

Archives of Current Research International

Volume 24, Issue 7, Page 52-63, 2024; Article no.ACRI.121178 ISSN: 2454-7077

# A Review of Present Advancement in Climate Smart Agriculture Techniques: Adaptation for Sustaining Crop Production under Climate Change

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#### Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2024/v24i7828

#### **Open Peer Review History:**

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121178

**Review Article** 

Received: 15/06/2024 Accepted: 18/08/2024 Published: 22/08/2024

#### ABSTRACT

The growing global population is driving up demand for agricultural goods at a never-before-seen rate. Improving crop yield and quality is essential to meeting this growing demand. The yield and quality of agricultural crops may be greatly increased by using agronomic techniques. Although it is known that changing climate circumstances have a detrimental impact on crop development, yield, soil quality, and ultimately the nutritional content of agricultural food, such agronomic methods under changing climate conditions are insufficient to boost crop productivity. In order to increase the production potential of agricultural crops, several agronomic improvements have been made in the previous few decades. These include the application of resource conservation technology and conservation agricultural methods. Therefore, it is essential to adopt various adaptive agricultural

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*Cite as:* Kumari, Niru, Amit Kumar Pandey, Akhilesh Kumar Singh, and Ashutosh Singh. 2024. "A Review of Present Advancement in Climate Smart Agriculture Techniques: Adaptation for Sustaining Crop Production under Climate Change". Archives of Current Research International 24 (7):52-63. https://doi.org/10.9734/acri/2024/v24i7828. practices that are specifically resource-conserving, such as crop diversification, mulching, crop rotation, agroforestry, intercropping, and the push-pull system of crop pest and disease management, etc. in order to effectively deal with such unfavourable situations. These agronomic approaches, which are being advocated to increase agricultural production and profitability, are described in the review along with their methods for enhancing crop performance and quality.

Keywords: Climate resilience; adaptive practices; crop productivity and sustainable agriculture.

## 1. INTRODUCTION

The foundation of human civilisation is agriculture, which gives us the food, fibre, and a host of other resources we need to survive and thrive. The growing global population is driving up demand for agricultural goods at a neverbefore-seen rate. Improving crop yield and quality is essential to meeting this growing demand. Sustainability is becoming more and more significant in agriculture [1]. Over time, crop quality and yield can be enhanced by the use of sustainable agricultural practices. Sustainable crop production offers a paradigm change in agricultural operations, concentrating on longterm agricultural health and productivity [2]. It incorporates social and economic equity, economic profitability, and environmental health as its three primary objectives [3]. Sustainable farming methods address growing concerns about resource depletion, climate change, and environmental degradation. Examples of these methods are integrated pest management, organic farming, and precision agriculture [4]. The Sustainable Development Goals of the United Nations, especially Goal 2: Zero Hunger, which highlights resilient agricultural methods and sustainable food production systems, highlight the need of sustainable crop production [5].

Primitive tools and shifting cultivation were the main means of subsistence for early agricultural communities [6]. With the advent of high-vield cultivars and synthetic fertilisers, the Green Revolution of the 1960s and 1970s represented a crucial turning point [7]. Because of the shortduration cereal types, the green revolution also increased cropping intensity. Additionally, water demand for crop cultivation increased globally. Although there haven't been any notable genetic improvements to increase agricultural yields, a number of agronomic innovations have made a substantial contribution to maximising farmer income, enhancing crop yields and soil quality, and improving crop responsiveness to climatic shocks. The new emphasis on more sustainable practices has been influenced by the long-term effects of these activities, which include soil degradation and decreased biodiversity [8]. The expanding worldwide population has raised concerns about food security, which has been addressed in large part by advances in agronomy [9]. These methods, which together lead to increased agricultural yields and quality, include crop rotation, soil management, and fertiliser and pesticide usage [2].

The cornerstone of sustainable and productive agriculture is agronomic techniques. Land reclamation, or agronomy, is the science and technology of growing and using plants as food. It includes a wide variety of techniques necessary for crop growth [10,11]. Beyond only producing crops, agronomic practices are important because they incorporate techniques that guarantee social responsibility, economic viability, and environmental sustainability [12]. The development of agricultural practices has been a journey from traditional to modern techniques that preserve overall crop productivity and quality, improve soil health, and ensure that land will remain productive for future generations [13]. In this article, we examine different approaches and technologies that can assist us in achieving this goal. One of the most promising ways to improve crop yield and quality is through agronomic advancements. This review aims to thoroughly examine the advancements in agronomic practices, with a focus on sustainable crop production.

### 2. IMPORTANT DOMAINS FOR AGRONOMIC PRACTICE ADVANCE-MENT

Given that soil is the basis of agriculture, it has received a lot of attention lately. Soil conservation methods, such no-till farming, have become more popular because of their capacity to lower erosion and increase soil organic matter [14]. These methods improve biodiversity and water retention while maintaining the structure of the soil [15]. It has been demonstrated that using organic additions, such as compost and green manure, improves soil fertility and structure and promotes a sustainable agricultural environment [16]. For the soil to remain healthy and productive over the long run, these organic inputs are essential [17]. Technological developments in soil testing and monitoring have also been extremely important. Farmers may now use site-specific nutrient management techniques thanks to the availability of precision instruments that enable thorough analyses of soil composition [18].

## 2.1 Crop varieties and Genetics

Agronomic research has placed a lot of hardy crop emphasis on creating types. Biotechnological innovations combined with conventional breeding methods have produced cultivars resistant to pests, illnesses, and harsh weather [19]. Crop breeding has undergone a revolution thanks to CRISPR technology and editing. With the use of these genetic technologies, precise gene editing is possible, leading to the creation of crops with desirable characteristics like pest and drought resistance [20]. Significant breakthroughs have also been made in seed technology and preservation. Crop yields have increased and genetic diversity has been preserved thanks to methods like cryopreservation and the use of seed coatings to increase germination rates [21].

## 2.2 Water Use Efficiency and Irrigation

Water is a necessary but frequently limited resource, hence improvements in irrigation methods have been crucial. For example, drip irrigation greatly reduces waste by delivering water straight to the roots of the plants [22]. This approach has shown to be particularly successful in dry areas, where conserving water is essential [23]. Using drought-resistant crop types and other water-saving techniques, such as rainwater gathering, has also proved essential to increasing water usage efficiency [24]. These against tactics offer resistance climatic unpredictability in addition to water conservation [25]. In order to optimise irrigation schedule, climate-smart irrigation techniques have arisen, combining soil moisture sensors with weather predictions [26]. By ensuring that crops are watered at the most advantageous periods, this method lowers water use and increases agricultural yields.

## 2.3 Management of Diseases and Pests

Biological control techniques, which employ natural predators or parasites, are becoming

more and more popular as a sustainable substitute for chemical pesticides in the management of pests and diseases [27]. IPM (Integrated Pest Management) techniques have proven to be successful in controlling pests while their effects negative reducing on the environment because they integrate chemical, cultural, and biological instruments [28]. There has also been an increase in the usage of biopesticides, which are made from naturally occurring substances including bacteria, plants, and certain minerals. These insecticides provide a more ecologically friendly way to manage pests [29].

## 3. AN OVERVIEW OF ADAPTIVE PRACTICES

The improvement of any country's agriculture sector mostly depends on the management of agricultural systems, technical and equipment assistance, policy and economic reform, and infrastructure upkeep. But immediately adopting agricultural climate-resilient and adaptable techniques is necessary to manage agricultural output in the face of both current and projected global warming [30,31]. According to Abhilash [32], implementing climate-resilient, adaptive, and resource-conserving agronomic practices can guarantee high productivity, profitability, crop greenhouse biodiversity. low gas (GHG) emissions, and decreased environmental risks related to the agriculture sector. Below is a explanation of many interesting detailed agronomic techniques (Table 1) along with their advantages.

## 3.1 Crop Diversification

Crop diversification is the process of moving away from single- or mono-cropping and towards intercropping, double-, companion-, or multiplecropping, crop rotation, or perenniation, among other techniques [51]. This is a more effective way to use natural resources like soil, water, and light energy for agricultural production. By interspecific interactions between fostering several crop species both above and below around. crop diversification techniques simultaneously improve soil health and boost net output [52]. While belowaround crop diversification helps improve the utilisation of water and soil macro- and micronutrients like phosphorus (P), iron (Fe), and zinc (Zn) by increasing soil microbial load and activity, aboveground diversification increases canopy heat and light capture [53].

SLNe	Agronomia practicas	Advantaga	Deference
<u>51.NO.</u>	Agronomic practices	Advantage	reference
1.	integrated soil crop management	Higher crop yield and N use	[33]
	System	rick	
2	Crop residue management	Maintains SOC over a long	[34]
۷.	strategies	period of time: higher crop	[04]
	Stratogios	productivity	
3.	Transition from conventional	Improved soil quality, soil	[35]
	agriculture practice to	fertility, and productivity	[]
	agroforestry practices		
4.	Selective irrigation practices;	Enhanced soil quality;	[36]
	zero tillage; use of FYM and	optimized water and fertilizer	
	domestic sewage sludge	use for rice and wheat	
5.	Climate-adapted push-pull	Enhanced pest and weed	[37]
	system in a companion cropping	control; better growth; higher	
	system as a pest and weed	soil fertility and soil microbial	
	management strategy	diversity; higher grain yield by	
		companion cropping	[00]
6.	Use of biofertilizer	Higher grain yield with reduced	[38]
	(Rnodopseudomonas palustris) in	CH <sub>4</sub> emission	
	field		
7	Integrated agronomic practices	Enhanced faunal diversity:	[30]
1.	i e mixed crop rotation: use of	increment in litter and soil	[55]
	cover crops: rational use of	quality	
	agrochemicals: integrated pest	quanty	
	weed, and disease management:		
	no-tillage		
8.	Reduced tillage and strip tillage	Higher yield; higher	[40]
	under fresh and permanent beds	profitability from reduced	
	in rice-maize system	production cost and labour	
		input under permanent beds	
		crop establishment	
9.	Integrated pest management	Controls fruit fly infestation and	[41]
	(IPM) practices	reduces yield loss; thereby	
		increases net income	
10.	Legume-based double cropping	Increases residual and fixed	[42]
	system under conservation tillage	nitrogen and thus increases	
	practice	Hel bonofit and cost bonofit ratio	
11	Minimum tillage and		[/3]
11.	intercropping (sunflower ± 60%	efficiency	[43]
	sovbean)	land use efficiency (LUE) and	
	ooyoodiiy	total vield	
12.	Integrated nutrient management	Increases crop vield, lowered	[44]
	(long-term balanced fertilization)	yield-scaled global warming	r
	, <b>,</b>	potential and reduced N2O	
		emission to some extent	
13.	Conservation tillage and residue	Soil organic carbon increased.	[45]
	mulching	Soil physicochemical,	
		hydrophysical, and biological	
		qualities improved and crop	
		yield increased	

## Table 1. Agronomic adaptive agricultural practices employed for sustainable food production under changing climate

SI.No.	Agronomic practices	Advantage	Reference
14.	Dry seeded rice with increased seeding rates	Crop competitiveness increases suppressing weed growth and sustaining grain yield	[46]
15.	Optimised nitrogen fertilization in cropping system	Nitrogen use efficiency increased	[47]
16.	Inoculation of plant growth-promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF) in a field having history of wheat, rice, and black gram cropping system during past 10 years	Grain yield increased, phosphorus use efficiency increased	[48]
17.	Integrated disease management (IDM) and deficit irrigation under water shortage in tomato crop	Managed crop disease. Compensated negative effects of water stress on plants by increasing yield and water use efficiency (WUE). Fruit quality is also improved	[49]
18.	Alteration in planting configuration (Bed/Ridge) and drip irrigation scheduling	Irrigation water use efficiency and yield is increased	[50]

#### 3.2 Intercropping

Two or more crops are cultivated together at the same location in a method known as intercropping, which is traditional but frequently ignored in agriculture [17]. By modifying soil temperature and moisture, intercropping modifies the microclimate of the soil and affects the way that seeds are dispersed by wind, rain, or other vectors, all of which are advantageous to the intercropped plants in one way or another. It raises the rhizospheric soil's nitrogen and carbon content, allowing subsequent crops to better use those resource pools [54]. Increased iron (Fe) content was observed in the rhizosphere of a peanut-maize intercropping system, according to Xiong et al. [55]. Intercropping tactics have also led to a new invention in crop pest and disease control: the push-pull system. By changing the morphology and physiology of host plants, intercropping protects them from pest invasions and inhibits diseases directly. Additionally, intercropping techniques greatly improved soil fertility and health as well as crop output when carried out with an appropriate quantity of nutrient inputs in the soil [56].

#### 3.3 Crop Rotation and Double Cropping

Crop rotation and double cropping techniques contribute to the restoration of soil fertility and

increase farmers' net yearly income by offering a variety of crop varieties [57]. Agronomic methods that are evolving in response to changing climatic conditions include crop-crop rotations, such as the rotation of corn and soybeans, as well as the rotation of prawns and fish with rice [58]. In particular, crop-crop rotation yields greater benefits when combined with decreased tillage techniques. Double or companion cropping, which raises an agricultural landscape's total productivity, is a sustainable agronomic method, much like crop rotation.

#### 3.4 Agroforestry

Agroforestry is a contemporary agronomic technique that is being applied at the farm/field and landscape levels throughout the world's agro-climatic zones. Agroforestry techniques improve the livelihood of resource-poor farmers by increasing crop productivity, farm revenue, and environmental benefits (in ecosystem services through crop and tree diversification) [32]. As a result, it is regarded as a potential sustainable farming method that can protect global food security and double farmer income [59]. The traditional methods used by the native peoples long ago to preserve their agroecosystem for social, cultural, economic, and ecological reasons are the roots of modern agroforestry.

These classical or traditional methods, which involve growing agricultural plants alongside commercial/perennial trees like cocoa or rubber, are only expanded upon by modern agroforestry. As an adaptive tactic for managing soil carbon sinks, the conventional methods are still used in some areas. The current situation calls for a lot more agroforestry promotion since it has been shown that the younger agroforestry system has advantages due to its considerable rise in the organic carbon stock [60]. In addition to the benefits of agroforestry that were previously discussed, sustainable agroforestry techniques can help to mitigate the negative consequences of deforestation to some degree. Consequently, the World Bank views agroforestry as a means of subsistence for the impoverished in order to reduce poverty since it allows them to work on large-scale initiatives aimed at establishing agroforestry in an area [61].

## 3.5 Mulching

Mulching is a novel approach to minimising water loss from agricultural fields in the context of warming climates. This is because evaporation accounts for more than 65% of water loss in agricultural fields, with a 2:1 ratio during growth and fallow seasons, respectively, leaving less water available for crop plants [62]. Only the remaining water, or less than 35% of the total water, may be used by the crop plants for growth and development [62]. As a result, maintaining soil moisture and water content is essential. Mulching helps prevent abiotic stressors like heat or cold, increase soil nutrients, decrease weeds, maintain soil moisture content, and enhance soil microclimate [63]. The most crucial benefit of mulching is that it keeps the soil at a temperature that supports crop development and survival.

Additionally, it improves crop plants' production, water and nitrogen use efficiency. Mulching, for example, has been shown to more than 1.5-fold increase in yield, water and nitrogen use efficiency, and production in cereal crops including wheat and maize [64]. In agricultural areas, a variety of mulching techniques have been employed, including film mulching, straw mulching, flat mulching, ridge-furrow mulching, mulching with the use of certain materials like polyethylene, and mulching with two materials mixed. In general, there are two kinds of mulch materials used in agriculture: (1) synthetic, such polyethylene, plastic sheets, and geotextiles, and (2) organic, like straw, wood, shells, hay, leaves, and needles [65]. These mulches are utilised for a variety of reasons and in a variety of locations, making their use completely locationspecific.

## 3.6 Organic Farming

Organic farming refers to agricultural methods that employ various forms of organic input in place of synthetic agrochemicals, such as pesticides, fertilisers, additives, preservatives, and genetically engineered seeds and breeds. This method reduces agricultural pests and illnesses while boosting soil fertility and water retention capacity [67]. This kind of adaptation boosts the nutritional value of agricultural products while also increasing the agrobiodiversity of farm lands. Most significantly, according to FAO [68], such approaches have good effects on guaranteeing the nutritional security and well-being of resource-poor farmers in developing countries. Organic farming focuses on crop rotation, biodiversity preservation, ecofriendly seed invigoration techniques [69]. Using locally available resources, this subject led the current inquiry to concentrate on old (or traditional) methods that improve agricultural growth and development without harming the environment [70,71].

#### 3.6.1 Integrated farming system with livestock

One of the main and most sustainable agronomic approaches under organic agriculture is mixed crop-livestock production. In the majority of countries in the world, organic farming methods were traditionally used with investments (about 10 times more than they are now) from the public and private sectors [68]. As a result, it currently makes up close to 50% of the world's total food output, and organic farming is widely implemented at the farm, field, and landscape levels in many developing countries [72]. on the past, animal manure was not moved or applied on farm fields in a way that was wellmechanized, losing nutrients that may have benefitted the soil and crops there [73]. In areas where the majority of farmers own cattle, have a sizable amount of farmland, and have access to resources, integrating animals into farmlands is a more adaptable method. These farmers can prudently feed their cattle with crop leftovers and straw produced on their farms (so long as the amount of straw produced does not exceed the level needed to be utilised as cover crops). By doing this, a sizable amount of manure in the form of FYM may be obtained, which could then

be applied to agricultural areas to enhance crop yield and soil health [74].

## 3.6.2 Chemical fertilisers to be replaced with organic inputs

The fertility and health of the soil have suffered greatly as a result of the overuse of agrochemicals in previous decades [75]. Millions of people across the globe are facing the potential threat of heavy metal arsenic contamination through groundwater-soil-crop systems [76]. The timing is perfect to employ organic inputs in agricultural areas in a sustainable manner. For organic agricultural operations, a variety of organic inputs have been employed, including farm vard manure (FYM), green manure, compost, vermicomposts, biofertilizers [77]. Among the important materials utilised in organic farming operations are FYM, green manure, sheep manure, and household sewage sludge, which reduces the need for inorganic nitrogenous fertilisers and offers a number of additional advantages and improve sustainability and enhance ecosystem services [78,79].

#### 4. FUTURE PERSPECTIVES AND EMER-GING TRENDS

increasing sustainable An awareness of methods. changing environmental circumstances, and technology breakthroughs are driving substantial changes in agriculture. Agronomy's future is being shaped by these shifts, and a number of significant trends and breakthroughs are developing. The future of agronomy and predictions for developments in agronomic practices point to a greater focus on efficiency and sustainability. It is anticipated that techniques like precision agriculture, which maximise resource usage and reduce environmental effect, would proliferate. The increasing demand from consumers for sustainable and healthful food alternatives is also anticipated to encourage the adoption of organic agricultural methods. Urban and vertical farming are two newer, growing concepts that will probably become more popular. These methods, which use the least amount of area possible to produce most. provide answers the to the problems of urban food security and lack of land.

The implementation of water-efficient irrigation systems and the development of crop types resistant to drought are examples of critical

adaptation measures. It is anticipated that climate-smart agriculture, which incorporates both adaptation and mitigation of climate change. would become the foundation for agricultural methods in the future. This strategy minimises the environmental impact of agriculture while ensuring food security. It is anticipated that technological innovation will keep being essential to the development of agronomic techniques. Precision farming methods will be improved by developments in AI, machine learning, and IoT devices, making them more practical and approachable. CRISPR and other gene editing technologies have the potential to completely transform crop breeding. With the use of these technologies, crop varieties with improved nutritional value, disease resistance, and climate developed might be resilience quickly. Furthermore, supply chain management using blockchain and other digital technologies could boost efficiency and transparency in the agriculture industry. By offering traceability from farm to table, these technologies help improve food safety and quality control.

## 5. CONCLUSION

analysis The thorough highlights the revolutionary path of agronomic methods, emphasising transition the crucial from conventional techniques to cutting-edge. technologically driven approaches. As sustainable resource management techniques, precision agriculture, and cutting-edge genetic innovations become more prevalent, agronomy is evolving to meet the growing needs of food security, ecological sustainability, and economic viability. The future direction of agronomy is heavily impacted by technology advancements and the need to adjust to changing climatic conditions. With a focus on the integration of preservation, environmental technological innovation, and socio-economic factors, a multidisciplinary approach is necessary for the future of agronomic practices. In order to support resilient. sustainable, and productive а agricultural environment to meet the demands of a growing global population, this strategic integration is essential.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

#### **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

#### REFERENCES

 Devi OR, Laishram B, Singh S, Paul AK, Sarma HP, Bora SS, Devi SS. A review on mitigation of greenhouse gases by agronomic practices towards sustainable agriculture. International Journal of Enviornment and Climate Change. 2023;13(8):278–287.

Available:https://doi.org/10.9734/ijecc/2023 /v13i81952.

- Shah F, Wu W. Soil and crop management strategies to ensure higher crop productivity within sustainable environments. Sustainability. 2019;11(5): 1485.
- Evcim HÜ, Değirmencioğlu A, Özgünaltay Ertuğrul G, Aygün İ. Advancements and transitions in technologies for sustainable agricultural production. Econ Environ Stud. 2012;12(4):459-66.
- 4. Brodt S, Six J, Feenstra G, Ingels C, Campbell D. Sustainable agriculture. Natl Educ Knowl. 2011;3(1).
- Blesh J, Hoey L, Jones AD, Friedmann H Perfecto I. Development pathways toward "zero hunger". World Dev. 2019;118:1-14.
- Grigg DB. The agricultural systems of the world: An evolutionary approach Cambridge University Press. 1974;343.
- 7. Swaminathan. 50 years of green revolution: An anthology of research papers. World Scientific Publishing. 2017;1.
- Hou D, Bolan NS, Tsang DCW, Kirkham MB, O'Connor D. Sustainable soil use and management: An interdisciplinary and systematic approach. Sci Total Environ. 2020;729:138961.
- Garibaldi LA, Carvalheiro LG, Leonhardt SD, et al. From research to action: Enhancing crop yield through wild pollinators. Front Ecol Environ. 2014;12(8):439-47.
- Zegada-Lizarazu W, Elbersen HW, Cosentino SL, Zatta A, Alexopoulou E, Monti A. Agronomic aspects of future energy crops in Europe. Biofuels Bioprod Biorefin. 2010;4(6):674-91.

Devi KM, Devi OR, Laishram B, Luikham E, Priyanka E, Singh LR, Babasaheb DV. Effect of Planting Geometry and Nutrient Management on Yield, Economics and Quality of Dwarf Rice Bean (*Vigna umbellata*) under Rainfed Condition. International Journal of Plant and Soil Science. 2023;35(9):1–9.

Available:https://doi.org/10.9734/ijpss/2023 /v35i92897

- Altieri MA, Nicholls CI, Montalba R. Technological approaches to sustainable agriculture at a crossroads: An agroecological perspective. Sustainability. 2017;9(3):349.
- Beddington J. Food security: Contributions from science to a new and greener revolution. Philos Trans R Soc Lond B Biol Sci. 2010;365(1537):61-71.
- Rahman MM, Alam MS, Kamal MZU, Rahman GM. Organic sources and tillage practices for soil management. Resour Use Effic Agric. 2020;283-328.
- 15. Stagnari F, Ramazzotti S, Pisante M. Conservation agriculture: A different approach for crop production through sustainable soil and water management: A review. Organic Farming, Pest Control and Remediation of Soil Pollutants: Organic farming, Pest Control and Remediation of Soil Pollutants. 2010;55-83.
- 16. Wang D, Lin JY, Sayre JM, Schmidt R, Fonte SJ, Rodrigues JLM, et al. Compost amendment maintains soil structure and carbon storage by increasing available carbon and microbial biomass in agricultural soil–A six-year field study. Geoderma. 2022;427:116117.
- 17. Dwivedi AK, Dwivedi BS. Impact of long term fertilizer management for sustainable soil health and crop productivity: Issues and Challenges. 2015;374:49(3).
- Verma P, Chauhan A, Ladon T. Site specific nutrient management: A review. J Pharmacogn Phytochem. 2020;9(5S):233-6.
- 19. Singh RK, Prasad A, Muthamilarasan M, Parida SK, Prasad M. Breeding and biotechnological interventions for trait improvement: Status and prospects. Planta. 2020;252(4):54.
- 20. Kumar K, Gambhir G, Dass A, Tripathi AK, Singh A, Jha AK, et al. Genetically modified crops: Current status and future prospects. Planta. 2020;251(4):91.

- Kaviani B. Conservation of plant genetic resources by cryopreservation. Aust J Crop Sci. 2011;5(6):778-800.
- 22. Sidhu RK, Kumar R, Rana PS, Jat ML. Automation in drip irrigation for enhancing water use efficiency in cereal systems of South Asia: Status and prospects. Adv Agron. 2021;167:247-300.
- Deng XP, Shan L, Zhang H, Turner NC. Improving agricultural water use efficiency in arid and semiarid areas of China. Agric Water Manag. 2006;80(1-3):23-40.
- 24. Luo L, Mei H, Yu X, Xia H, Chen L, Liu H, et al. Water-saving and drought-resistance rice: from the concept to practice and theory. Mol Breed. 2019;39:1-15.
- Srivastav AL, Dhyani R, Ranjan M, Madhav S, Sillanpää M. Climate-resilient strategies for sustainable management of water resources and agriculture. Environ Sci Pollut Res Int. 2021;28(31):41576-95.
- 26. Saggi MK, Jain S. A survey towards decision support system on smart irrigation scheduling using machine learning approaches. Arch Comput Methods Eng. 2022;29(6):4455-78.
- 27. Kwenti TE. Biological control of parasites. Nat Rem Fight Parasites. 2017;23-58.
- Barzman M, Bàrberi P, Birch ANE, Boonekamp P, Dachbrodt-Saaydeh S, Graf B, et al. Eight principles of integrated pest management. Agron Sustain Dev. 2015;35(4):1199-215.
- 29. Verma DK, Guzmán KNR, Mohapatra B, Talukdar D, Chávez-González ML, Kumar V, et al. Recent trends in plant- and microbe-based biopesticide for sustainable crop production and environmental security. Recent Dev Microb Technol.2021:1-37.
- Devi OR, Sarma A, Borah K, Prathibha RS, Tamuly G, Maniratnam K, Laishram B. Importance of zinc and molybdenum for sustainable pulse production in India. Environment and Ecology. 2023;41(3C):1853–1859. Available:https://doi.org/10.60151/envec/lc ch4556
- 31. Dubey PK, Singh A. Adaptive agricultural practices for rice-wheat cropping system in Indo-Gangetic plains of India. IUCN-CEM Agroecosyst Newslett. 2017;1(1):13–17. Available:https://www.iucn.org/sites/dev/file s/content/documents/agroecosystems\_sg\_ iucn\_cem\_newsletter\_1.pdf

- Abhilash PC, Tripathi V, Dubey RK, Edrisi SA. Coping with changes: Adaptation of trees in a changing environment. Trends Plant Sci. 2015;20:137–138.
- 33. Meng QF, Yue SC, Hou P, Cui ZL, Chen XP. Improving yield and nitrogen use efficiency simultaneously for maize and wheat in China: A review. Pedosphere. 2016;26(2):137–147.
- Ventrella D, Stellacci AM, Castrignano A, Charfeddine M, Castellini M. Effects of crop residue management on winter durum wheat productivity in a long term experiment in Southern Italy. Eur J Agron. 2016;77:188–198.
- 35. Schwab N, Schickhoff U, Fischer E. Transition to agroforestry significantly improves soil quality: A case study in the central mid-hills of Nepal. Agric Ecosyst Environ. 2015;205:57–69.
- 36. Bhaduri D, Purakayastha TJ. Long-term tillage, water and nutrient management in rice-wheat cropping system: Assessment and response of soil quality. Soil Tillage Res. 2014;144:83–95.
- Midega CAO, Toby JA, Bruce Pickett JA, Pittchara JO, Muragea A, Khan ZR. Climate-adapted companion cropping increases agricultural productivity in East Africa. Field Crop Res. 2015;180:118–125.
- Kantachote D, Nunkaew T, Kantha T, Chaiprapat S. Biofertilizers from Rhodopseudomonas palustris strains to enhance rice yields and reduce methane emissions. Appl Soil Ecol. 2016;100:154– 161.
- Bedano JC, Domínguez A, Arolfo R, Wall LG. Effect of good agricultural practices under no-till on litter and soil invertebrates in areas with different soil types. Soil Tillage Res. 2016;158:100–109.
- 40. Gathala MK, Timsina J, Islam MS, Rahman MM, Hossain MI, Rashid MHR, Ghosh AK, Krupnik TJ, Tiwari TP. Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice-maize systems: evidence from Bangladesh. Field Crop Res. 2015;172:85–98.
- 41. Muriithi BW, Affognon HD, Diiro GM, Kingori SW, Tanga CM, Nderitu PW, Mohamed SA, Ekesi S. Impact assessment of integrated pest management (IPM) strategy for

suppression of mango-infesting fruit flies in Kenya. Crop Prot. 2016;81:20–29.

- 42. Hassan A, Ijaz SS, Lal R, Barker D, Ansar M, Ali S, Jiang S. Tillage effect on partial budget analysis of cropping intensification under dryland farming in Punjab, Pakistan. Arch Agron Soil Sci. 2016;62:151–162.
- 43. Hamzei J, Seyyedi M. Energy use and input–output costs for sunflower production in sole and intercropping with soybean under different tillage systems. Soil Tillage Res. 2016;157:73–82.
- 44. Dhadli HS, Brar BS, Black TA. N2O emissions in a long-term soil fertility experiment under maize-wheat cropping system in Northern India. Geoderma Reg. 2016;7:102–109.
- 45. Das TK, Bhattacharyya R, Sudhishri S, Sharma AR, Saharawat YS, Bandyopadhyay KK, Sepat S, Bana RS, Aggarwal P, Sharma RK, Bhatia A, Singh G, Datta SP, Kar A, Singh B, Singh P, Pathak H, Vyas AK, Jat ML. Conservation agriculture in an irrigated cotton–wheat system of the western Indo-Gangetic plains: Crop and water productivity and economic profitability. Field Crop Res. 2014a;158:24–33.
- 46. Ahmed S, Salim M, Chauhan BS. Effect of weed management and seed rate on crop growth under direct dry seeded rice systems in Bangladesh. Plos One. 2014;9(7):e101919.

Available:https://doi.org/10.1371/journal.po ne.0101919

- Ju XT, Xing GX, Chen XP, Zhang SL, 47. Zhang LJ, Liu XJ, Cui ZL, Yin B, Christie P, FS. Reducing Zhub ZL, Zhang by improving risk environmental N management in intensive Chinese agricultural systems. Proc Natl Acad Sci. 2009;106:3041-3046.
- Mäder P, Kaiser F, Adholey A, Singh R, Uppal HS, Sharma AK, Srivastava R, Sahai V, Aragno M, Wiemken A, Johri BN, Fried PM. Inoculation of root microorganisms for sustainable wheat-rice and wheat-black gram rotations in India. Soil Biol Biochem. 2011;43:609–619.
- 49. Cantore V, Lechkar O, Karabulut E, Sellami MH, Albrizio R, Boari F, Stellacci AM, Todorovic M. Combined effect of deficit irrigation and strobilurin application on yield, fruit quality and water use efficiency of "cherry" tomato (Solanum

*lycopersicum L.*). Agric Water Manag. 2016;167:53–61.

- 50. Seva NP, Bautista AS, Galarza SL, Maroto JV, Pascual B. Response of drip-irrigated chufa (Cyperus esculentus L. var. sativus Boeck.) to different planting configurations: yield and irrigation water-use efficiency. Agric Water Manag. 2016;170:140–147.
- 51. Boudreau MA. Diseases in intercropping systems. Annu Rev Phytopathol. 2013; 51:499–519.
- 52. Rakshit A, Sarkar B, Abhilash PC. Soil amendments for sustainability: Challenges and perspectives. CRC Press, Boca Raton, FL; 2018.
- 53. King AE, Hofmockel KS. Diversified cropping systems support greater microbial cycling and retention of carbon and nitrogen. Agric Ecosyst Environ. 2017;240:66–76.
- 54. Zang H, Yang X, Feng X, Qian X, Hu Y, Ren C, Zeng Z. Rhizodeposition of nitrogen and carbon by mungbean (*Vigna radiata L.*) and its contribution to intercropped oats (*Avena nuda L.*). Plos One. 2015;10(3):e0121132.
- Xiong H, Shen H, Zhang L, Zhang Y, Guo X, Wang P, Duan P, Ji C, Zhong L, Zhang F, Zuo Y. Comparative proteomic analysis for assessment of the ecological significance of maize and peanut intercropping. J Proteomics. 2013;78:447–460.
- Rakshit A, Abhilash PC, Singh HB, Ghosh S. Adaptive soil management: From theory to practices. Springer Nature Singapore Pvt Ltd., Singapore; 2017. Available:https://doi.org/10.1007/978-981-10-3638
- Gaudin ACM, Tolhurst TN, Ker AP, 57. Janovicek K, Tortora C, Martin RC, Deen W. Increasing crop diversity mitigates weather variations and improves stability. Plos vield One. 2015: 10(2):e0113261. Available:https://doi.org/10.1371/journal.po ne.0113261
- Loc HH, Diep NTH, Can NT, Irvine KN, Shimizu Y. Integrated evaluation of ecosystem services in prawn-rice rotational crops, Vietnam. Ecosyst Serv. 2017; 26:377.

Available://doi.org/10.1016/j.ecoser.2016.0 4.007

- 59. Mbow C, Noordwijk MV, Luedeling E, Neufeldt H, Minang PA, Kowero G. Agroforestry solutions to address food security and climate change challenges in Africa. Curr Opin Environ Sust. 2014a; 6:61–67.
- 60. Devi OR, Ojha N, Laishram B, Dutta S, Kalita P. Roles of Nano-fertilizers in sustainable agriculture and biosafety. Environment and Ecology. 2023;41 (1B):457—463.
- 61. World Bank, Independent Evaluation Group. World Bank assistance to agriculture in Sub-Saharan Africa: An IEG review. World Bank Publications, Washington, DC; 2007.
- 62. Qin W, Chi B, Oenema O. Long-term monitoring of rainfed wheat yield and soil water at the loess plateau reveals low water use efficiency. Plos One. 2013;8 (11):e78828.
- Kiran Doggali G, Tiwari U, Pandey PK, Devi OR, Gireesha D, Laishram B, Patel A. Discovering new frontiers in plant breeding: The fascinating world of advancements shaping future growth. International Journal of Research in Agronomy. 2024;7(1):441–445. Available:https://doi.org/10.33545/2618060 x.2024.v7.i1f.262
- 64. Qin W, Hu C, Oenema O. Soil mulching significantly enhances yields and water and nitrogen use efficiencies of maize and wheat: a meta-analysis. Sci Rep. 2015;5:16210.
- 65. Salman M, Bunclark L, AbuKhalaf M, Borgia C, Guarnieri L, Hoffmann O, Sambalino F, Steenbergen FV, Lebdi F. Strengthening agricultural water efficiency and productivity on the African and global level Status, performance and scope assessment of water harvesting in Uganda, Burkina Faso and Morocco Food and Agriculture. Organization of the United Nations, Rome; 2016.
- 66. Scialabba NEH, Lindenlauf MM. Organic agriculture and climate change. Renew Agric Food Syst. 2010;25:158 –169.
- 67. FAO. Organic agriculture and climate change mitigation—a report of the round table on organic agriculture and climate change. Food and Agriculture Organization of United Nation, Rome; 2011.

- 68. World Bank. World development report 2008: Agriculture for development. World Bank, Washington, DC; 2007.
- 69. Devi OR, Halder R, Pandey ST, Verma O, Chaturvedi P. Effect of seed priming with liquid organic on germination, seedling development and enzymatic activity of wheat (*Triticum aestivum L*.). Environment and Ecology. 2022;40(3C):1720–1725.
- Devi OR, Harish BM, Doggalli G, Laishram B, Verma O, Sharma A, Ojha N. Effect of liquid fermented organic manure concoctions and their foliar spray under different dose of nutrients on chlorophyll content of late sown wheat. Plant Archives. 2024;24(1):1244-1248.
   DOI:doi org/10 51470/PLANTARCHIVES 2

DOI:doi.org/10.51470/PLANTARCHIVES.2 024.v24.no.1.173

- Devi OR, Verma O, Laishram B, Raj A, Singh S, Gaurav K. Influence of seed invigoration with organic Kunapajala on seed quality and biochemical activity in late sown wheat. International Journal of Environment and Climate Change. 2023;13(9):900-906.
- 72. Herrero M, Thornton PK, Notenbaert AMO, Msangi S, Wood S, Kruska RL, Dixon JA, Bossio DA, Van de Steeg JA, Freeman HA, Li X. Drivers of change in crop– livestock systems and their potential impacts on agro-ecosystems services and human wellbeing to 2030: A study commissioned by the CGIAR Systemwide Livestock Programme. ILRI, Nairobi; 2012.
- Sun B, Zhang L, Yang L, Zhang F, Norse D, Zhu Z. Agricultural non-point source pollution in China: Causes and mitigation measures. Ambio. 2012;41:370–379.
- 74. Devi OR, Ojha N, Laishram B, Devi OB. Opportunities and challenges of soil fertility management in organic agriculture. Vigyan Varta. 2023;4(8):228-232.
- 75. Abhilash PC, Singh N. Pesticide use and application: An Indian scenario. J Hazard Mater. 2009;165:1–12.
- Devi OR, Laishram B, Debnath A, Doggalli G, Ojha N, Agrawal S, Dutta S. Mitigation of arsenic toxicity in rice grain through soilwater-plant continuum. Plant, Soil and Environment. 2024;70(7):395–406.
   Available:https://doi.org/10.17221/470/202 3-PSE.
- 77. Laishram B, Devi OR, Ngairangbam H. Insight into microbes for climate smart agriculture. Vigyan Varta. 2023;4(4):53-56.

 Laishram B, Singh TB, Devi OR, Khumukcham PS, Ngairangbam H. Yield, Economics, nutrient uptake and quality of Lentil (*Lens culinaris L.*) as influence by salicylic acid and potassium nitrate under Rainfed condition. Environment and Ecology. 2023;41(3A):1591–1596.

Available:https://doi.org/10.60151/envec/h dsa3286

79. A Review of Precision Irrigation Water-Saving Technology under Changing Climate for Enhancing Water Use Efficiency, Crop Yield, and Environmental Footprints Agriculture 2024, 14, 1141 and 2) Plastic Pollution in Agriculture as a Threat to Food Security, the Ecosystem, and the Environment: An Overview Agronomy. 2024;14:548.

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Peer-review history: The peer review history for this paper can be accessed here: https://www.sdiarticle5.com/review-history/121178