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Bibliometric Analysis of Peer-Reviewed Literature on Stress Factors Affecting Agricultural Productivity

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Abstract

Sustaining agricultural productivity is essential to ensuring food security. Climate change, increasing population and dwindling resources are factors of concern threatening crop productivity. Research across the globe have focused on seeking innovative measures to protect and enhance crop yield. We explored and analyzed peer-reviewed literature to provide an understanding of current and emerging trends in the field. A bibliometric method was followed using the database Scopus. Search queries used to retrieve documents were "Agriculture/crop productivity" and "Plant stress". The study period was restricted to the last five years, from 2017-2021. The search query found 2207 documents in Scopus under the agriculture and plant stress theme. Increasing growth of publications was observed in successive years. Research activities in this field have the most contributors from Asian countries – China and India followed by the US. The major stresses affecting agricultural productivity being investigated were-Water stress, Temperature stress, Salinity stress. Amongst these, the theme related to water stress/ precipitation/ drought stress was the most investigated. The availability of water has a pivotal role in sustainable agriculture. The use of conservation agricultural practices such as intercropping, no-tillage, and soil mulching has proven to be effective in retaining soil water content and reducing the dependency on irrigation, especially in rainfed areas, thereby assisting in drought mitigation and increasing crop yield. Precision agriculture approach employing satellite data to predict weather and rainfall and early detection of stress signals using hyperspectral reflectance has shown promising results in ensuring sustained productivity. Breeding and transgenic approaches for plants with higher water use efficiency (WUE) and the ability to tolerate water stress are key areas of research being followed throughout the world.

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Introduction

Rapidly increasing population and climate change are considered the biggest challenges affecting crop productivity. Abiotic stresses such as drought, salinity and temperature etc., cause significant yield loss and threaten the sustainability of agriculture, as well as expose the vulnerability of livelihood of millions of farmers across the world. Between the 1800's to 1900's approximately a 1.1° C rise in global temperature has been recorded which is projected to exceed 1.5° C in this decade.[1] Climate change is also altering rainfall patterns and monsoon precipitation across the globe. The variability in rainfall causes is projected to increase significantly by the end of the 21st century.[2] Global warming is rapidly accelerated by rising levels of greenhouse gases with increased emissions of about 41.1% from 1990-2016.[3] Rising temperatures, reduced and variable precipitation patterns are resulting in frequent droughts throughout the world.

As the occurrence and severity of extreme climatic events increase, the threat to food security heightens, increasing the need to devise cultivation strategies and technological solutions that ensure stress-resilient crops with higher yield potential.[4] It is imperative to understand the physiological, biotechnological and ecological interventions required for overcoming the abiotic stresses. Crop growth and yield are negatively impacted by heat and drought stresses caused by physiological disruptions and cellular imbalances. Plant responses to stresses vary from species to species and the complexity is further compounded by the simultaneous presence of more than one stress at a time.[5] The complexity of plant responses requires an in-depth understanding for devising remedies and management strategies.

The present study uses bibliometric approach to analyze research trends in the area of stress factors affecting agriculture productivity. Bibliometric analysis is a statistical tool to investigate, identify and analyze information pertaining to a specific area of knowledge with the purpose of prospecting research opportunities.[6] Bibliometric analysis of research activity on factors affecting crop productivity can help identify the major themes researched globally, identify research gaps in the field, main authors and the countries with the highest number of publications, and measure inter-relationships, collaborations and impact of publications. Network analysis using keyword co-occurrence, co-authorship and co-citation analysis can assist in identifying ongoing and emerging research areas. Visualization tools such as VOS viewer can be used to construct bibliometric network maps of large-scale data and produce graphic visual maps that can help prospective researchers, universities and funding agencies find suitable references, and identify research gaps and new frontiers in a specific field of research.[7] This paper systematically explores and analyzes peer-reviewed literature to provide an overall structure, current research opportunities and emerging themes in the field of abiotic stress and agricultural crop productivity.

Materials and Methods

The Scopus database was used to retrieve relevant information. A comprehensive search query was used to retrieve articles. The search was based on keywords that included but were not restricted to, "Agricultural productivity" or "crop productivity" or "agriculture" and "Plant stress" were used as a search query. The search hits were scrutinized to ensure that they fit within the scope of the study. False positives were excluded. Retrieved data was exported to Microsoft excel and to the VOS viewer program to create network visualization maps. Keywords were analyzed to identify the key areas of research. Keywords related to research themes, and the co-occurrence of keywords revealed the associations in themes of the retrieved articles. Words used more than 20 times in titles, author keywords and abstract were defined as keywords and used for analysis. The visualization of similarities (VOS) method was used to estimate the similarity and, based on association strength, grouped the keywords into clusters, each cluster was identified with a different colour. The size of the label was indicative of the number of occurrences, and the distance between the words represented the degree to which they are associated. The study period from 2017 to 2021 was used.

Results and Discussion

Type and Growth of Publications

The search query yielded 2207 documents on the research theme of agriculture and stress. The annual growth in the number of publications showed a continuous increase (Fig. 1.), with 552 documents recorded in 2021. Research articles constituted the highest percentage at 65 per cent (n= 1439), followed by review articles at 19.5 per cent (n= 431).

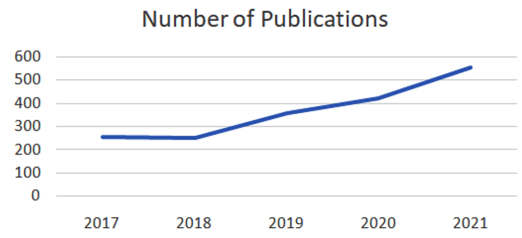

Fig. 1: Annual growth of documents on agricultureproductivity and stress (2017-21).

Most Active Countries and Region-Based Analysis of Research Activities (Collaborations)

Fig. 2. shows the top ten active countries publishing the maximum number of documents on agriculture and stress. India led with 30 % (n=666), followed by China with 19.6 % (n=433) documents. Mapping of research collaborations yielded four clusters with India, China and the USA at the center of the map and India and USA showing the strongest association (link strength = 40). A higher number of European countries collaborated for research on stress factors affecting agriculture with similar interests as shown by the red cluster (Fig. 3.). India and China shared similar research interests with most countries as these were located in the center of the map.

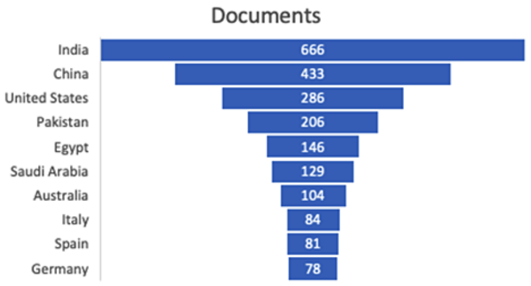

Fig. 2: Top ten countries showing higher publications on stress affecting agricultural productivity (2017-21)

Most Active Institutions/Organizations and Funding Agencies

The institutions and organizations from the Asian sub-continent dominated the list of most active institutions and organizations followed by the American based institutions (Table 1). The Chinese Academy of Science was ranked first with 216 (18.5% of the top ten) documents. For investigations on agriculture and stress factors affecting productivity the National Natural science Foundation of China was the most active funding agency (n=211; 9.5%) followed by the Department of Science and Technology, Ministry of Science and Technology, India (n=57; 2.58%) (Table 2).

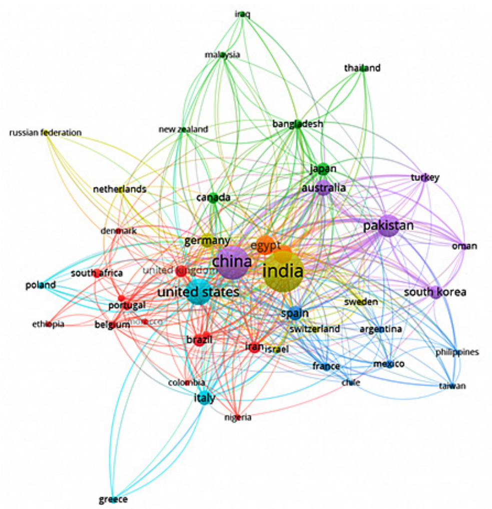

Fig. 3: Network visualization map showing international research collaborations. The link strength or the extent of cooperation is expressed in terms ofthe thickness of the connecting line. Node size is indicative of the number of documents by each country and similar research interests by the same colour of the node.

Table 1: Top ten active institutions in publishing literature on agriculture and stress (2017-21)

Institutions	Number of Publications
Chinese Academy of Sciences	216
Ministry of Education China	146
University of Agriculture, Faisalabad	128
Ministry of Agriculture of the People's Republic of China	110
Northwest A & F University	98

China Agricultural University	95
Chinese Academy of Agricultural Sciences	95
Consejo Superior de Investigaciones Científicas	94
USDA Agricultural Research Service	93
Indian Council of Agricultural Research	90

Table 2:Top ten funding agencies involved in publishing literature on agriculture and stress (2017-22)

Funding Agency	Number of publications
National Natural Science Foundation of China	211
Department of Science and Technology, Ministry of Science and Technology, India	57
National Key Research and Development Program of China	51
National Science Foundation	51
University Grants Commission	45
Indian Council of Agricultural Research	42
Council of Scientific and Industrial Research, India	41
European Commission	39
National Research Foundation of Korea	36
Science and Engineering Research Board	36

Most Active Journals, Citations and Authors

Identification of top journals is important in all fields of research to assess the publication trend and plan future research. The top most active journals in field are listed in Table 3. The journal – Science of the Total Environment had highest number of articles on the theme with 197 documents. Lee Injung of Kyungpook National University and Youssef Rouphael of Università degli Studi di Napoli Federico II, Naples, Italy were the authors with the maximum number of publications (n=12 each) on the subject (Table 4). The top five most cited articles were reviews principally exploring the effect of abiotic stresses on plant growth and the remedial measures that are being used for amelioration of these stresses. The most cited review article with 377 citations entitled "Impact of combined abiotic and biotic stresses on plant growth and avenues for crop improvement by exploiting physio-morphological traits" was authored by. Pandey *et al.*, 2017.[8]

Table 3: Top fifteen active journals publishing literature on agriculture and stress (2016-21)

Journal	Number of Publications
Science of the Total Environment	197
Agricultural Water Management	117
Plos one	105
Scientific Reports	97
Frontiers In Plant Science	84
Agronomy	75
Environmental Science and Pollution Research	75
Sustainability Switzerland	75
Chemosphere	74
Environmental Pollution	66

Table 4: Top ten active authors publishing literature on stress factors affecting agricultural and crop productivity (2017-21)

Author	Number of Publications
Lee, I.J.	12
Rouphael, Y.	12
Babalola, O.O.	11
Prasad, S.M.	11
Ali, S.	10
Colla, G.	10
Farooq, M.	10
Siddique, K.H.M.	10
Singh, V.P.	10
Tripathi, D.K.	10

Mapping Author Keywords

Author critical words with a minimum occurrence of 10 were visualised and presented in a visualisation map. The most frequently used author keywords were grouped into six clusters, as shown in Fig. 4. The most prominent clusters were those related to water stress, agriculture, climate change, abiotic stress, salt stress, and sustainable agriculture. Amongst all abiotic stresses affecting agricultural yield and productivity water, salt and temperature stress are the most investigated stressors.

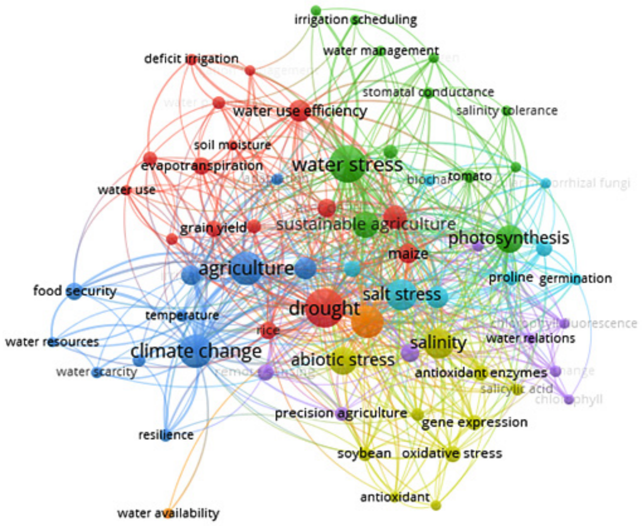

Fig. 4: Network visualisation of author keywords in articles on stress factors affecting agricultural productivity. Node size represents the frequency of occurrence of keywords.

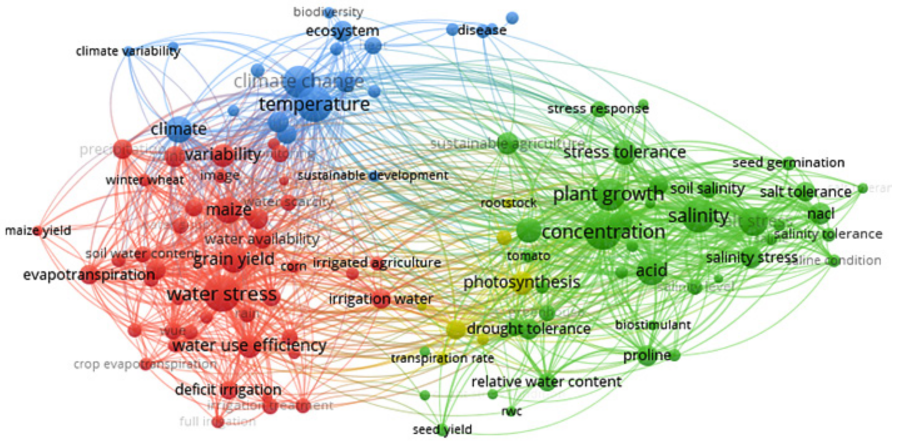

Fig. 5: Network visualization map of terms in title/abstract fields related to stress factors affecting agriculture (2017-22). Each node represents a keyword, the size of the node indicates the occurrence of the keyword and the link between nodes represents the co-occurrence between keywords. Different colors represent the common theme of each cluster.

Research Themes of Publications Studying Stress Factors Affecting Agricultural Productivity

Three clusters- water, salinity and temperature, were identified on analysis of the terms used in the title and abstract fields of the screened documents (Fig 5).

Water Stress

Seventy per cent of the freshwater on our planet is consumed by agriculture. Despite this, agricultural productivity is limited by water availability, and with cases of severe drought reported across the earth as the temperature rises, it is a serious matter of concern. Globally a yield loss of almost 21% to 40 % for wheat and maize respectively has been reported due to drought stress.[9] Agriculture is dependent either on rainfall or irrigation. Irregular precipitation in rainfed areas negatively impacts crop yield[10] with consequent negative economic repercussions.[11] In rainfed areas, in the absence of reliable and regular rainfall to sustain agriculture, farmers rely principally on irrigation. However, irrigation uses valuable and limited water resources. It is understood that sustainable agriculture would require improving water use efficiency.[12] Identifying and breeding resilient crops having efficient water use efficiency (WUE) and low water footprints will be critical to maintaining productivity in water-limited areas.[13–15]

A holistic approach would involve water management strategies that involve efficient use of rainwater and thereby lessen the requirement for irrigation. Precision agriculture based on satellite data to predict growing season rainfall can be used to estimate the time and quantity of nitrogen application to the soil, maximizing yield.[16] Rapid high-throughput identification of early symptoms of stress in plants using a photochemical reflectance index allows real-time and precise control of growth conditions enhancing quality and yield.[17,18] Water management strategies such as the growing of crop plants under irrigation deficit conditions, subsurface drip irrigation, and alternate wetting and drying irrigation during specific growth stages allow judicious use of irrigation water without affecting yield and nutritional quality.[19–21] Adopting indigenous rainwater harvesting techniques suited to meet local demands is a promising solution.[22]

The use of Conservation Agriculture Practices involving crop rotation and replacing the conventional tillage with a mulching system have shown promising results with increasing gaining yield in Africa, where agriculture is dependent on highly variable rainfall. Soil mulching improves water productivity and consequently enhances crop yield, which is especially important in water-limited regions.[23] The use of these practices provides more significant buffering of the crops to water stress by conserving soil moisture, enhancing infiltration and the availability of water thereby impacting crop yield.[24] A similar study in India has shown promising results with an increase in productivity by employing conservation agriculture practices that involve crop rotation, precision land leveling methods of tillage, and permanently raised broad bed furrow methods that showed enhanced water use efficiency.[25] In tropical regions, using a no-tillage strategy can reduce the average amount of irrigation water significantly by enabling soil moisture retention and can be used under optimum water management practices.[26] A combination of no-tillage with cover crops increases carbon and nitrogen stability with a concomitant increase in microbial diversity and enzyme content in the plants, building resilience into the system.[27] Rainwater loss results primarily due to deep percolation into the soil, and measures such as absorbent polymers help retain rainwater and enhance plant growth and water use efficiency, especially in rainfed areas.[28] Foliar application of nutrients such as potassium (K) and phosphorus (P) resulted in modulation of biochemical and physiological attributes improving drought stress tolerance in plants.[29,30] Exogenous application of hormones such as abscisic acid and jasmonic acid etc. have also been shown to promote plant growth under drought stress.[31]

The use of plant growth-promoting rhizobacteria (PGPR) alleviates water stress. It improves crop yield by enhancing physiological traits such as the ability to retain water, increase in proline and total soluble carbohydrates and change in lipid profile.[32,33] Exogenous inoculation of endophytic fungi such as *Piriformospora indica, Acrocalymma vagum*, and *Paraboeremia putaminum* has also been known to reduce drought stress in host plants directly.[34,35] Endophytic fungi also indirectly modify the root microbiome composition by changing edaphic factors such as soil water content, organic matter, and availability of nitrogen, phosphorus and potassium.[35] Following the inoculation of endophytic fungi, the increase in abundance of beneficial symbiotrophic fungi and bacterial population offers the opportunity to develop such biofertilizers that can enhance crop productivity in water-stressed areas.

Interestingly the adoption of technology solutions such as the Internet of Things (IoT) to monitor water levels and control irrigation as per need shows promising results in increased water use efficiency.[36] Climate change projections and crop modeling have shown increased crop productivity with increasing CO_2 levels. This is important as it helps to overcome the rising temperature and water stress.[37] Traits such as water use efficiency and drought tolerance are complex traits with complex signaling networks modulating the plant response to stress. Breeding for developing drought-resistant varieties can help sustain productivity.[38] A transgenic approach to developing drought tolerant species by identifying and introducing single genes[39] in their combination[40] is being used to improve plant performance under stress. Successful use of these drought-tolerant crop varieties would need raising awareness of their usefulness and a sustained supply of seeds at a competitive cost to farmers.[41]

Temperature Stress

Global warming and climate change with unexpected climatic changes such as extremes of temperature and drought in recent years have negatively affected agricultural production across the globe. The intensity, persistence and frequency of heat stress are responsible for variation in crop yield.[13] Simulation models are being used to predict the effect of changing precipitation, temperature, and CO_2 levels on crop yields across various latitudes.[42] High-resolution thermal imagery has been used to assess tropical coastal regions where temperature patterns influence the extent of precipitation. Monitoring temperature fluctuations and forecasting models can be of a predictive value and support suitable remedies.[43] The effectiveness of irrigation to mitigate temperature stress has declined over time.[13] On the other hand, increasing CO_2 concentrations are predicted to compensate for the rising temperatures.[44] Breeding crops for heat tolerance and requiring lower water input will be the key to maintaining the resilience of agroecosystems under heat stress.[45]

Salinity Stress

Crops are increasingly being affected by salinity as the levels of salt have increased worldwide due to natural and anthropogenic causes. Additionally, due to the scarcity of quality irrigation water in arid and semi-arid regions, saline water is commonly used for irrigation, further adding to the soil salt content. Improper drainage systems also often result in the accumulation of salt in the topsoil.[46] Increased soil salinity leads to soil compaction and a reduction in plant growth, nutrient acquisition and yield due to altered carbon and nitrogen metabolism.[47] High salt concentrations negatively impact the physiology and development of plants by disturbing cellular ion balance, causing osmotic loss, disturbing membrane integrity and increasing the production of reactive oxygen species. Adopting suitable agronomic strategies to mitigate the impact of salt stress and identifying salt-tolerant varieties is the key to developing resilience in agricultural systems. Irrigation with salt water in the vegetative growth stage has a lesser negative impact on seed production than in the fruiting stage.[48] Using water with different electrical conductivities and adding nitrogen, phosphorus and potassium salts can alleviate salt stress in plants by promoting ion homeostasis.[49,50] It has been reported that a mixture of organic matter, sulfur, and gypsum can reduce soil salinity and maintain soluble and exchangeable cations, promoting plant growth.[51] Iron (Fe) availability in saline soils is reduced, resulting in Fe-deficient crops. Using salt-tolerant siderophore PGPR as a bio fertilizer has proven to be beneficial in salinized soils.[52] Similarly, algal-based biostimulants can mitigate salinity stress by promoting ion homeostasis.[53,54] Breeding tolerant varieties and identifying and introducing resistance genes can help maintain productivity under salinity stress.[55,56]

Research Gaps and Future Directions

The resilience of agricultural systems under stress is impacted by the adoption of conservative agricultural practices for effectively mitigating abiotic stress such as drought and salinity and increasing crop yield. Integrating good agronomic practices that incorporate efficient use of water and nutrients can help in improving crop yield without compromising on sustainability. Data from simulation models need to be corroborated by detailed field data for wider acceptance. In addition, the genotypic variability of crop varietal response needs to be considered to ensure the success of suggestive remedies. This emphasizes the fact that the issue is complex and interconnected between the local and regional climatic conditions and the simultaneous presence of several stressors together affecting crop productivity. It, therefore, requires detailed assessment and sustainable solutions suited to regional requirements.

Conclusions

The study analyses the research profiles of papers published in the last five years on stress factors affecting agricultural productivity through a bibliometric analysis. Amongst all challenges, climate change is considered the greatest for world food security. Unpredictable precipitation patterns, rising temperatures and increasing drought events have created immense challenges for agriculture. These can be addressed only in the context of sustainability as a critical paradigm. An integrative approach will be essential as we move to assess the impact of climate stress and assuage the effect on agroecological fragile ecosystems while addressing the needs of the ever-increasing humanity.

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Conflict of Interest
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