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Evaluating Structural Interdependence of Cereal Productivity under Climate Variability: A Study on Main and Coarse Cereals in India

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ABSTRACT

Background: India's cereal economy is largely centred on rice and wheat, leading to uneven growth across other vital crops such as coarse cereals-millets, maize and barley. These coarse cereals, often termed as climate-resilient and nutrient-rich, are critical for sustainable agriculture, especially in semi-arid and marginal farming regions. However, the productivity of coarse cereals has remained relatively stagnant, raising concerns about disproportionate capital allocation and growing climatic stress.

Methods: This study explores the structural relationship between the marginal productivity of capital and land in main cereals (rice and wheat) and that in coarse cereals, with a specific focus on how climate variability moderates these dynamics. Based on annual data from 1996-97 to 2020-21, the research constructs standardized marginal productivity indicators for both capital and land, along with a composite Climate Index derived from rainfall and temperature variations. Two regression models are employed to estimate the interdependencies under normal and climate-stress conditions.

Result: The findings reveal a strong positive spill over from capital productivity in main cereals to coarse cereals under normal climatic conditions, but a significantly weaker effect during climate-stress years. Conversely, land productivity in main cereals shows a negative relationship with that in coarse cereals, hinting at possible competition or displacement. To conclude the capital productivity of main cereals and coarse cereals complements each other under normal climatic conditions whereas the land productivity reveals the displacement of coarse cereals by the main cereals.

Key words: Climate stress, Coarse cereals, Input allocation, Marginal productivity.

INTRODUCTION

Agriculture remains a cornerstone of the Indian economy, contributing about 16% to the GDP and supporting nearly half the population (Economic Survey, 2024-25). Agricultural growth is estimated to be 2-3 times more effective in reducing poverty than growth in other sectors (Gulati and Roy, 2021a). Yet, the sector's performance has been modest, growing at just 3.2% annually between 2000-01 and 2018-19-well below the targeted 4% and significantly behind the overall GDP growth of 7.2% (Gulati and Roy, 2021b).

This underperformance is rooted in legacy policies from the Green Revolution, which prioritized rice and wheat through input-intensive technologies. While these efforts increased yields, they also created long-term ecological and structural imbalances, including groundwater depletion, soil degradation and biodiversity loss (NABARD, 2023; India Water Portal, 2024). Simultaneously, these policies marginalized coarse cereals like millets, which are climate-resilient, nutritionally dense and require fewer inputs (Pingali *et al*., 2017; Kazi *et al*., 2022).

Climate variability has intensified these systemic challenges. With two-thirds of India's cultivated land being rainfed (DST, 2016), shifts in rainfall and temperature patterns critically affect crop productivity (Shukla *et al*., 2023). Coarse cereals, although more resilient to stress, remain vulnerable when not supported by adequate capital investment such as irrigation or adaptive machinery (Aggarwal *et al*., 2018; Malathi *et al*., 2016; Davis *et al*., 2019; Meena *et al*., 2021).

The structural neglect of millets is evident in capital and input allocation. For instance, in 2003-04, rice and wheat absorbed 31.8% and 21% of fertilizer use, while millets like sorghum, maize and pearl millet received only 2.9%, 2.3% and 1.7%, respectively (FAO, 2005). Studies have confirmed that capital and land productivity in millets are directly influenced by the intensity of investments in major cereals (Mittal *et al*., 2008; Ashrit, 2021). Moreover, climate sensitivity varies across cereals: while millets withstand higher temperatures and drought (Thilakarathna

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et al., 2015; Kheya *et al*., 2023), they suffer yield instability under extreme or prolonged stress if not backed by innovation and adaptive inputs (Rakshit *et al*., 2017; Kumar and Sharma, 2014).

Emerging research also points to asymmetric relationships between cereal types under climatic stress, where capitalized crops like rice often show resilience, while land-dependent millets falter unless supported by targeted adaptation strategies (Pal and Mitra, 2018; Bellon and Van, 2014). These patterns raise fundamental questions about interdependencies between major and coarse cereals-particularly regarding how productivity in one crop system may influence or constrain another under variable climate conditions.

The present study aims to explores the interrelationships between land and capital productivity across cereal systems, emphasizing the mediating role of climate variability. Understanding these structural linkages is essential for reconfiguring agricultural priorities toward a more resilient, equitable and sustainable cropping system in India.

MATERIALS AND METHODS

Variable selection

For this study, secondary data are sourced from the Annual Reports of the Ministry of Agriculture and Farmers' Welfare, Government of India. The dataset includes information on productivity and cost of production for two categories of cereals: main cereals, specifically wheat and paddy and coarse cereals, including jowar (sorghum), bajra (pearl millet), maize, ragi (finger millet) and barley. Key variables extracted for both cereal groups included gross area sown (in hectares), yield (per thousand hectares) and cost of production (in rupees per quintal).

The present dataset comprises annual time series data from 1996-97 to 2020-21, encompassing agro-economic and climatic variables relevant to Indian agriculture. The dataset focuses on the marginal productivity of land (MPL) and marginal productivity of capital (MPK) for two major cereals-rice and wheat and coarse cereals. To derive the marginal productivity of land (MPL) for each cereal category, we calculated the change in total output with respect to changes in the gross area sown. Similarly, the marginal productivity of capital (MPK) was computed by measuring the change in total output relative to the change in the cost of production. Additionally, the dataset includes average of annual temperature (in ^{o}C) and total annual rainfall (June-May, in mm), which are important for analyzing the influence of climatic variability on crop productivity.

To facilitate comparative analysis and ensure consistency in scale across variables with different units of measurement (*e.g*., temperature in ^{o}C, rainfall in mm, productivity in quintal/hectare), we applied Z-transformation (standardization). The process enabled us to create dimensionless, standardized variables suitable for regression analysis.

$$\text{Z value} = \frac{(O - \mu)}{\sigma}$$

Where,
O = Observed value.
μ = Population mean.
σ = Standard deviation.

Climate index

Recognizing that agricultural productivity is jointly influenced by both temperature and rainfall, we constructed a composite Climate Index (formulated as a linear function of standardized temperature and rainfall) to capture the combined effect of climatic variability. The index is formulated as:

Climate index =

$$\alpha \text{ Z_Annual temperature} - \beta \text{ Z_Annual rainfall}$$

Where Z_Annual temperature, Z_Annual Rainfall represent the standardized (Z-transfo-rmed) values of annual temperature and rainfall, respectively. The coefficients α and β denote the relative weights assigned to temperature and rainfall in shaping climatic conditions. Given the assumption that temperature and rainfall exert an equal influence on the agricultural environment, both weights were assigned a value of 0.5. This balanced weighting ensures that the index shows net climatic stress, where positive values indicate higher temperature coupled with lower rainfall (indicative of climatic stress) and negative values indicate more favourable agro-climatic conditions. we use positive weight for temperature (as higher temperature often increases stress) and negative weight for rainfall (as lower rainfall increases stress).

Climate index =

$$0.5 \text{ Z_Annual temperature} - 0.5 \text{ Z_Annual rainfall}$$

This index shows higher values when there is higher temperature and lower rainfall (climate stress) and lower values when conditions are favourable. This standardized climate index is used as an explanatory variable in regression models to assess its influence on the marginal productivity of capital and land in coarse cereals.

Climatic categorization

The interpretation of the Climate Index (CI) is central to understanding the variability in agro-climatic conditions across years. In this study, we define climatic stress periods as those years in which the Climate Index value falls below 0.5. Such values represent instances where the combined effect of elevated temperatures and/or deficient rainfall results in sub-optimal environmental conditions, potentially constraining crop growth, input efficiency and overall productivity-particularly in rainfed or semi-arid agricultural systems such as those in which coarse cereals are commonly cultivated.

Conversely, years in which the Climate Index exceeds 0.5 are considered to reflect favourable climatic conditions. These periods are characterized by a more balanced temperature and rainfall profile, which typically supports enhanced physiological functioning of crops, better soil moisture retention and more stable input-output relationships. The threshold of 0.5 serves as a standardized inflection point for differentiating between years of climatic adversity and climatic advantage, enabling stratified analysis of productivity behavior across contrasting environmental scenarios.

Econometric model

In this study we used two models, Model I analyses the impact of marginal productivity of capital of Main cereals and climate stress on the marginal productivity of coarse cereals.

$$Z_MPK_{CCt} = \beta_0 + \beta_1 Z_MPK_{MCT} + \beta_2 CI_t + \varepsilon_t \quad \ldots(i)$$

Where,

Z_MPK_{CCt} = Z value of marginal product of capital of coarse cereals.

Z_MPK_{MCt} = Z value of marginal product of capital of main cereals.

CI_t = Climate index.

Model II analyses the impact of marginal productivity of land of main cereals and climate stress on the marginal productivity of land of coarse cereals.

$$Z_MPL_{CCt} = \beta_0 + \beta_1 Z_MPK_{MCT} + \beta_2 CI_t + \varepsilon_t \quad \ldots(ii)$$

Where,

Z_MPL_{CCt} = Z value of marginal product of land of coarse cereals.

Z_MPL_{MCt} = Z value of marginal product of land of main cereals

CI_t = Climate index.

RESULTS AND DISCUSSION

Descriptive statistics

The descriptive statistics presented in Table 1 shows MPL and MPK in both main and coarse cereals, along with annual temperature and rainfall, gives important understandings into how these factors interact under varying climatic conditions in India. The results reveal a marked divergence in input productivity between cereal categories and highlight the vulnerability of coarse cereals to climate variability.

In the case of main cereals, the MPL demonstrates substantial efficiency, with a mean value of 76.50 in the overall period and peaking at 106.71 during favourable years. However, it drops precipitously to 0.03 during stress periods, indicating that land productivity in main cereals is highly sensitive to climate fluctuations. The considerable standard deviation, especially under favourable conditions (278.67), suggests regional and temporal variability in land use efficiency. The skewness statistics reinforce this, showing a leftward skew during stressful periods, implying

Table 1: Descriptive analysis of marginal productivity of capital of main cereals (MPK_{MC}), marginal productivity of land of main cereals (MPL_{MC}), marginal productivity of capital coarse cereals (MPK_{CC}), marginal productivity of land of coarse cereals (MPL_{CC}), annual temperature and annual rainfall, N=24 from 1996 to 2021.

Particular	MPK_{MC}			MPL_{MC}			MPK_{CC}			MPL_{CC}			Annual temperature			Annual rainfall		
	T	F	S	T	F	S	T	F	S	T	F	S	T	F	S	T	F	S
Mean	5.51	5.29	0.86	76.50	106.71	0.03	0.44	-2.59	-0.18	-0.75	-5.55	0.54	25.53	25.32	0.20	1130.07	1180.78	0.72
SD	11.54	14.14	0.29	278.67	232.35	0.44	10.17	9.82	1.29	41.59	18.53	0.89	0.55	0.56	1.60	92.09	63.65	0.38
Skewness	1.05	1.02	0.55	-0.99	-0.27	-0.44	-0.60	-1.45	-1.20	2.81	-0.34	1.39	-1.37	-1.08	2.05	-0.13	0.40	-0.52
Max.	-20.80	-20.80	0.58	-742.80	-397.29	-0.78	-26.42	-26.42	-3.00	-70.14	-47.76	-0.54	24.10	24.10	-1.70	931.80	1079.80	0.14
Min.	42.11	42.11	1.29	546.06	546.06	0.69	24.96	8.06	1.34	166.98	35.60	2.46	26.21	25.78	4.12	1327.00	1327.00	1.26

Note: T- Overall period, F- Favourable period and S- Stressful period.

Source: Authors calculation.

that most years yield below-average returns on land under climate stress.

The MPK in main cereals follows a more stable pattern. The mean MPKMC remains relatively high in both the overall (5.51) and favourable periods (5.29), with a notable decline in stressful years (0.86). While still impacted by climatic conditions, the smaller relative drop compared to MPLMC suggests that capital investments in main cereals may retain some productivity even during adverse periods-likely a result of greater capital deepening, irrigation infrastructure and policy support. The skewness is positive across all periods, indicating the presence of a few high-performing years, likely driven by technological advancements or favourable policy conditions.

In contrast, coarse cereals show consistently lower and more climate-sensitive productivity outcomes. The MPL in coarse cereals averages -0.75 in the overall period, with a moderate improvement during favourable years (0.54), but becomes strongly negative during stress conditions (-5.55). This pattern reflects the structural vulnerabilities of coarse cereals, which are typically cultivated in rainfed and resource-poor settings.

The MPKCC mirrors this sensitivity, with an overall mean of 0.44, dropping to -2.59 in stressful years. Even during favourable conditions, capital productivity remains marginal (-0.18), suggesting that returns on capital in coarse cereal production are persistently low and highly susceptible to climate shocks. The data underline a critical point: capital and land inputs in coarse cereal cultivation are not only underutilized but also poorly buffered against climatic variability, unlike main cereals.

The climate variables further contextualize these patterns. While temperature remains relatively stable across all periods (~25.5°C), rainfall exhibits considerable fluctuation-with the lowest mean rainfall recorded during stress periods. This validates the construction of the CI and supports its explanatory power in understanding productivity shifts.

The data confirm a structural disparity between main and coarse cereals. While main cereals benefit from robust input productivity and resilience under varying climatic conditions, coarse cereals remain highly vulnerable.

Inferential statistics

The regression analysis from Model I in Table 2 reveals a consistently strong and statistically significant positive relationship between the marginal productivity of capital in main cereal and that in coarse cereals. This suggests that improvements in capital productivity within main cereals are closely associated with corresponding gains in coarse cereals, pointing to systemic interdependence and possible spillover effects in input use and efficiency across cereal categories.

The climate index, constructed as a differential standardized measure of temperature and rainfall, shows a negative and marginally significant impact on capital productivity in coarse cereals. This indicates that greater climatic stress-marked by above-normal temperatures and below-normal rainfall-tends to suppress productivity, albeit modestly in the overall sample. The model demonstrates a moderate explanatory power, accounting for approximately 43% of the variance in the marginal productivity of capital in coarse cereals and reflects a reasonably well-specified structural relationship.

When the analysis is segmented based on climatic conditions, further nuances emerge. During stress years (CI < 0.5), the influence of marginal productivity of capital in main cereals on marginal productivity of coarse cereals remains positive and statistically significant, though the magnitude is smaller. Importantly, the climate index exerts a more pronounced negative effect (-0.507) in this subsample, underlining that capital productivity in coarse cereals is particularly vulnerable to adverse climate conditions. Notably, the model's explanatory power increases to 52%, suggesting that linkages between capital productivity in cereal systems become more structurally evident when external stressors are high.

Conversely, in favourable years (CI > 0.5), the capital productivity relationship strengthens substantially, with a much larger coefficient (2.295), reinforcing the idea of strong complementarity and synergy in capital allocation and effectiveness between cereal types under benign conditions. However, the climate index becomes statistically insignificant in this context, implying that when weather conditions are favourable, climate does not impose significant constraints on capital productivity in coarse cereals. This asymmetry in climate influence across regimes underscores the critical role of environmental stability in moderating or amplifying productivity responses.

The empirical findings from Model II in Table 3 pertaining to the marginal productivity of land in coarse cereals offer valuable insights into the structural dynamics

Table 2: Output of model I.

	Overall time	Stress (CI<0.5)	Favourable (CI>0.5)
Constant	-0.023 (0.165)	260.66 (330.141)	-0.133 (0.134)
Z_MPK_MC	0.672*** (0.172)	0.141*** (0.055)	2.295* (0.140)
Climate index	-0.415* (0.219)	-0.507* (0.651)	0.041 (0.201)
R^2	0.428	0.525	0.285
Adjusted R^2	0.374	0.36	0.166
Durbin watson	2.029	1.958	1.892

Source: Authors calculation.

Table 3: Output of Model II.

	Overall	Stress (CI<0.5)	Favourable (CI> 0.5)
Constant	0.000 (0.189)	-32.214 (58.118)	-0.357 (0.280)
Z_MPK_MC	-0.370 * (0.189)	0.462 (0.689)	-0.443** (0.180)
Climate index	-0.319 (0.232)	-0.069* (0.113)	-0.092 (0.365)
R^2	0.207	0.118	0.318
Adjusted R^2	0.135	0.175	0.213
Durbin watson	2.554	1.222	1.988

Source: Authors calculation.

within the cereal economy. A statistically significant negative association between capital productivity in main cereals and capital productivity in coarse cereals suggests a potential resource allocation trade-off. This pattern indicates that increases in capital productivity within main cereals driven by mechanization, irrigation infrastructure, or input intensification are occurring at the expense of land productivity in coarse cereals.

The climate index, derived as a composite of standardized temperature and rainfall deviations, registers a negative but statistically insignificant coefficient in the full sample model. This outcome suggests that, while climatic variability is intuitively important for agricultural productivity, its direct linear effect on land productivity in coarse cereals may be limited or mediated through other interacting variables. Moreover, the relatively low R-squared value indicates a weak model fit, implying that land productivity is likely influenced by a broader set of unobserved or localized factors.

When the sample is disaggregated by climatic regimes, further complexity emerges. During stress years (CI < 0.5), the influence of land productivity of main cereals on land productivity of coarse cereals becomes statistically insignificant and only the climate index shows a marginal effect. This finding suggests that in climatically adverse conditions, land productivity in coarse cereals is less responsive to capital dynamics in other cereal groups and more likely contingent on micro-climatic conditions, crop-specific resilience traits and farmer adaptation strategies. The model's explanatory power also declines in this subsample, reinforcing the notion that land productivity during climatic stress is shaped by highly localized, non-systemic variables.

In contrast, during favourable climatic conditions (CI > 0.5), the negative relationship between capital productivity of main cereals and capital productivity of coarse cereals becomes stronger and statistically significant, pointing to the re-emergence of competitive dynamics in input use. It is plausible that in the absence of climate-induced constraints, systemic biases in investment and input delivery become more distinct, favouring main cereals over coarse cereals. Notably, the climate index remains statistically insignificant in this regime, suggesting that favourable weather conditions may neutralize direct climatic constraints, thereby amplifying the role of structural and institutional factors in influencing land productivity.

CONCLUSION AND SUGGESTIONS

The study examined the structural interdependence of cereal productivity in India with a focus on the interplay between capital and land productivity across main cereals (rice and wheat) and coarse cereals, under the influence of climatic variability.

The findings reveal a dual-layered asymmetry. First, across inputs, *i.e,* capital productivity exhibits stronger systemic linkages and spillover potential across cereal types, while land productivity remains more fragmented and location-specific. Second, across climatic Regimes, that is, under favorable conditions, structural relationships are amplified, while under stress, productivity outcomes are mediated by localized vulnerabilities, access gaps, and adaptation capabilities.

These findings have critical policy implications. The input asymmetry highlights the need to correct historical investment biases favoring rice and wheat by improving capital access for coarse cereals through mechanization, micro-irrigation, financing and climate-resilient infrastructure. The higher climate sensitivity of coarse cereals calls for drought-tolerant varieties, improved soil-water management and real-time weather advisories. Moreover, the systemic interdependence between main and coarse cereals suggests moving beyond crop-specific policies toward integrated frameworks that recognize cross-crop linkages and resource trade-offs. Given the weak, localized response of land productivity, region-specific support systems must align with local agro-ecological and institutional contexts.

Therefore, achieving inclusive and climate-resilient growth requires repositioning coarse cereals as climate-adaptive, nutritionally vital crops. Addressing input asymmetries, strengthening adaptive capacity, and mainstreaming coarse cereals into agricultural policy are key to building an equitable and sustainable cereal economy in a climate-constrained future.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are

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Informed consent

Informed consent was not applicable in this study.

Conflict of interest

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REFERENCES

Aggarwal, P.K., Calderini, D.F. and Connor, D.J. (2018). Challenges and responses to ongoing and projected climate change for dryland cereal production systems throughout the world. *Agronomy.* **8(4):** 34. https://doi.org/10.3390/agronomy8040034.

Ashrit, R.R. (2021). Input demand and output supply elasticities of coarse cereals in India: A translog profit and SURE approach. *Asian Journal of Agricultural Extension, Economics and Sociology.* **39(11):** 46-60.

Bellon, M R. and Van Etten, J. (2014). Climate change and on-farm conservation of crop landraces in centres of diversity. In Genetic Resources and Climate Change. *Routledge.* (pp. 137-150) https://www.researchgate.net/publication/259308819.

Davis, K.F., Chhatre, A., Rao, N.D. and Singh, D. (2019). Assessing the sustainability of post-green revolution cereals in India. *Proceedings of the National Academy of Sciences*. **116(50):** 25034-25041. https://doi.org/10.1073/pnas.1910935116.

Department of Science and Technology. (2016). Climate change and agriculture. DST India. https://dst.gov.in/sites/default/files/Report_DST_CC_Agriculture.pdf.

FAO. (2005). Chapter 4: Fertilizer use by crop. FAO. https://www.fao.org/4/x0172e/x0172e04.htm.

Government of India. (2025). Economic Survey 2024-25. Ministry of Finance, Government of India.

Gulati, A. and Roy, R. (2021a). Linkage Between Agriculture, Poverty and Malnutrition in India. In A. Gulati, R. Roy and S. Saini (Eds.), Revitalizing Indian Agriculture and Boosting Farmer Incomes (India Studies in Business and Economics). Springer, Singapore. https://doi.org/10.1007/978-981-15-9335-2_3.

Gulati, A. and Roy, R. (2021b). Agricultural challenges and policies. NABARD. https://www.nabard.org/hindi/auth/writereaddata/tender/2501230903paper-6-agri-challenges-and-policies.pdf. https://ageconsearch.umn.edu/record/358159/files/Ashrit39112021AJAEES75146.pdf.

India Water Portal (2024). Impact of agricultural subsidies on groundwater stress in India. https://www.indiawaterportal.org/groundwater/impact-of-agricultural-subsidies-on-groundwater-stress-in-india.

Kazi T.S., Laware S.L., Auti S.G. (2022). Analysis of nutritional diversity and antioxidant activity of finger millet landraces. *Indian Journal of Agricultural Research*. **56(1):** 1-6. doi: 10.18805/IJARe.A-5741.

Kheya, S.A., Talukder, S.K., Datta, P., Yeasmin, S., Rashid, M.H., Hasan, A.K., Anwar, M.P., Islam, A.K.M.A. and Islam, A.K.M.M. (2023). Millets: The future crops for the tropics - Status, challenges and future prospects. *Heliyon*. **9(11):** e22123. https://doi.org/10.1016/j.heliyon.2023.e22123.

Kumar, A. and Sharma, P. (2014). Climatic effects on food grain productivity in India: A crop-wise analysis. *Studies in Agricultural Economics*. **116(3):** 113-129. https://www.researchgate.net/publication/344317437.

Malathi, B., Chari, A., Reddy, R.G., Dattatri, K., Sudhakar, N. (2016). Growth pattern of millets in India. *Indian Journal of Agricultural Research*. **50(4):** 382-386. doi: 10.18805/ijare.v50i4.11257.

Meena, R.C., Ambawat, S., Satyavathi, T.C., Ram, M., Khandelwal, V., Yadav, S.L. (2021). Screening of pearl millet genotypes suitable for drought tolerance at early seedling stage. *Indian Journal of Agricultural Research*. **55(6):** 773-775. doi: 10.18805/A-5718.

Mittal, S., Kumar, P. and Hossain, M. (2008). Agricultural growth accounting and total factor productivity in South Asia: A review and policy implications. *Agricultural Economics Research Review*. **21(2):** 145-154. https://ageconsearch.umn.edu/record/47669/.

National Bank for Agriculture and Rural Development. (2023)./ Annual Report 2022-23. NABARD. https://www.nabard.org/pdf/2023/the-year-in-context-eng.pdf.

Pal, D. and Mitra, S.K. (2018). Asymmetric impact of rainfall on India's food grain production: Evidence from quantile autoregressive distributed lag model. *Theoretical and Applied Climatology.* **134(1-2):** 473-485. https://doi.org/10.1007/s00704-016-1942-3.

Pingali, P. and Sunder, N. (2017). Transitioning toward nutrition-sensitive food systems in developing countries. *Annual Review of Resource Economics*. **9:** 439-459. https://doi.org/10.1146/annurev-resource-100516-053552.

Rakshit, S., Chikkappa, K.G. and Jat, S.L. (2017). Best practices of maize production technologies in South Asia. In Maize Improvement. ICAR. (pp. 43-56). https://www.researchgate.net/publication/325389786.

Shukla, M., Jangid, B.L., Khandelwal, V., Keerthika, A. and Shukla, A.K. (2023). Climate change and agriculture: An Indian perspective: A review. *Agricultural Reviews*. **44(2):** 223-230. https://doi.org/10.18805/ag.R-2190.

Thilakarathna, M.S. and Raizada, M.N. (2015). A review of nutrient management studies involving finger millet in the semi-arid tropics of Asia and Africa. *Agronomy.* **5:** 262-290.