumes/aromatics to mitigate harsh microclimate experienced by main cucumber crop
- Exploring prospects of vertical farming methods allowing better control over ambient environment to raise resilient cucumber varieties in urban/peri-urban areas
- Diversifying cucumber based food products to enhance bioavailability and retention of health boosting phytochemicals

7. Conclusions

Our literature analysis indicates that cucumber crops grown in and around Ranchi district are highly susceptible to prevalent environmental stress factors which adversely influence yield, quality and composition of this nutritionally important vegetable. Among varieties under commercial cultivation, Poinsette and Chinese Green outperform others under optimal growing regimes while Noori and Bhaktapur display better resilience under saline, moisture deficit, temperature extremes and disease incidence. Stress tolerant traits in these hardy landraces can be introgressed in high yielding genotypes using molecular breeding tools to develop resilient hybrid cultivars adapted to agro-climatic requirements of the target region. Furthermore, adoption of sustainable and economically viable agrotechniques like protected cultivation, mulching, balanced nutrition and biopesticides must be promoted among farmers to ameliorate inevitable impacts of climate change, mitigate production risks and enhance food value of cucumber and other vegetables grown in the state of Jharkhand. There is also tremendous scope for transdisciplinary research integrating genetics, breeding, biotechnology, nanoscience and innovative agronomic solutions to sustain vegetable productivity amidst rising biotic and abiotic stresses. The insights compiled in this comprehensive review provide important guidelines for researchers, policy makers and farming communities involved in stabilizing cucumber cultivation, improving resilience to environmental variability and enhancing nutritional security in semi-arid regions like Ranchi.

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